OPERATIONAL POWER FLOW OPTIMIZATION FOR AN INDUSTRIAL ELECTRICAL NETWORK

Professor **Mariana DUMITRESCU**

University „Dunarea de Jos" from Galati

REZUMAT. Obiectivul lucrarii este sa simuleze si sa optimizeze functionarea unui sistem electroenergetic real din mediul industrial cu consumatori importanti, precum si sa calculeze parametrii de performanta electrica ai acestuia. Problemele unu sistem industrial, atat in faza de proiectare cat si in cea de expolatare, implica analiza si optimizarea circulatiei de putere. Controlul nivelului de tensiune si determinarea valorilor de curent pe ramuri si tensiune la noduri este realizata cu ajutorul programului Edsa Paladin. Sistemul electroenergetic analizat este un caz real din mediul industrial, fiind foarte importanta optimizarea functionarii acestuia in regimul de exploatare.

Cuvinte cheie: sistem electroenergetic, circulatie de putere, optimizare, distributie de energie electrica

ABSTRACT. The objectives of the paper are to simulate the operational stage and to compute the electrical performance in an industrial environment with important power consumers. Solving of the electrical problems from design to exploitation phase takes in account also to optimize the power flow and to give the voltage and current measures taking in account the voltage control. The paper presents an Edsa Paladin digital simulation for a real case study from a power industrial delivery system with the purpose to optimize the operational stage of the system.

Keywords: Power system, power flow, optimization, power delivery

1. INTRODUCTION

The power system needs to be simulated in the design phase but also in the exploitation phase [5-9]. On this purpose software tools are used [10-12]. The paper proposes to use Edsa Paladin which represent a collection of 50 software programs dedicated for project, analysis, grid operation and electrical system [2]. The set of tools proposed of Edsa Paladin are used for calculation and modeling and they permit solving of the electrical problems. It covers a big share on market in the most required industrial application to customer like: transport, delivery of electrical energy, power plants, drawings and monitoring of power systems.

After the design and implementation in practice of a medium voltage electrical station, Edsa Paladin software gives methods and computing algorithms to determine buses drop voltage, to optimize and maintain the level of voltage, methods to compute the branch power flow, branch current flow, transformer loading, short circuit current analysis (tri phase and mono phase), torque and performance of the motors. Edsa can help us to determine the most efficient solution of the power flow for the analyzed system [1], [3-4].

2. STUDY CASE INDUSTRIAL DELIVERY SYSTEM

Edsa Paladin software will be used for a real industrial system analysis (Figure 1) consists of two Utility Supplies 110kV, which feeds two bus bars system. Buses are supplied via two 10 MVA transformer T1 and T2 that steps the voltage down to 6 kV and supplies power to a complex radial delivery network

The electrical station at medium voltage 6kV contains two voltage transformers T_1 and T_2 from 110kV to 6kV each with the power rate 40mVA. From each of these busbar (bus1 and bus 2) two stations are supplied Station 1 (bus3 and bus4) and Station 2 (busbar5 and busbar7). In Station1 there are three air compressors and two voltage transformers from 6kV to 0,4kV which provide electric power for two busbars with two asynchronous motors. Station 2 contains 3 busbars which supply 3 synchronous motors and has 2 voltage transformers from 6kV to 0,4kV for other 2 asynchronous motors.

