Numerical Simulation of Single Phase Faults in Medium Voltage Electrical Networks

DUMITRU TOADER, STEFAN HARAGUS, CONSTANTIN BLAJ, IULIA CATA
Department of Physical Foundation of Engineering
"Politehnica" University of Timisoara
Bd.Vasile Pârvan Nr.2 300223 Timisoara
ROMANIA
dumitru.toader@et.upt.ro http://www.et.upt.ro

Abstract: - In the paper is presented a virtual simulator for three-phased medium voltage electric circuits. The simulator allows analyzing transient regimes caused by the faults produced in electric distribution networks (simple grounding, double grounding, broken and grounded conductor). Also, in paper are presented the results of measurements made in the experimental area that was conceived for verification results obtained by numerical simulation in real condition. There are analyzed the dependence of the transient regimes on the initial phase of the voltage at the faulty place, the dependence on the grounding resistance at the faulty place and on the method used for grounding the neutral point of the electric network.

Key-Words: - medium voltage electric networks, grounding faults, numerical simulation

1 Introduction

One of the main and most important problems of the electric distribution networks, in order to assure the function at requested parameters, is that to notice as soon as possible and with the most accurate precision all the deviations from normal functioning regime. This can be done using the real time survey of the most important parameters of the electric line. It is very expensive to have online survey devices on each electric network and most of the suppliers cannot afford these costs. In order to choose the adequate electric equipments for protection and to control it properly it is necessary to know the limits of the values for voltages and current between which their modification does not affect the good service of the distribution network. The analyze of the transient regimes produced by different breakdowns in the electric distribution network allows to establish the variation of voltages and currents during these failure of function. Because of the complexity of the equivalent electric schemes of the electric distribution networks and also because of the very large type of the breakdown possible to appear in function, it is very difficult to make the conception of an analytic model, and even if such an analytic model is conceived it would be extremely difficult to use it. That's why researchers in the domain have looked for new solution able to assure a better precision, but in the same time easier to be used. Last decades the researchers in the domain have used more and more frequently numeric methods for analyzing the more and more frequently numeric methods for analyzing the electric circuits. These studies based on numeric methods have lead to numeric models. Two of the most frequently used programming media in order to implement the numeric models for the analyze of the electric circuits are Matlab-Simulink [1, 2, 3, 4, 5, 6,7,20,23] and PSpice [1, 2, 3, 4, 5, , 8, 9, 10,11, 12, 13, 14, 15, 16, 18, 19]. The virtual system for the numeric simulation presented in the followings it is based on using PSpice.

2. The Elements of the System

The systems for the electric energy distribution consist of the transformer station 110kV/MV (MV – medium voltage), the MV electric lines, the consumers connected directly on the MV, the transformers MV/LV (LV – low voltage), the consumers at LV, the coil that produces the artificial null point, the coil for compensation or the resistor for the null grounding, the commutation devices. The single-wire scheme of the distribution system is presented in figure 1.

The meanings of the notations used in figure 1 are as follows: Tr – the transformer 110kV/MV (the MV is usually 6kV, the transformer is in Y_0 connection, with the null on the 110kv side and Δ triangle connection on the MV side; T.S.I. – the transformer for the internal services (having zig-zag connection on the MV side and Y_0 star connection on the 0.4 kV); Z_0 –the coil for the artificial creation of the null, in zigzag connection, on which null is connected the resistor for the null treatment, Zn; L_1, L_2, ... L_n - the medium voltage lines connected to the same medium voltage bar in the transformer station Tr. 6/0,4kV - the transformers medium voltage/low voltage, having triangle connection or Y without null connection on the medium voltage and Y_0 star with null connection or zig-zag with null connection on the LV side, C – the consumers on LV side.

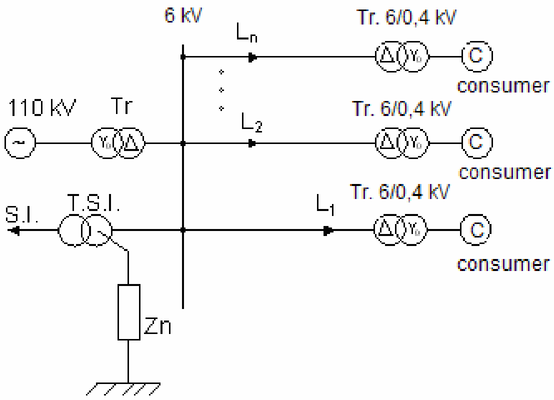

Fig.1. The single wire connection scheme

In order to analyze the behavior of the medium voltage network during a transient regime caused by a fault produced on one or more medium voltage lines must be known the structure of the consumer supplied by the medium voltage line.

In literature [8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19,21,22] is generally accepted that the analyzed faulty line is functioning with no load, and this might affect the results.

The transient regimes caused by faults in medium voltage networks contain two time periods completely different in their evolution:

- the first time interval when appears also the dead-beat component (the free component) in the evolution of the voltages and the currents; during this period the voltages and the current have non sinusoidal evolution,
- the second time interval when the dead-beat component is damping and the voltages and the currents have sinusoidal variation.

During the second time interval the three phased circuit is unbalanced, the three phased system of the voltages and of the currents being nonsymmetrical, but with sinusoidal time variation.

For the analyze of such a problem in three phased electric circuits the most used method is the symmetric component method (the positive, the negative and the zero sequence components).

The virtual system for numeric simulation allows the analyze in both, previously mentioned, time periods.

3 The Configuration of the Numeric Simulator

The numeric simulator for three phased electric circuit must be able to reproduce, as simple as possible, most of the possible faults that occur in the function of the medium voltage network.

Each element of the real system must be modelized in order to obtain a numeric simulator for the equivalent electric circuit. Numeric models for the following elements were made:

- power supply (source);
- transformer 110kV/MV;
- medium voltage network;
- consumer supplied directly from the MV network;
- coil for the creation of the artificial null;
- element for the null treatment;
- resistance of the grounding fault.

In fig.2 is presented the virtual system that contains all these elements:

- the source (power supply), with V_1, V_2, V_3 voltages
- the model of the 110kV/6kV transformer, with the parameters R_1, R_2, R_3, L_1, L_2, L_3 ;
- the model of the medium voltage electric line with the resistive parameters R_{c1}, R_{c2}, R_{c3}, and the capacitive parameters C_1, C_2, C_3; (depending on the electric line structure the parameters mentioned above might have different values),
-the model of the gounding of the line without fault with the parameters R_{p1}, R_{p2}, R_{p3}, L_{p1}, L_{p2}, L_{p3}, and transversal parameters C_4, C_5, C_6 with R_{C4}, R_{C5}, R_{C6} in parallel;
- the grounding parameters from fault point to the transformation station R_p, L_p.
- the model of the transversal fault (Sb) with fault rezistance R_t
- the controlled connector with variable closing time moment and variable grounding fault resistance,
- the model of the PSpice modelization of the coil creating the artificial null point, with the parameters R_{4a}, R_{5a}, R_{6a}, L_{4a}, L_{5a}, L_{6a} , R_{4b}, R_{5b}, R_{6b}, L_{4b}, L_{5b}, L_{6b}.
- the elements for the null treatment L_{BC}, R_{BC}.

When the null treatment is made by using a compensation coil, the two parameters, L_{BC}, R_{BC}., represent the equivalent parameters of the coil for the treatment of the null of the network. In this case the inductive reactance is much bigger than the resistance.By modifying, in the simulator the two parameters L_{BC} and R_{BC} it can be imposed the regime of functioning for the electric network:

- at resonance,
- some % overcompensated
- some % under compensated.

