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SIMULATION AND ANALYSIS OF HARMONIC PROPAGATION IN AN ELECTRICAL NETWORK USING ETAP SOFTWARE

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Abstract— At first, we measured the harmonics in our electrical network of an industrial installation for different power of the load (P=2MW, P=4MW, P=6MW and P=10MW), through these results we created a harmonic model depending on the power of the load. Subsequently we connected this harmonic model that we called harmonic generator to bus 6 of IEEE 09 bus network system, to see the propagation of harmonics by the use of ETAP simulation software, representing the spectrum harmonic in the different nodes of this electrical network to know how harmonics propagate in an electrical system.

Keywords- *simulation;harmonics; experimental tests ; etap; model*

I. INTRODUCTION

The different users, regardless of the voltage level to which they are connected, expect a voltage whose waveform is as sinusoidal as possible. In practice, the waveform of the voltage is not sinusoidal because the currents circulating in the line include, in addition to their fundamental, harmonics due on the one hand to the magnetizing currents that the electrotechnical components consume in order to ensure their function. preferred conductor of the magnetic flux, and on the other hand to the currents drawn into the network by the power electronics converters [1].

The harmonics contained in the non-sinusoidal currents drawn to the line by a converter generate harmonic voltage drops in the line chokes, which deteriorate the quasi-sinusoidal waveform of the voltage produced at the head of the line, the distortion of the voltage sinusoid is all the more marked as the rms value of each of the current harmonics is less negligible compared to the nominal value of the rms value of the line current [2]. A harmonic voltage is associated with the rms value of the harmonic of order n of the line current, and the harmonic distortion of the voltage is defined by the ratio of the rms value of the harmonic voltage to the nominal rms value of the line voltage. line. In recent years, there has been a sharp increase in non-linear loads connected to the electrical network: computers, fax machines, discharge lamps, arc furnaces, battery chargers, inverters, electronic power supplies, etc.

The consequences on the electrical power system are becoming a concern due to the increasing use of this equipment, but also the application of electronics to almost all electrical loads. Indeed, a non-linear load draws a large, distorted current from the network, which can be broken down into harmonics. Harmonic currents have negative effects on almost all components of the electrical system, creating new dielectric, thermal and/or mechanical stresses [3] Non-linear receivers such as arc furnaces, lighting, converters, rectifiers, absorb non-sinusoidal currents which cross the network impedances and thus cause a deformation of the supply voltage sinusoid. The deformation of the waveform is characterized by the appearance of voltage harmonic frequencies [4]. The amplitude of rank 1 is called the fundamental component of the periodic electrical signal; in our case it is (50 HZ). The amplitude of each harmonic is inversely proportional to its order. The first harmonic orders such as (3, 5, 7.9) have high amplitudes, hence the importance of the injected currents, which is why these harmonics must be limited in the standards [5].

In this work we measured the harmonics in our electrical network of an industrial installation for different load powers (P=2MW, P=4MW, P=6MW and P=10MW), through these results we created a model harmonic according to the power of the load. Then we connected this harmonic model which we called harmonic generator to bus 6 of the IEEE 09 bus network system to see the propagation of harmonics in the nodes of this network by ETAP software [6].

A. Distortion Rate

The distortion rate characterizes the level of network pollution. There are two definitions [7].

$$THD(\%) = \frac{\sqrt{\sum_{i=2}^{n} I_{ci}^2}}{I_{c1}} \qquad (1)$$

With :

The rms value of the fundamental component of the load current and the exact values of the various harmonic components of the load current.

The overall rate of harmonic distortion of the voltages can be written

$$THD(\%) = \frac{\sqrt{\sum_{i=2}^{n} U_{ci}^2}}{U_{c1}} \qquad (2)$$

II. REPRESENTATION DE PUISSANCES SOUS L’EFFET DES HARMONIQUES

A. Active Power

Each harmonic provides a contribution to the average power which can be positive or negative.

However, the resulting harmonic power is very small relative to the fundamental frequency active power [8].