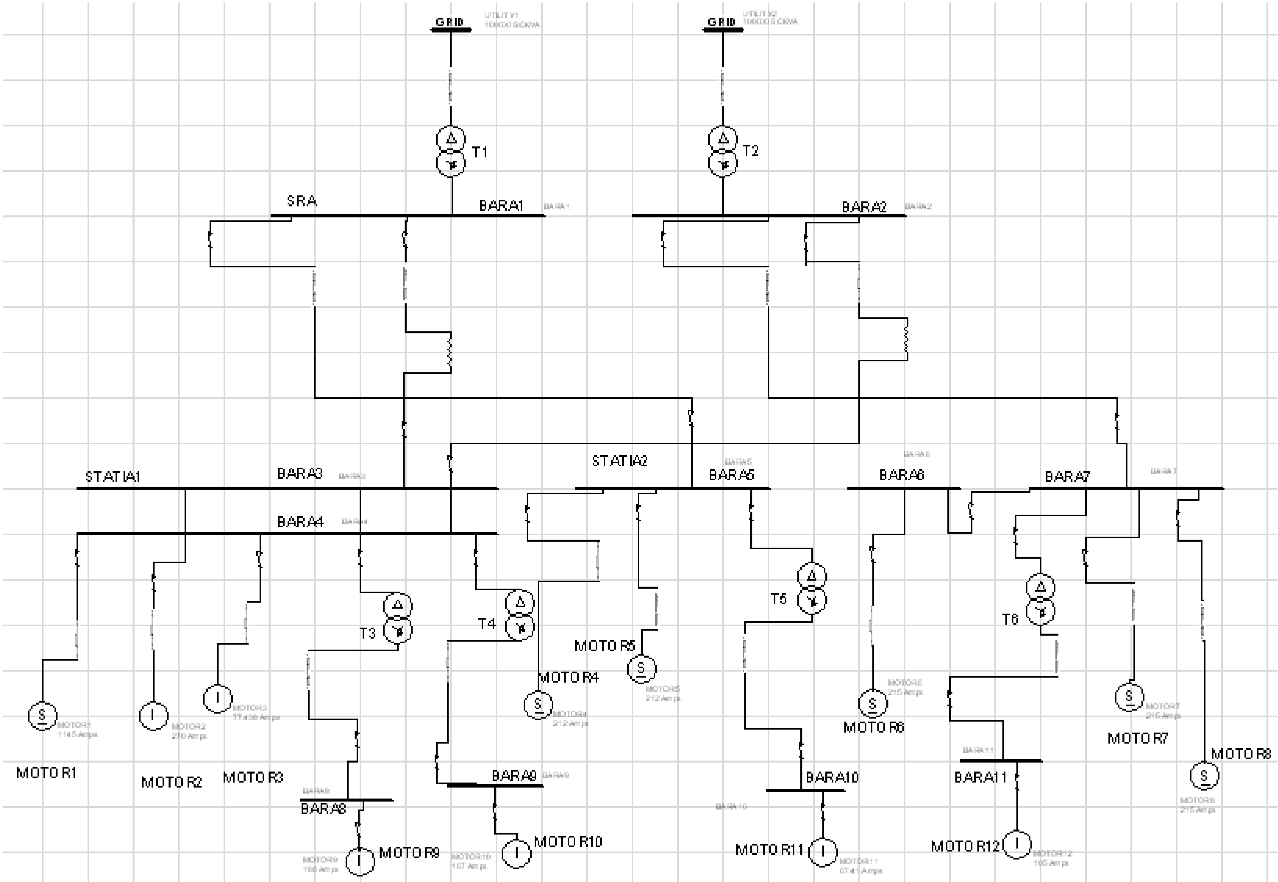

Fig. 1 Industrial 110/6kV power delivery system-study case.

The analyzed power system is composed by the elements described below:

- T_1 and T_2 voltage transformers from 110kV to 6kV;
- Bus bar 1 and bus bar 2, 6kV voltage ;
- Bus bar 3 and bus bar 4, 6kV voltage;
- Bus bar 5, bus bar 6 and bu sbar 7, 6kV voltage;
- T_3 and T_4 voltage transformers from 6kV to 0,4kV;
- T_5 and T_6 voltage transformers from 6kV to 0,4kV;
- Motor 1 8MW; Motor 2 2MW; Motor 3 500MW;
- Motor 4, 5, 6, 7 and 8, 1,75MW.

The analysis starts with the setting up for the power electrical station: the type of grid – three phase 6 kV, the power of transformers, the type of cooling- oil, the voltage of each bus bar, the grid frequency, the power of the motors, and the maximum and minimum power range of an entire power station.

Table 1

Bus bars voltage

Bus	Voltage(kV)
Bara 1	5.964
Bara 2	5.901
Bara 3	5.799
Bara 4	5.244
Bara 5	5.963
Bara 6	5.9
Bara 7	5.9
Bara 8	0.387
Bara 9	0.35
Bara 10	0.398
Bara 11	0.393

Table 2

Branches current

Nr.	From	To	Current(A)
1	Utility1	BARA1	38
2	Utility2	BARA2	39
3	BARA1	BARA5	423
4	BARA1	BARA3	269
5	BARA2	BARA4	1174
6	BARA2	BARA7	642
7	BARA3	MOTOR2	269
8	BARA3	BARA8	177
9	BARA4	MOTOR1	1101
10	BARA4	MOTOR3	74
11	BARA4	BARA9	178
12	BARA5	MOTOR4	212
13	BARA5	MOTOR5	212
14	BARA5	BARA10	65
15	BARA6	MOTOR6	214
16	BARA6	BARA7	214
17	BARA7	BARA11	101
18	BARA7	MOTOR7	214
19	BARA7	MOTOR8	214
20	BARA8	MOTOR9	186
21	BARA9	MOTOR10	180
22	BARA10	MOTOR11	105
23	BARA11	MOTOR12	105

The Load flow module from EDSA Paladin gives the voltage level to all the busses (table 1) and also the associated voltage drops. Figure 2" and Figure 3 show the voltage level and the voltage drop in percent, respectively. The blue line curve presents the real study case voltage drop and the red line curve presents the voltage rate. Edsa Object Oriented Load Flow results show us the branch current flow Figure 4 and table 2.