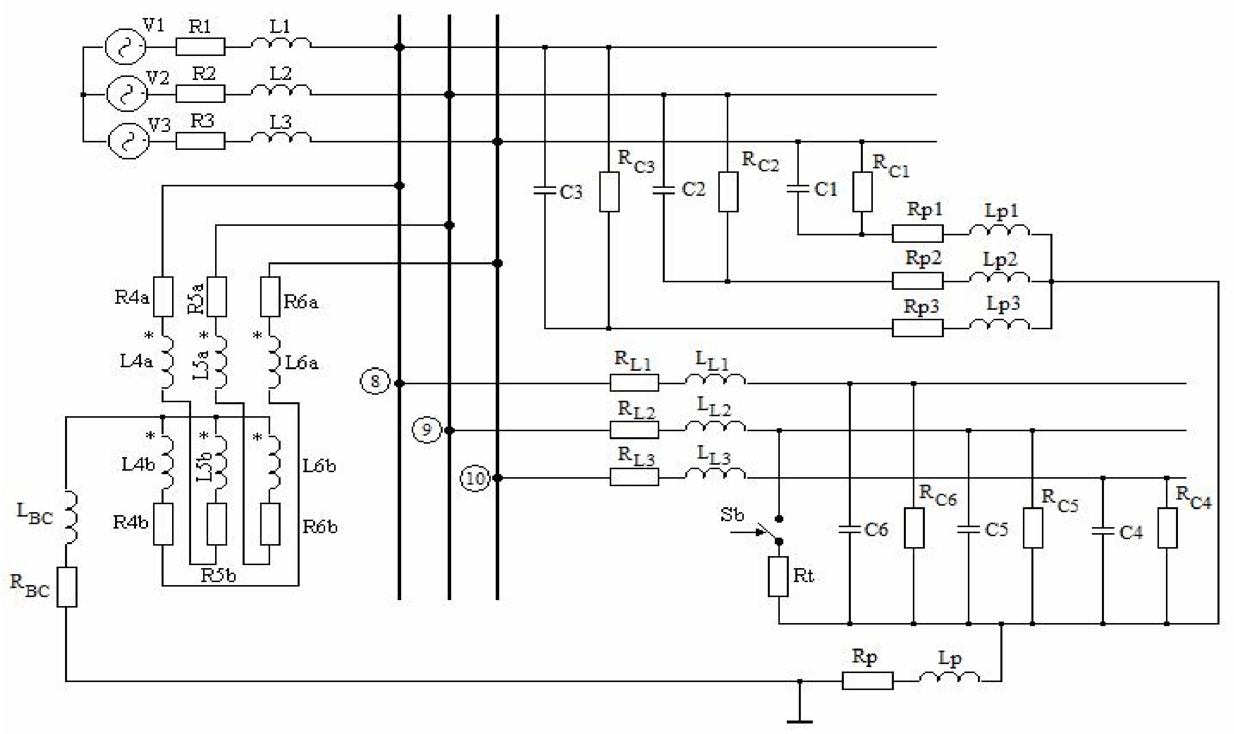

Fig. 2. The electric scheme used in the PSpice simulations

If the network of the medium voltage has the neutral point isolated, one of the two parameters is imposed with a very high value.

If the network has the neutral point grounded by a resistor, for the inductivity L_{BC} is taken the zero value, and to the R_{BC} resistance is given the value equal to the value of the resistor used for grounding the null point of the network.

4 Numeric Simulation of a Phase to Ground Fault

Some of the following results are obtained for the situation when the electric medium voltage network has the neutral grounded trough compensation coil and it is functioning at resonance [8, 9, 14, 15, 18, 19].

The variable elements taken in the analyze were: the initial phase of the voltage of the faulty phase (namely in the moment when the fault was produced) and the value of the grounding resistance at the place of the fault (R_t)

The simulator (the model) reproduces the MV line from the experiment aria.

The total value of the capacitive current of the MV line is 27A, while the capacitive current of the faulty line is 2.7A

In order to verify the accuracy of the numeric simulation and its concordance with the real evolution of grounding faults were made measurements on a 6kV line. Simple grounding fault was produced succesively for the line at resonance, 10% overcompenated and, respectively, 10% undercompensated.

For the resistance at the fault point (R_t) sucesively were used the values of 5Ω, 250Ω and 500Ω.

The initial phase of the voltage in the moment when the fault is produced was equal (aproximatively) with that one from the corresponding experiment in the real 6kV network.

The results obtained by numerical simulation are presented in fig.3a, fig.4a,…,fig.11a for the currents and in fig.3b, fig.4b,…, fig.11b for voltages.

The zero sequence current trough the faulty line (I(LL1) + I(LL2) + I(LL3))/3 and the current trough the compensation coil I(LBC) are presented in the figures with “a” indice.

The phase voltages V(8), V(9), V(10) and the zero sequence voltage (V(8) + V(9) + V(10)/3 are presented in the figures with “b” indice.

The results obtained by numerical simulation are presented in fig.3a, fig.4a,…,fig.11a for the currents and in fig.3b, fig.4b,…, fig.11b for voltages.

The zero sequence current trough the faulty line (I(LL1) + I(LL2) + I(LL3))/3 and the current trough the compensation coil I(LBC) are presented in the figures with “a” indice.

The phase voltages V(8), V(9), V(10) and the zero sequence voltage (V(8) + V(9) + V(10)/3 are presented in the figures with “b” indice.

The following values of the parameters were used for the numeric simulation:

- Power suply voltages

$V_1(t) = 3468\sqrt{2}\sin(100\pi t);$

$V_2(t) = 3468\sqrt{2}\sin(100\pi t\ 2\pi/3)$

$V_3(t) = 3468\sqrt{2}\sin(100\pi t+2\pi/3)$

- Parameters of the 110/6 kV transformer

$R_1 = R_2 = R_3 = 4,1$ mΩ, $L_1 = L_2 = L_3 = 0,344$ mH

- Transversal parameters of the healthy lines

$R_{C1} = R_{C2} = R_{C3}$ 2,28 kΩ, $C_1 = C_2 = C_3 = 7,443$ μF

- Equivalent parameters of the earth from the fault point to the healty lines

$R_{p1} = R_{p2} = R_{p3} = 0,5\Omega$, $L_{p1} = L_{p2} = L_{p3} = 33,4$mH

- Parameters of the faulty line till the fault point

$R_{L1} = R_{L2} = R_{L3} = 0,5\Omega$, $L_{L1} = L_{L2} = L_{L3} = 1,11$mH

-Transversal (parallel) parameters of the faulty line

$R_{C4} = R_{C5} = R_{C6} = 22,8$ kΩ, $C_4 = C_5 = C_6 = 0,827$μF

-Earth parameters from the fault point to the transformer station

$R_p = 0,05\ \Omega$, $L_p = 3,34$ mH

-Parameters of the zig-zag coil, creating the artificial null

$R_{4a} = R_{5a} = R_{6a} = R_{4b} = R_{5b} = R_{6b} = 0,14\ \Omega$

$L_{4a} = L_{5a} = L_{6a} = L_{4b} = L_{5b} = L_{6b} = 3,26$ H

coupling factor k = 0,95

-Parameters of the coil for null compensation

$R_{BC} = 2,16\ \Omega$, $L_{BC} = 0,395$ H

The results of the simulation, currents and voltages ,are shown in the following figures as oscillograms.

4.1. The resistance at the fault point 5Ω

4.1.1. The MV network at resonance

The initial phase of the V(10) voltage α = 270°.
Results are shown in figures 3a and 3b.

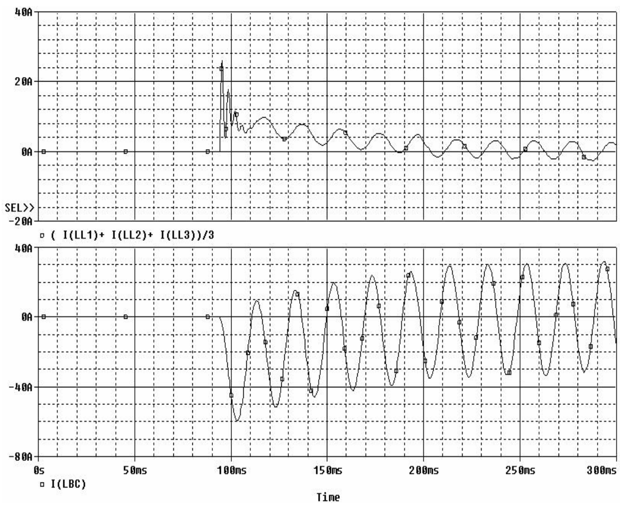

Fig. 3a. Single phase grounding R_t= 5 Ω, network at resonance, currents representation

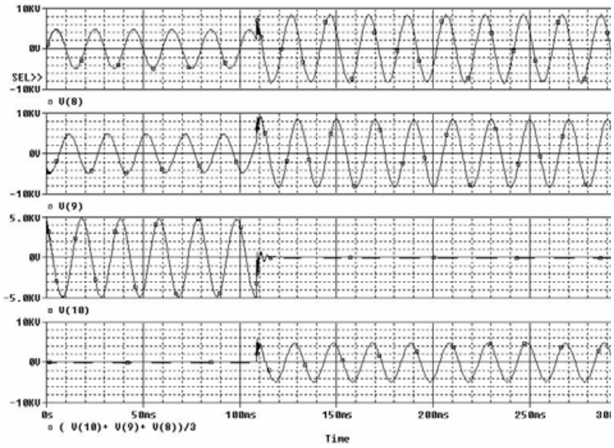

Fig. 3b. Single phase grounding R_t= 5 Ω, network at resonance, voltage representation

4.1.2. The MV network functions at 10% overcompensation

The parameters of the compensation coil are

$R_{BC} = 2,16\Omega$, $L_{BC} = 0,355$H

The initial phase of the V(10) voltage is α = 270°.
Results are shown in figures 4a and 4b.

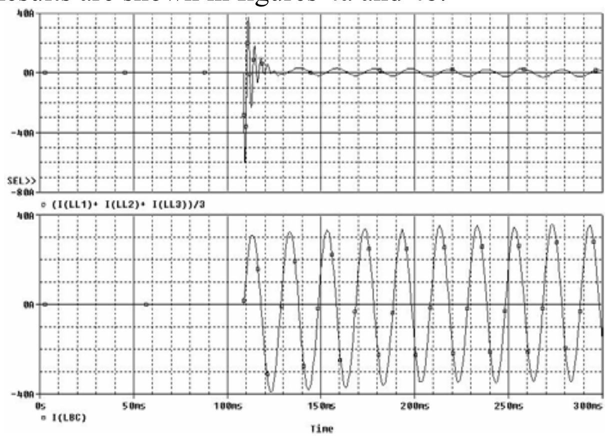

Fig. 4a. Single phase grounding R_t= 5 Ω, network at 10% overcompensation, currents representation

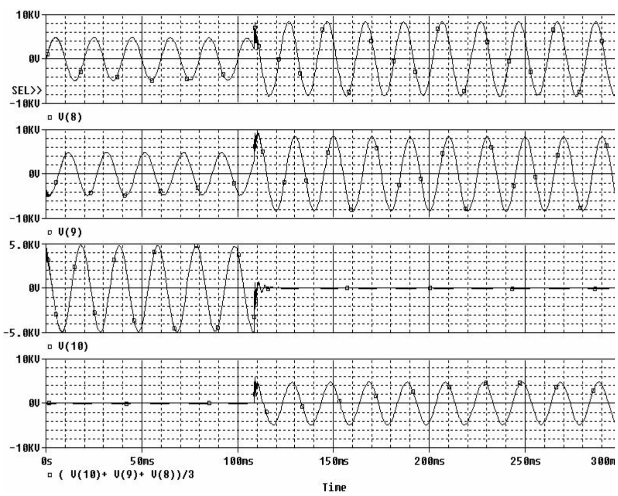

Fig. 4b. Single phase grounding R_t= 5 Ω, network at 10% overcompensation, voltage representation

4.1.3. The MV network functions at 10% undercompensation

The parameters of the compensation coil are

R_{BC} = 2,16Ω, L_{BC} = 0,434H

The initial phase of the V(10) voltage is α = 56°.
Results are shown in figures 5a and 5b.

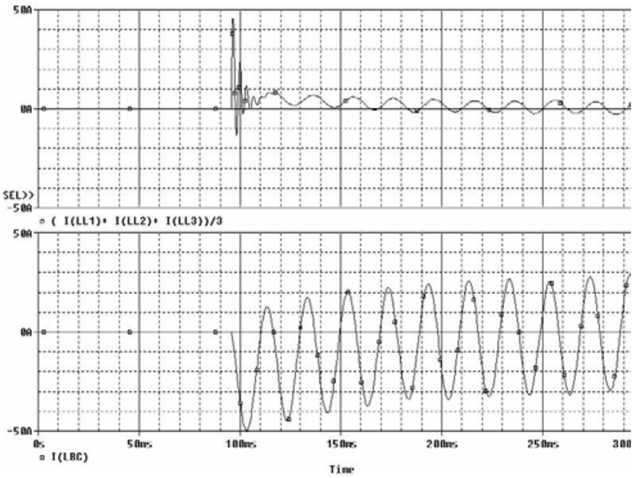

Fig. 5a. Single phase grounding R_t= 5 Ω, network at 10% undrcompensation, currents representation

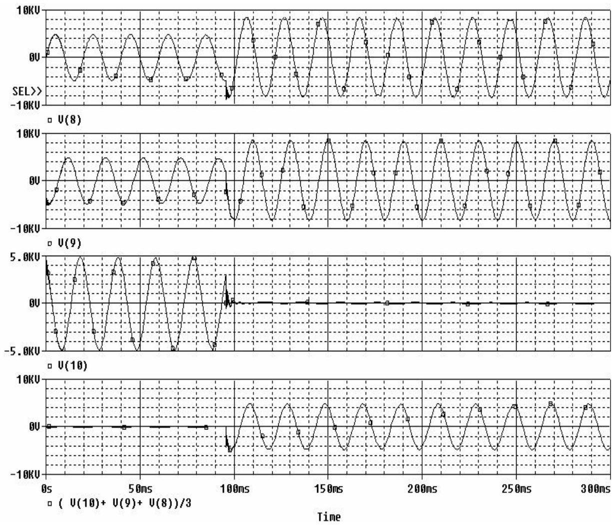

Fig. 5b. Single phase grounding R_t= 5 Ω, network at 10% undercompensation, voltage representation

4.2. The resistance at the fault point 250Ω

The value of the resistance introduced in the network for measurements after causing a single phase grounding fault is 250 Ω. The same value vas used in the simulation.