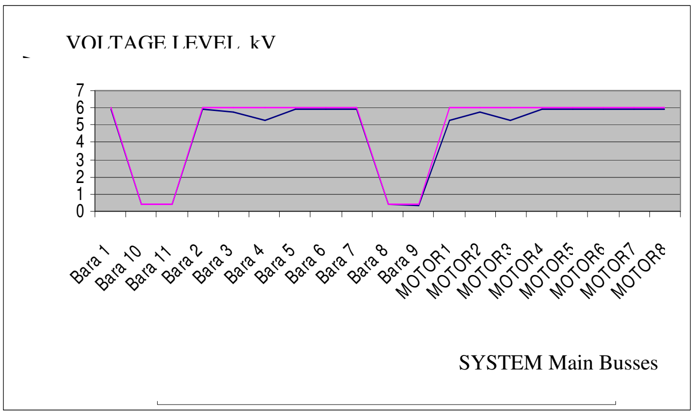

Fig. 2 The bus bars voltage .

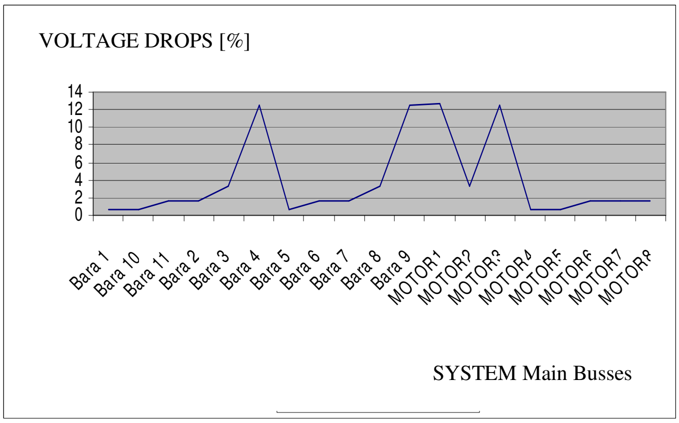

Fig. 3 The bus bars voltage drop.

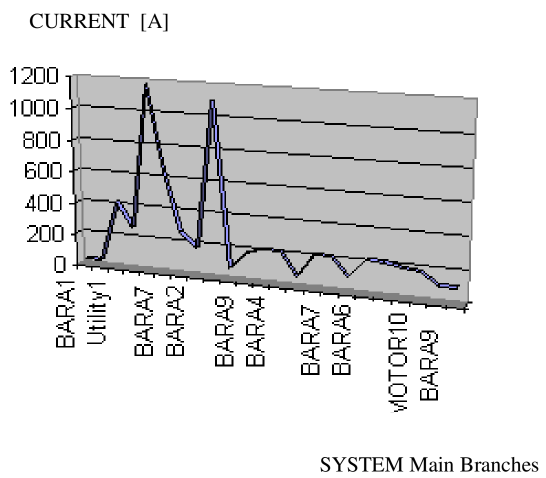

Fig. 4 The branches current flow.

3. VOLTAGE CONTROL OF THE DELIVERY SYSTEM

For the all the busses voltage control, we will make tap transformers adjustment, this means changing high voltage taps to all the transformers. The task is possible to simulate on Edsa Paladin using the menu to set up 'on' the command at automatic tap adjustment.

With the same command we will set up every each motors to control the voltage level to the motors. After setting the control we can run again Object oriented flow and we will obtain the new drop voltage of the power station with respect to the voltage level control, Table 3, Figure 5, Figure 6.