4.2.1. MV network functions at resonance

The compensation coil parameters are

R_{BC} = 2,16Ω, L_{BC} = 0,395H

The initial phase ot the V(10) voltage is α = 36°.
Results are shown in figures 6a si 6b.

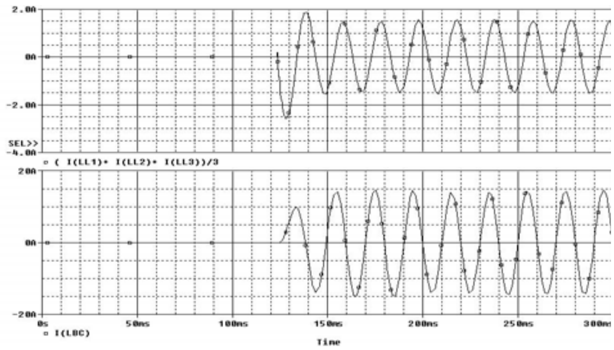

Fig. 6a. Single phase grounding R_t= 250 Ω, network at resonance, currents representation

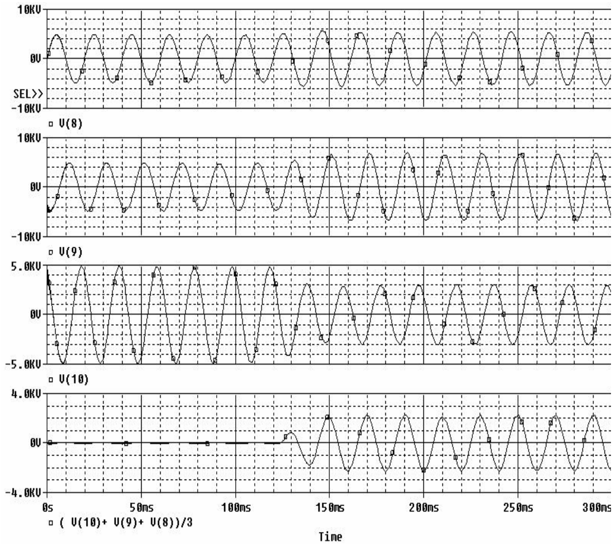

Fig. 6b. Single phase grounding R_t= 250 Ω, network at resonance, voltage representation

4.2.2. MV network functions at 10% overcompensation regime

The compensation coil parameters are

R_{BC} = 2,16Ω, L_{BC} = 0,355H

The initial phase ot the V(10) voltage is α = 30°.
Results are shown in figures 7a si 7b.

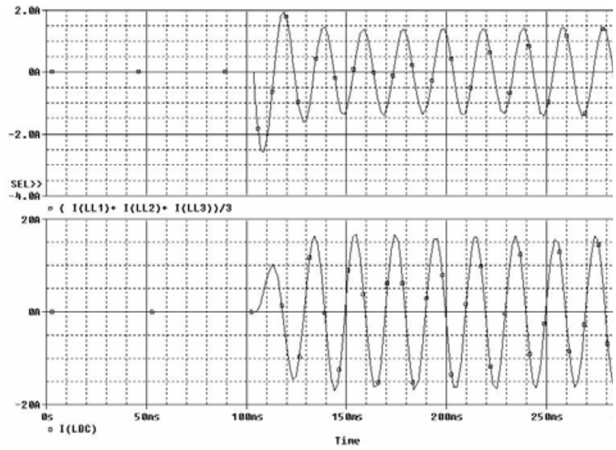

Fig.7a. Single phase grounding R_t= 250 Ω, 10% overcompensation ,currents representation

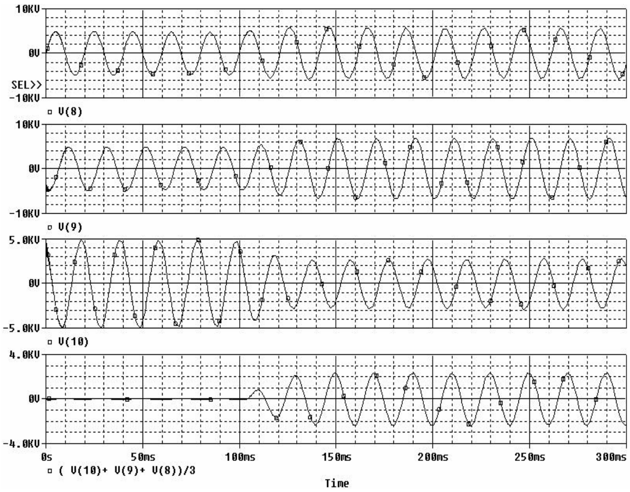

Fig.7b. Single phase grounding R_t= 250 Ω, 10% overcompensation ,voltage representation

4.2.3. MV network functions at 10% undercompensation regime

The compensation coil parameters are

$$R_{BC} = 2{,}16\Omega,\ L_{BC} = 0{,}434H$$

The initial phase ot the V(10) voltage is α = 85°. Results are shown in figures 8a si 8b.

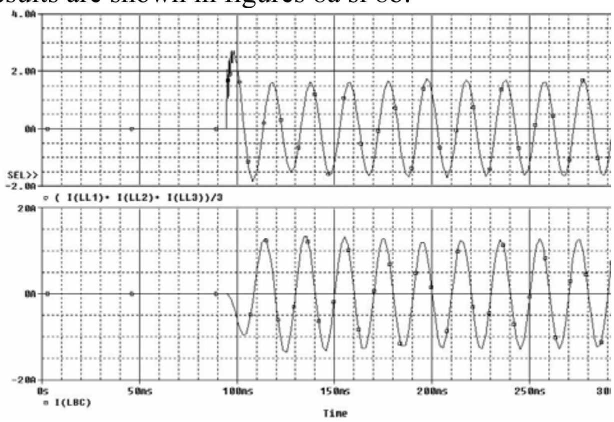

Fig. 8a. Single phase grounding R_t= 250 Ω, network 10% undercompensated, currents representation

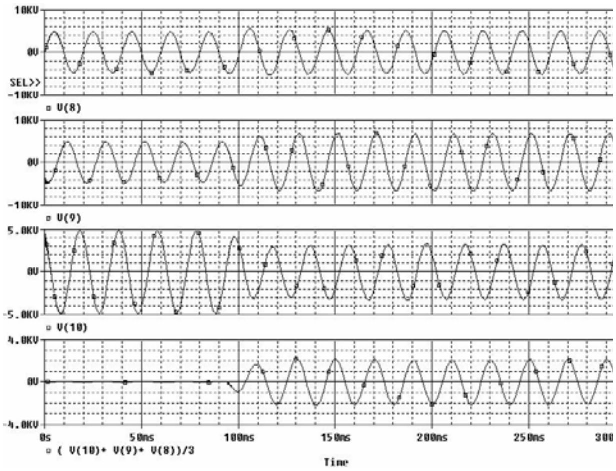

Fig. 8b. Single phase grounding R_t= 250 Ω, network 10% undercompensated, voltage representation

4.3. The resistance at the fault point 500Ω

4.3.1. MV network functions at resonance

The compensation coil parameters are

$$R_{BC} = 2{,}16\Omega,\ L_{BC} = 0{,}395H$$

The initial phase ot the V(10) voltage is α = 26°. Results are shown in figures 9a si 9b.

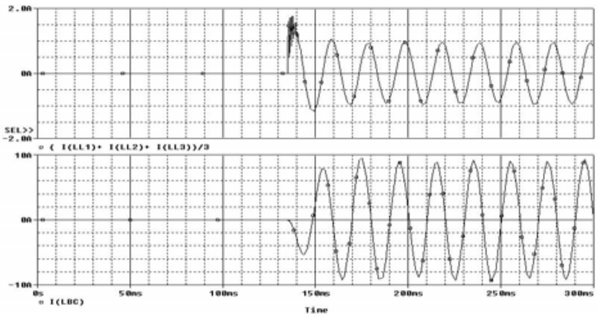

Fig.9a. Single phase grounding R_t= 500 Ω, network at resonance, currents representation

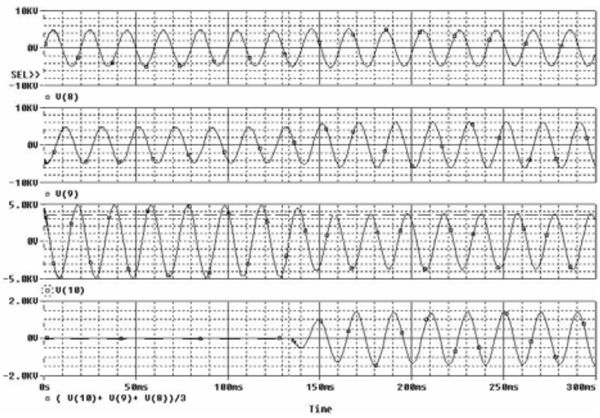

Fig. 9b. Single phase grounding R_t= 500 Ω, network at resonance, voltage representation

4.3.2. Network functions 10% overcompensated

The compensation coil parameters are

$$R_{BC} = 2{,}16\Omega,\ L_{BC} = 0{,}355H$$

The initial phase ot the V(10) voltage is α = 96°. Results are shown in figures 10a and 10b.

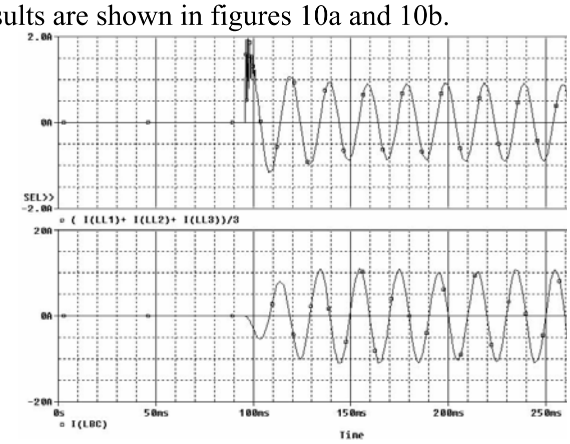

Fig.10a.Single phase grounding R_t= 500 Ω, 10% overcompensated, currents representation

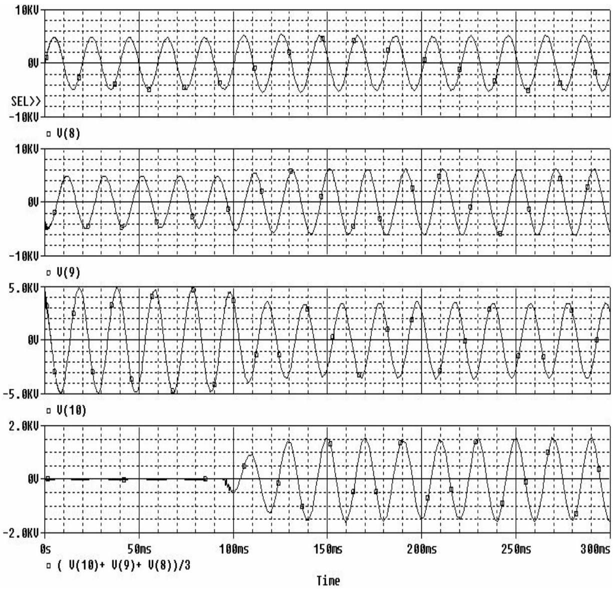

Fig. 10b. Single phase grounding R_t= 500 Ω, network 10% overcompensated, voltage representation

4.3.2. Network functions 10% undercompensated

The parameters of the compensation coil are

R_{BC} = 2,16Ω and L_{BC} = 0,434H

The initial phase of the V(10) voltage is α = 126°. Results are shown in fig. 11a and 11b.

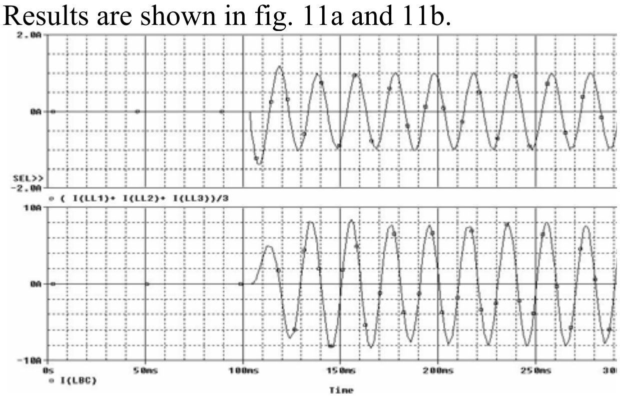

Fig. 11a. Single phase grounding R_t= 500 Ω, 10% undercompensation, currents representation

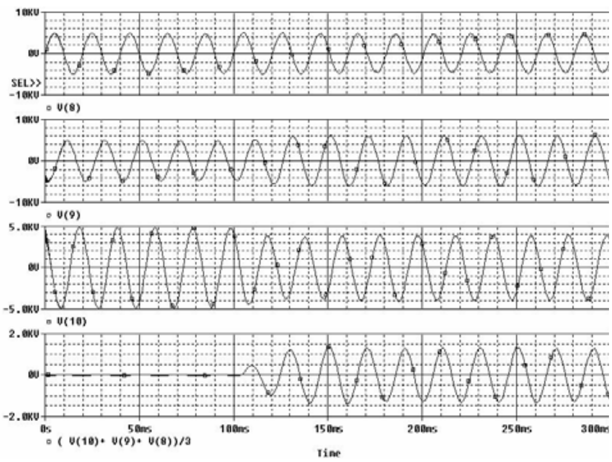

Fig. 11b. Single phase grounding R_t= 250 Ω, 10% undercompensation, voltage representation

5. Results of the Experiment

The results obtained during the measurements in the experiment aria, while faults were produced on purpose are shown in the followings. The fault produced was of type single phase grounding.

The experimental aria contains 7 electric lines of 6kV, with total value of the capacitive current of 27A

From the 7 electric linea 6 are connected at first system of bars and at the second bar system was connected the line on which the faults were produced. The capacitive current of this line is 2.7A.

The transformer station contains a transversal switch in connected position.

For recording the currents and the voltages during the experiment was used a CDR oscilloperturbograph.

Figures 12 to 20 show the following:

- the zero sequence current of the faulty line $I^0_{PT\ Turn}$
- current trough the compensation coil I_B
- the star voltages, V_a, V_b, V_c
- the zerosequence voltage of MV bars from the transformer station U^0

The experiment was made in order to verify the concordance with the numeric simulation and to validate the accuracy of the simulator.

The experiment consisted on producing on purpose faults of the type single-phase grounding, namely;

- metallic grounding of a phase R_t = 0;
- grounding through the passing resistance R_t= 250 Ω;
- grounding through the passing resistance R_t= 500 Ω

The functioning regimes of the MV network were:

-MV network functioning at resonance

-MV network functions at 10% overcompensation

-MV network functions at 10% undercompensation

The three recordings, corresponding to the three functioning regimes for metallic grounding are shown in figures 12, 13 and 14.