Table 3

Bus bars voltage

Bus	Voltage(kV)
Bara 1	6.255
Bara 2	6.307
Bara 3	6.098
Bara 4	5.712
Bara 5	6.255
Bara 6	6.306
Bara 7	6.306
Bara 8	0.417
Bara 9	0.381
Bara 10	0.417
Bara 11	0.413

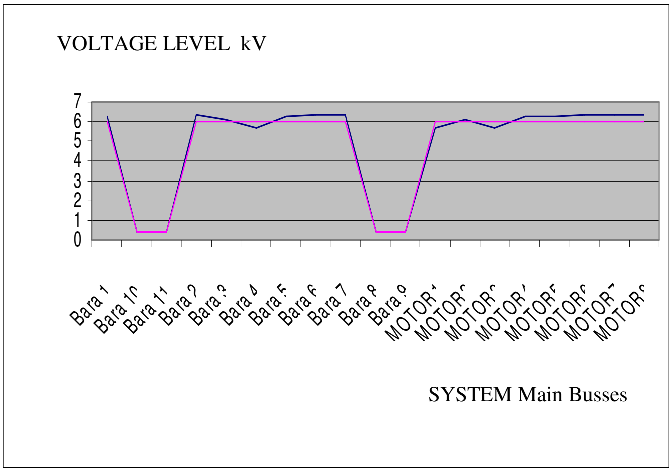

Fig. 5 The bus bars voltage.

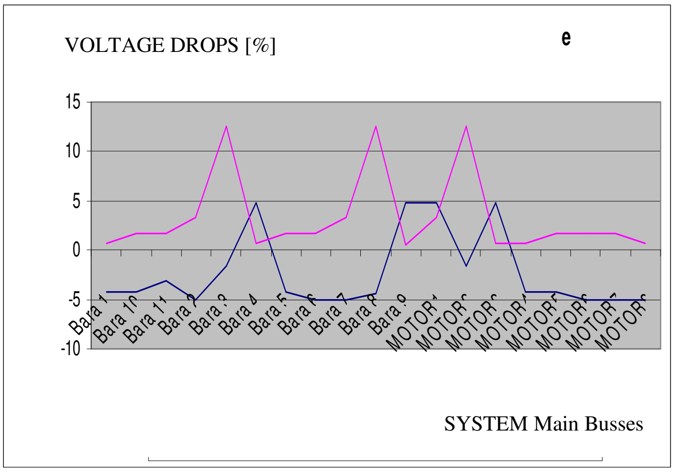

Fig. 6 The bus bars voltage drop.

In figure 5 the blue line curve represents the real study case voltage level and the red line curve represents the voltage rate. In figure 6 the blue line curve represents the voltage drop level after the automatic control and the red line curve presents the voltage drop level before the automatic control.

For the calculation of the advanced power flow we have to set up again the all transformers in power system. To start up the 'controlled bus option' at transformers T_1 and T_2 we define bus bar 1 as being controlled with a minimum limit of voltage by 3%. For other transformers T_3, T_4, T_5 and T_6 we define the rest of bus bars as being controlled with a minimum limit of voltage by 7%. This means that we accept a drop voltage from 3% up to 7% on the bus bars. After adjustment of transformers we can set up the motors and remove the automatic control of voltage from menu Load flow on each motor.

In this case we can run Advanced power flow options from Edsa Paladin menu and below we have the report of Branch power flow, Table 4 and Figure 7 (the blue line curve presents the active power flow and and the red line curve presents the reactive power flow).

Table 4

Power flow for the delivery system

Nr	From	To	P(Mw)	Q(Mvar)
1	BARA 1	BARA 3	2.435	1.593
2	BARA 1	BARA 5	4.066	2.174
3	BARA 2	BARA 4	10.295	7.613
4	BARA 2	BARA 7	6.104	3.288
5	BARA 4	MOTOR 1	9.197	5.141
6	BARA 3	MOTOR 2	2.299	1.425
7	BARA 4	MOTOR 3	0.575	0.356
8	BARA 3	BARA 8	0.114	0.059
9	BARA 4	BARA 9	0.107	0.043
10	BARA 5	MOTOR 4	2.012	1.076
11	BARA 5	MOTOR 5	2.012	1.076
12	BARA 5	BARA 10	0.042	0.02
13	BARA 6	MOTOR 6	2.012	1.087
14	BARA 6	BARA 7	2.012	1.087
15	BARA 7	BARA 11	0.067	0.027
16	BARA 7	MOTOR 7	2.012	1.087
17	BARA 7	MOTOR 8	2.012	1.087