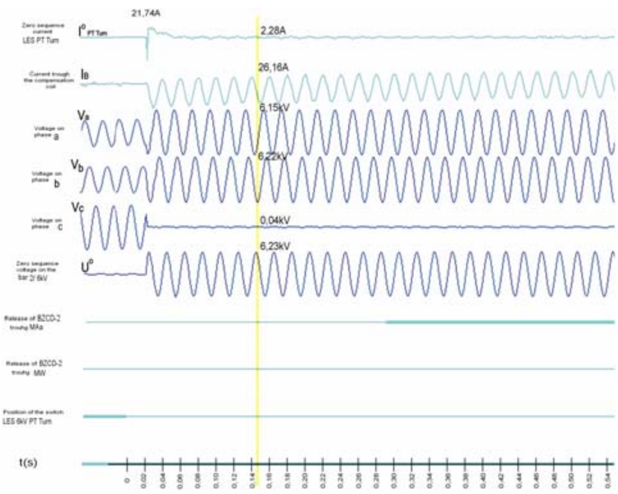

Fig. 12. Single phase metallic grounding, R_t= 5 Ω, network at resonance

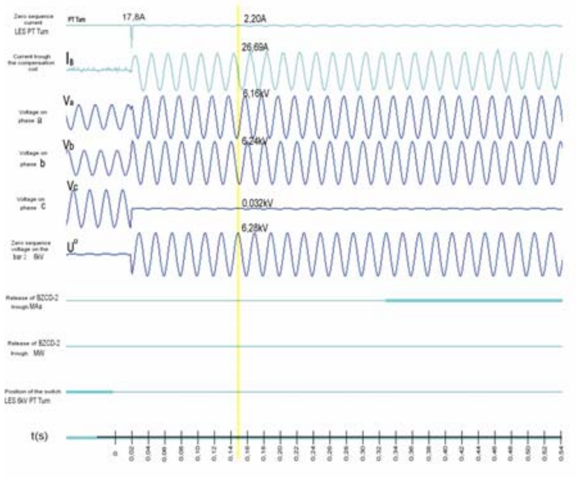

Fig. 13. Single phase metallic grounding, R_t= 5 Ω, network at 10% overcompensation

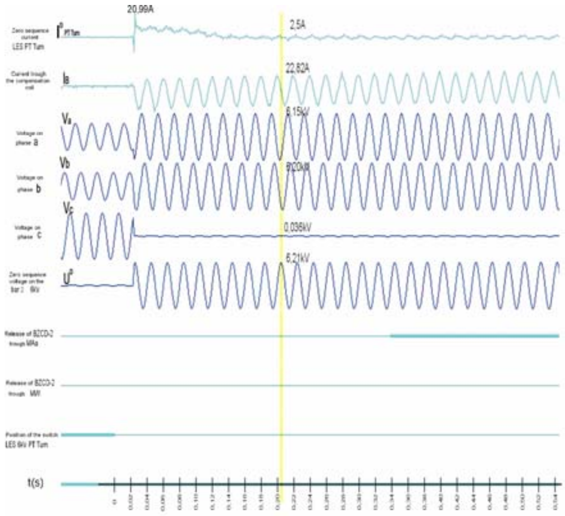

Fig. 14. Single phase grounding with R_t=5 Ω, 10%under-compensated network

By comparing the shape of the current of the faulty line during the transient regime (the zero sequence current of the faulty line) obtained by numeric simulation with the one obtained by recording the same current during experiment it can be observed that the simulated current has an oscillating component greater than in recorded experiment. This difference is due to a greater equivalent resistance of the experimental equivalent circuit than the simulated one.

In the same maner, as for the metallic grounding, but with a 250Ω grounding resistance for the three functioning regimes of the network the, results are presented in figures 15, 16 and 17.

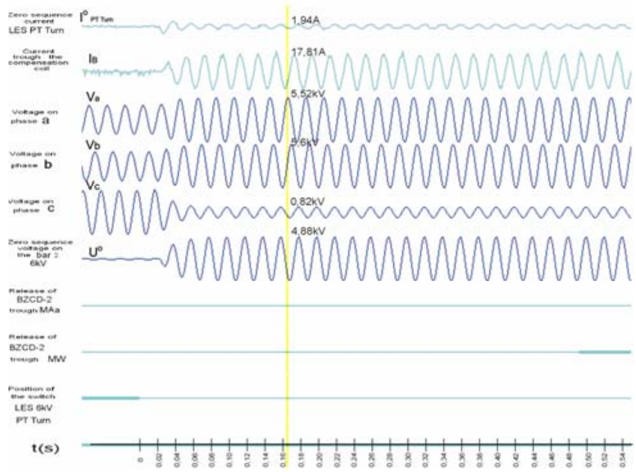

Fig. 15. Single phase grounding with R_t=250 Ω, network at resonance

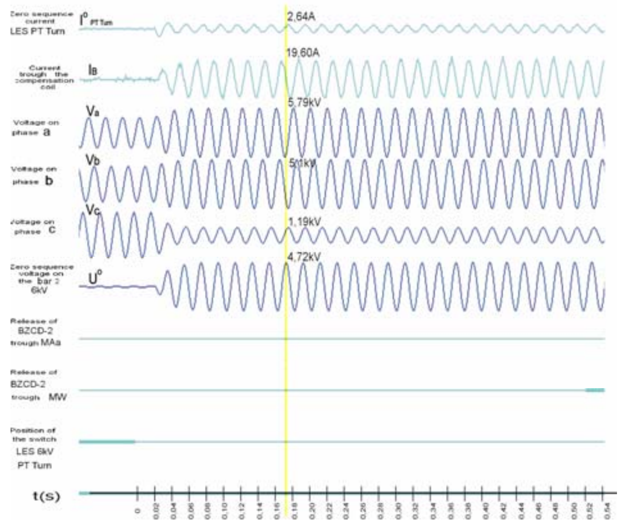

Fig. 16. Single phase grounding with R_t=250 Ω, 10% over-compensated network

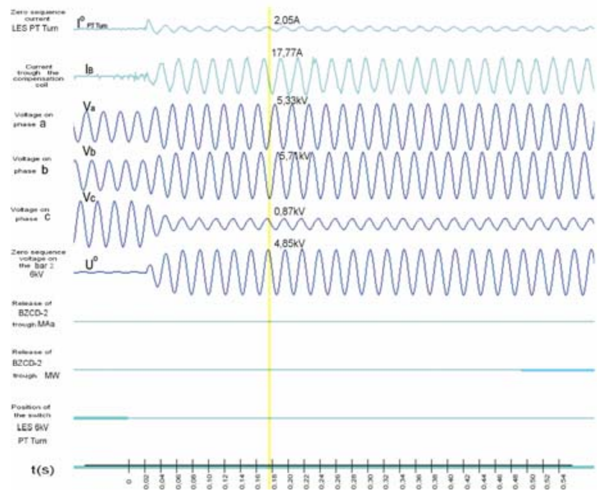

Fig. 17. Single phase grounding with R_t=250 Ω, 10%under-compensated network

The third value for the grounding resistance used in the experiment is 500Ω and the results for the resonant regime, for 10% overcompensated and for 10% undercompensated are presented, respectively, in the figures 18, 19 and 20.

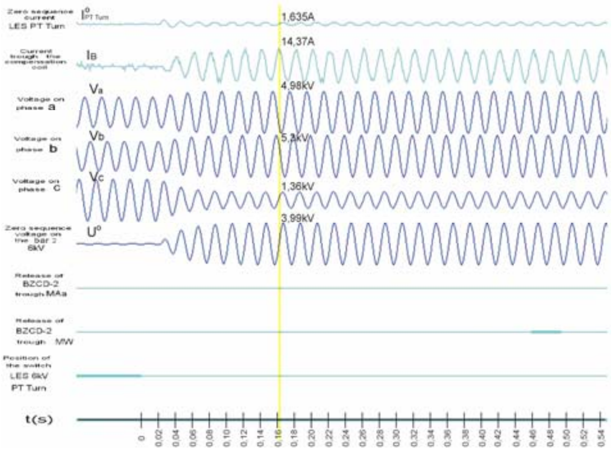

Fig. 18. Single phase grounding resistance, R_t= 500 Ω, network at resonance

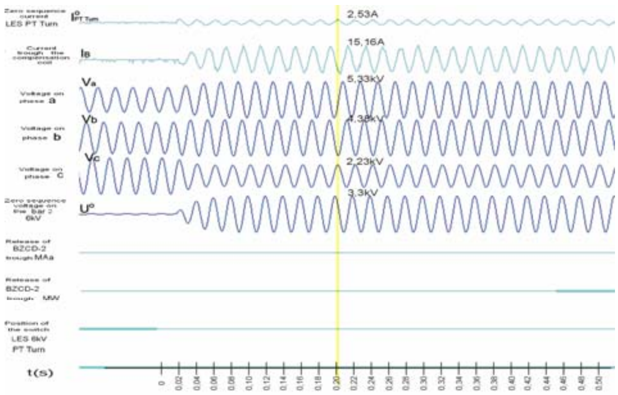

Fig. 19. Single phase grounding resistance R_t= 500 Ω, network at 10% overcompensation

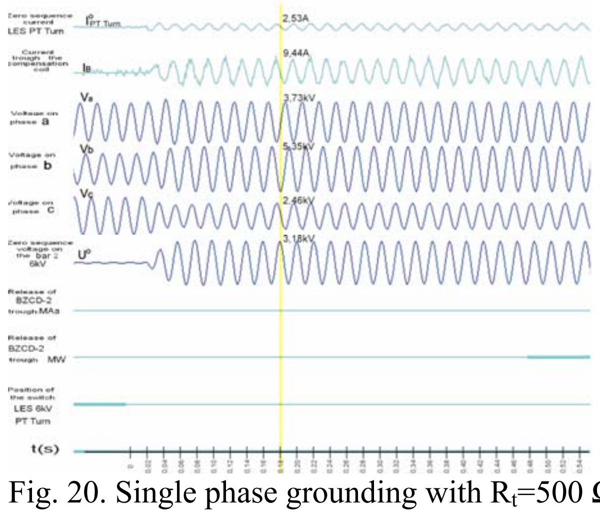

Fig. 20. Single phase grounding with R_t=500 Ω network at 10% undercompensation

The tables 1, 2 and 3 campare some of the values measured during the experiment with the corresponding values obtained by numeric simulation.The significance of the symbols from the tables is as follows:

- I^0_{max} – maximal value of the zero sequence current on the faulty line
- I_B – current trough the compensation coil
- -I^0_{stab} – the zero sequence current of the faulty line, after the dumping of the dead-beat component;

-t_{am} – dumping time of the dead-beat component;

-U^0 – the zero sequence voltage at the MV bars of the transform station;

-U_f – voltage of the healty lines.

Table 1. Compared values for R_t = 5Ω

Regime of the network	Symbol of quan tities	Values obtained by		Error [%]
		Experiment	Simulation	
Reso-nance	I^0_{max}[A]	21,7	24,6	13,4
	I_B [A]	26,16	24,3	7,1
	I^0_{stab}[A]	2,28	2,42	6,1
	t_{am} [ms]	126	130	3,2
	U^0 [kV]	3,6	3,55	1,4
	U_f [kV]	6,22	6,03	3,1
10%Over -compen-sated	I^0_{max}[A]	17,8	58	226
	I_B [A]	26,69	24,82	7,0
	I^0_{stab}[A]	2,2	2,06	6,4
	t_{am} [ms]	80	86	7,5
	U^0 [kV]	3,63	3,55	2,2
	U_f [kV]	6,24	5,96	4,5
10% Under-compen-sated	I^0_{max}[A]	20,99	43	105
	I_B [A]	22,82	21,28	6,7
	I^0_{stab}[A]	2,5	2,32	7,2
	t_{am} [ms]	198	210	6,1
	U^0 [kV]	3,59	3,56	0,84
	U_f [kV]	6,2	5,97	3,7

Table 2. Compared values for R_t = 250Ω

Regime of the network	Symbol of quan-tities	Values obtained by		Error [%]
		Experiment	Simulation	
Reso nance	I^0_{max}[A]	4,8	4,5	6,3
	I_B [A]	17,81	16,2	9,1
	I^0_{stab}[A]	1,94	1,75	9,8
	t_{am} [ms]	38	34	10,5
	U^0 [kV]	2,62	2,43	7,3
	U_f [kV]	5,6	5,46	2,5
10%Over -compen-sated	I^0_{max}[A]	4,2	4,5	7,1
	I_B [A]	19,6	18,3	6,6
	I^0_{stab}[A]	2,64	2,42	8,3
	t_{am} [ms]	35	32	8,6
	U^0 [kV]	2,73	2,47	9,5
	U_f [kV]	5,69	5,21	8,4
10% Under-compen-sated	I^0_{max}[A]	4,3	4,5	4,7
	I_B [A]	17,77	16,5	7,1
	I^0_{stab}[A]	2,05	1,91	6,8
	t_{am} [ms]	31	28	8,6
	U^0 [kV]	2,8	2,53	9,6
	U_f [kV]	5,71	5,39	5,6

Table 3. Compared values for $R_t = 500\Omega$

Regime of the network	Symbol of quantities	Values obtained by		Error [%]
		Experiment	Simulation	
Reso nance	I^0_{max}[A]	2,8	2,6	7,1
	I_B [A]	14,37	12,84	10,6
	I^0_{stab}[A]	1,64	1,49	9,1
	t_{am} [ms]	57	54	5,3
	U^0 [kV]	2,31	2,17	6,1
	U_f [kV]	5,3	4,78	9,8
10%Over -compen-sated	I^0_{max}[A]	3,2	2,9	9,4
	I_B [A]	15,16	13,86	8,6
	I^0_{stab}[A]	2,53	2,27	10,3
	t_{am} [ms]	41	37	9,8
	U^0 [kV]	1,91	1,7	9,9
	U_f [kV]	4,38	4,76	8,7
10% Under-compen-sated	I^0_{max}[A]	3,1	2,8	9,7
	I_B [A]	9,44	9,22	2,3
	I^0_{stab}[A]	2,53	2,31	8,7
	t_{am} [ms]	23	21	8,7
	U^0 [kV]	1,84	1,67	9,1
	U_f [kV]	5,35	4,81	10,1

From all the three tabels results that the differences between the values obtained by the numerical simulation and the values measured during the experiment are reasonably small.

5. Conclusion

The numeric simulator conceived and made by us allows the analyze of the transient regimes caused by faults such as the simple grounding type, or double grounding type, or broken conductor grounded towards the consumer. In this paper we have compared the results, simulated and experimentala data, only for the fault of simple grounding. In these conditions the simulator is validated by the measurements, no matter how the neutral point of the medium voltage network is grounded and whatever are the functioning conditions of the electric network.