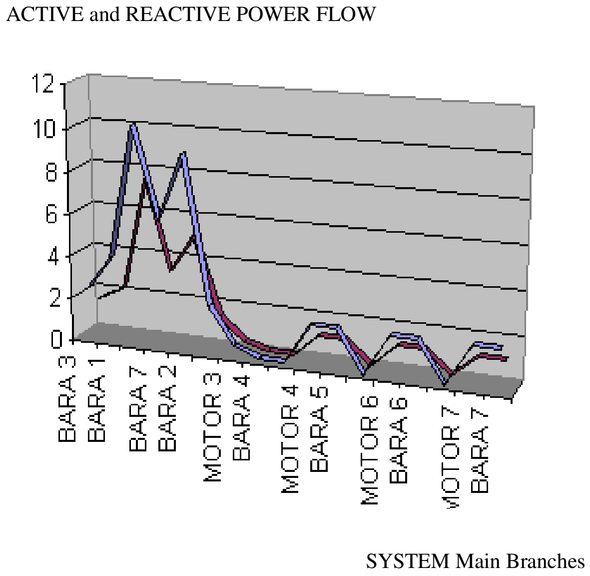

Fig. 7 Branches power flow.

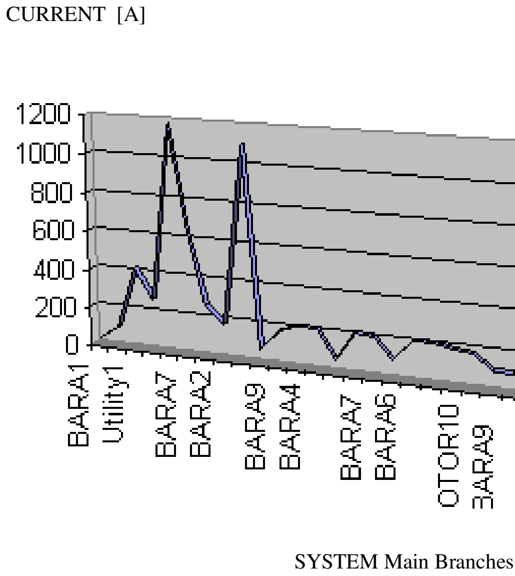

Fig. 8 Branches current.