Numeric simulation of the transient regimes caused by simple grounding faults produced in medium voltage networks shows to be an efficient method for analyzing such faults.

The initial value of the phase of the voltage on the line where the fault is produced determines mainly the dead-beat component that occurs during the transient regime, the biggest values being obtained when the initial phase is $\alpha = 90^\circ$.

Because the initial phase of the voltage, in the moment of producing the fault was almost the same as that one used in simulation, the differences between the maximal values of zero sequence component, obtained trough the two metods, are quite acceptables by technical point of view.

For small values of the grounding resistance at the place of the fault ($R_t < 10\Omega$) the error is a litle bit higher than in the situation with greater values ($R_t > 100\Omega$) of the grounding resistance at the fault point.

The precision of the simulation is essentially depending on the precision of the values used in simulation for the circuit parameters.

In the evolution of the transient regimes produced by faults in the electric distribution networks an important role has also the value of the electric resistance in the grounding point. When the value of this resistance is high, the dead-beat component is attenuated in a very short time (few milliseconds) and the value itself of this component is low. When the value of the grounding resistance in the place of the fault is small the dead-beat component during the transient regime is big, and its duration has significant values.

The voltages on the phases without fault (healty) and the currents on the phase with fault can attend high values during the transient regime.

The fact that both type of values from tables 1, 2 and 3 have similar values shows that the simplificatory conditions taken into account for creating the simulator are correct.

Even if, here, we have validated the accuracy of the simulator only in the case of a simple grounding type fault, the model is flexible, adaptable for different types of grounding faults. This gives the possibility to analyze, in a virtual manner, types of grounding faults and the transient regimes corresponding to them, without the expensive and difficult experiments.

For other types of faults the electric scheme of the simulator can be modified and completed with some other connectors introducing other desired faults.

References:

[1] D.Toader, St.Haragus, C.Blaj, Numeric Simulation of Faults in Electrical Network, *Proceedings of the 10th WSEAS International Conference on FUZZY SYSTEM,* Prague, March 2009, pp.128-135

[2] L.O. Chua, P.M. Lin,: *Computer-aided Analysis of Electronic Circuits,* Prentice-Hall, Inc. Englewood Cliffs, New Jersey, 1976.

[3] W. Blume, *Computer Circuit Simulation*, BYTE, July, 1986.

[4] M. Hasler, J. Neirynck: *Circuits non lineares*, Presses Polytechniques Romandes, Lausannes.

[5] T.M. Terni (Italy): *Laminieri magnetici laminati a freddo.*

[6] *** SIMULINK: *Dynamic System Simulation for MATLAB,* User's Guide, version 2.1 (Math Works, Inc)..

[7] *** *Power System Block set for use with Simulink:* User' Guide, version 1.0 (MathWorks, Inc.).

[8] D. Toader, Şt. Hărăguş, I. Haţegan, BHT – 10A a Zero-sequence Voltage Digital Protective Block for Medium-voltage Networks with Isolated Neutral-point. *Scientific bulletin of the "Politehnica" University of Timisoara.* Tom 48(62), Fascicula 1- 2, 2003, p.501.

[9] D. Toader, Şt. Hărăguş, I. Haţegan, I. Diaconu, N. Pinte, Digital Protective Blocks for Medium-Voltage Networks with Isolated Neutral-point. *Proceedings of the fifth International World Energy Sistem Conference a Reliable World Energy Sistem, IWESC* May 17-19, 2004, Oradea.

[10] D. Toader, Şt. Hărăguş, I. Haţegan Power Quality Improvement in Distribution Systems by Means of New Protective Blocks. *Proceedings The Sixth World Energy System Conference (WESC2006),* Torino, Italy, July 10-12, 2006, (on CD).

[11] G. Curcanu, D. Toader, T. Pandia Determination of Overvoltages in High Voltage Networks at Single Phase Faults by Numerical Simulation and Experiments. *Proceedings 12th International IGTE Symposium Gratz,* september 2006 (on CD).

[12] G. Curcanu, H. Ionescu, D. Toader, V. Toaxen, T. Pandia Optimization of Medium Voltage Network Neutral-point Treatment for Evaluation and Limitation of Earthling Single-phase Short Circuit Over-voltages. *Proceedings on the International Conference on Applied and Theoretical Electricity,* October 17-19, 2002, Craiova, p.302 -306.

[13] Şt. Hărăguş, D. Toader, M. Hamat, Numerical Simulation of Transient Phenomena Triggered by Single Grounding Faults. *Acta Universitatis Cibiniensis, Series Electrical Engineering and Electronics,* 1999, p.5-9.

[14] D. Toader, Şt. Hărăguş, C. Blaj, Virtual System for Numeric Simulation of Three-phased Circuits. Part 1. *Proceedings The 7th International Power Systems Conference,* November 22-23 2007, Timişoara, pp. 661-666.

[15] D. Toader, Şt. Hărăguş, C. Blaj, Virtual System for Numeric Simulation of Three-phased Circuits. Part 2. *Proceedings The 7th International Power Systems Conference,* November 22-23 2007, Timişoara, pp. 655-660.

[16] D. Trader, At. Hărăguş, C. Blaj, Fault Transient Simulation in Distribution Networks with Improved Neutral-point Grounding. *Proceedings of the IASTED International Conference, Power and Energy Systems,* September 19-22, 2000, Marbella Spain, p.125-8.

[17] D. Toader, Şt. Hărăguş, C. Blaj, Currents Closing via the Copper Ribbon of MV Cables at Single-Phase Short-Circuits on the HV Side of 110/20kV Station. *Proceedings of the 11th International Conference on Optimization of Electrical and Electronic Equipment*, May 22-23 2008, Brasov, pp. 191-197.

[18] D. Toader, C. Blaj, Şt. Hărăguş, Electrocution Danger Evaluation for Broken and Grounded Conductor. *Proceendings of the Eurocon 2007 Conference* September 9-12, 2007, Warsaw, Poland p.1392 – 1397.

[19] D.Toader, B.Lustrea, C.Blaj, I.Borlea, St.Haragus, A Fuzzy Approach Used in Expert System for Optimal Neutral Grounding, *Proceedings of the 10thWSEAS International Conference on FUZZY SYSTEMS*, Prague, March 2009, pp.122-127

[20] I. Rascoleanu, C. Isac, C. Dara, The Optimization of the Stockes within Coal Power Stations Using the Dynamic Programming Method, *Proceedings of the 8thWSEAS International Conference on Circuits, Systems, Electronics, Control & Signal Processing,* Teneriffe, Spain, December 14-16, 2009, pp.192-197

[21] J. Drapela, Performance of a Voltage Peak Detection-Based Flichermeter, *Proceedings of the 8thWSEAS International Conference on Circuits, Systems, Electronics, Control & Signal Processing,* Teneriffe, Spain, December 14-16, 2009, pp.296-301

[22] I. Bucatariu, Fl. Surianu, Optimal Placement of Fixed Series Capacitor in Distribution Networks, *Proceedings of the 9thWSEA/IASMES International Conference on Electric Power Systems High Voltages, Electric Machines Control & Signal Processing,* Genova, Italy, October 17-19, 2009, pp.65-70

[23] M. Istrate, M. Gavrilas, C. Istrate, R. Ursuleanu, Assessement of Two Double-end Data Fault Location Algorithms in Transmission Grids Using ATP Simulations, *Proceedings of the 9thWSEA/IASMES International Conference on Electric Power Systems High Voltages, Electric Machines Control & Signal Processing,* Genova, Italy, October 17-19, 2009, pp.109-114