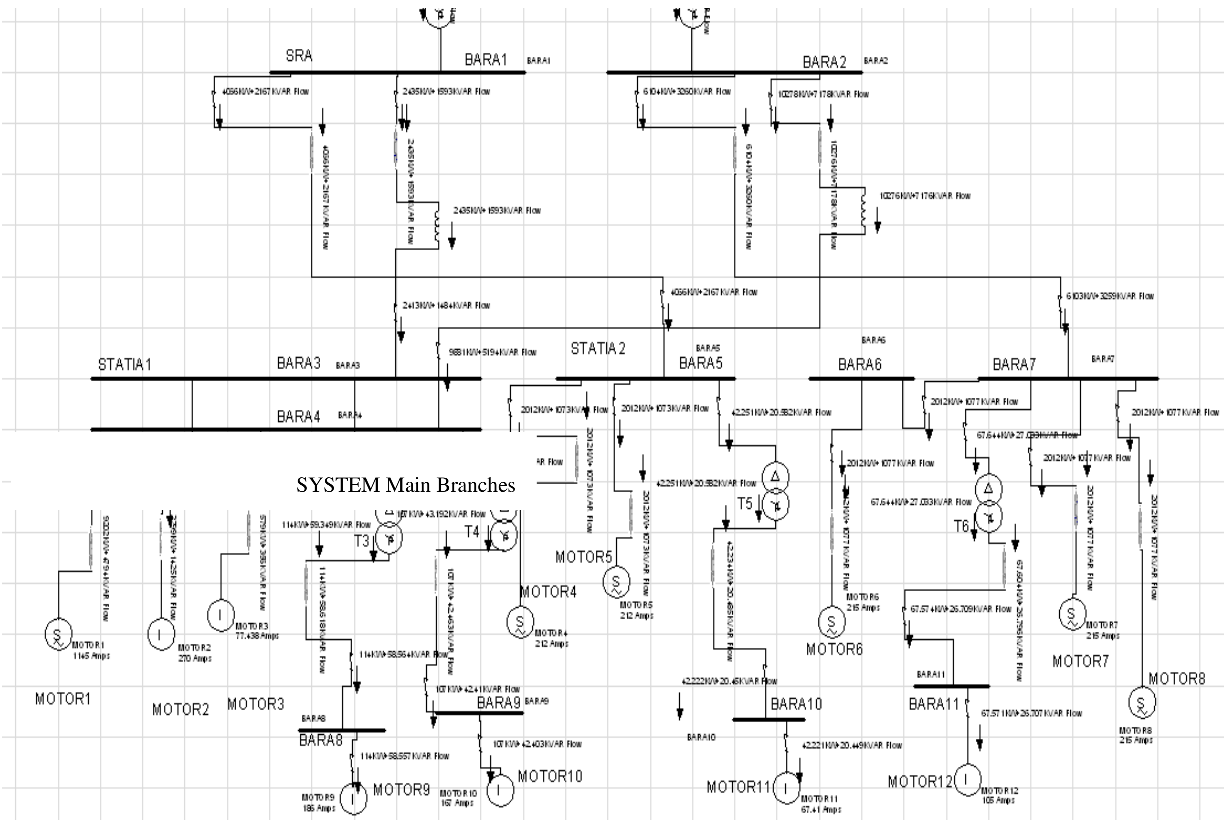

Fig. 9 Complete drawing of the optimized power flow for the power delivery system-study case

On the other hand, we can also report the branches current and the load of the transformers in the advanced power flow simulation for the analized power delivery system Figure. 8 and Table 5.

Table 5

The transformer loads

Nr	From	To	Capacity(Mva)	Loading Mva - %	Tap
1	T1	BARA1	47.2	7.557 -16%	0.956
2	T2	BARA2	47.2	19.747 - 42%	0.938
3	T3	BARA8	1	0.129 – 13%	0.975
4	T4	BARA9	1	0.116 - 12%	1
5	T5	BARA10	1	0.047 - 5%	1
6	T6	BARA11	1	0.073 - 7%	1.019

In the same time if we select in Edsa Paladin menu, the Edsa annotation from the tools bar - flow arrow, the measures for the voltage, the measures for the current and for the power flow- we can see the complete drawing with branches active and reactive power flow Figure 9.

5. CONCLUSIONS

We can see that the voltage drop of the power station were too high before setting up the voltage control. These could reach even 12,59% from the nominal voltage, which is 6kV. To change these values and try to control the voltage level, we could implement the optimisaton method for the reaal industrial analyzed system using the Edsa Paladin software. The methods possible to implement which consists in automatic voltage control by automatic tap adjustment, sizing and locate the capacity, adjust the reactive power of motors are subject to apply in the operational satte of the system. So the proposed method used in the paper shows the benefits of the voltage control and conducts to tehe efficiency increasing of the power delivery system..

BIBLIOGRAPHY

[1] **Dugan R. C., Beaty H. W. and McGranagham M. F.**, *Electrical power systems quality*, New York: Mc.Graw-Hill, (1996), 39-80

[2] **Edsa Micro Corporation** “Object oriented load flow ”.

[3] **IEC 61000-3-7**, Part 3: Limits - Section 7: Assessment of emission limits for fluctuating power in MV and HV power systems

[4] **IEEE P1366**, Trial Use Guide for Electric Power Distribution Reliability Indices, *Working Group on System Design*, Draft 5, Ian. (2001)

[5] **IEC 61400-21**, *Measurement and assessment of power quality characteristics of grids*

[6] **IEEE Standard 519-1992** Power Grids Distortion Limits. Voltage characteristics of electricity supplied by public distribution systems, *European Norm EN 50160*, Nov. (1999)

[7] **Ioan Novac, Emil Micu, Emil Rosu, Ioan Bivol** “Motors and electrical drives” 2003;

[8] **Mariana Dumitrescu**, *Power Systems*, edited on Didactica and Pedagogica Bucuresti 2002, 270-295

[9] **Mariana Dumitrescu**, *Efficiency and Reliability on Power Systems*, edited on Didactica and Pedagogica” Bucuresti (2003), 150-161

[10] **Mohan N., Undeland, T. M., and Robbins W. P.**: *"Power systems, applications and design",* 2nd Edition New York, Wiley & Sons, (2005), 102-152.

[11] **Saied M.**, “Measures for the supply efficiency in distribution network”, INT.J.Elect. Power Energy Systems, vol 23, (2001), 427- 434

[12] **Sergiu Calin, Eng. Stelian Popescu** “Automatics and relay protection” 1987;

About the author

Professor Eng. **Mariana DUMITRESCU**, PhD
University “Dunarea de Jos” from Galati
email: mariana.dumitrescu@ugal.ro

She has Power System Engineer degree from Politehnica University Bucharest and Power System Reliability Ph degree from University Dunarea de Jos Galati. She is Professor of the University Dunarea de Jos from Galati in the Automation and Electrical Engineering Department since 1991. The area of research interest is the simulation and analysis of power systems, with respect to its efficiency, quality and reliability.She published monographis in the area of Power Systems