B. Reactive Power

$$THD(\%) = \frac{\sqrt{\sum_{i=2}^{n} U_{ci}^2}}{U_{c1}} \quad (2)$$

C. Apparent Power

$$S^2 = P^2 + \sum_{i=1}^{n} V_1 I_1 \sin(\varphi_1) + D^2 \quad (5)$$

6Where the distorting power due to current harmonics.

For three-phase systems, the per-phase apparent power vector (k), SV, as proposed in Frank, can be expressed.

$$S_v = \sqrt{\left(\left[\sum_k P_k \right]^2 + \left[\sum_k Q_{bk} \right]^2 + \left[\sum_k D_k \right]^2 \right)} \quad (6)$$

And the arithmetic apparent power, Sa, as

$$S_a = \sum_k \sqrt{(P_k^2 + Q_{bk}^2 + D_k^2)} \quad (7)$$

Where P, Q_b , and D are the active, reactive and orthogonal power strain components respectively

$$S_e = \sum_k \sqrt{(P_K^2 + Qf_k^2)} = \sum_k V_K I_k \quad (8)$$

And the apparent power for a three-phase system, Ss:

$$S_s = V_{rms} I_{rms} = \sqrt{P^2 + Q_f^2} = \sqrt{\sum_k V_k^2} \sqrt{\sum_k I_k^2} \quad (9)$$

Where Q_f the reactive power

III. EXPERIMENTAL TESTS

Experimental tests to measure harmonics, in an Algerian industrial installation, were carried out using the Power Quality Analyzer: Chauvin Arnoux CA 8332B [9].

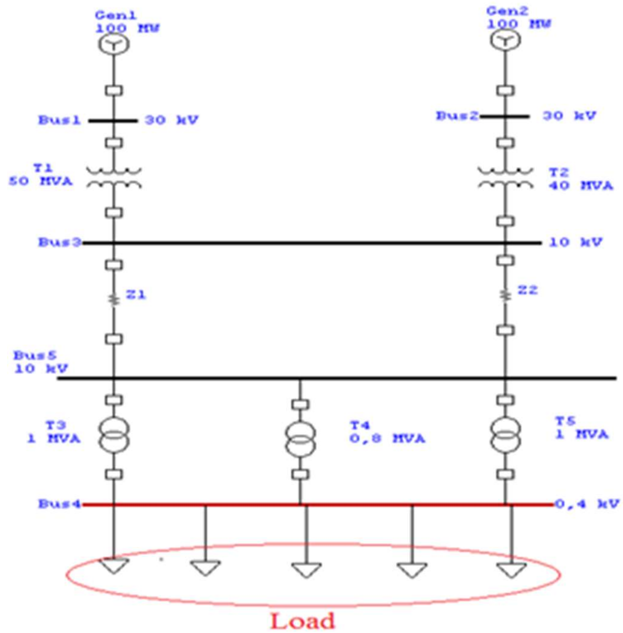

Figure 1. Our industrial installation

The following figure shows the equipment used for the measurement of harmonics (C.A 8332B).

Figure 2. Transient Power and Network Analyzer (C.A 8332B)

The histogram of the harmonics obtained through the measurements carried out using the Power Quality Analyzer C.A 8332B, as a function of the load power, is shown in the following figure:

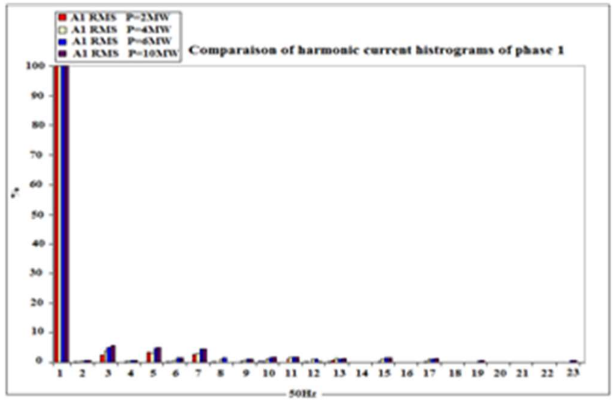

Figure 3.Comparison of the histogram of the harmonic currents for different load powers.

The current THD as a function of the load power is shown in the following figure:

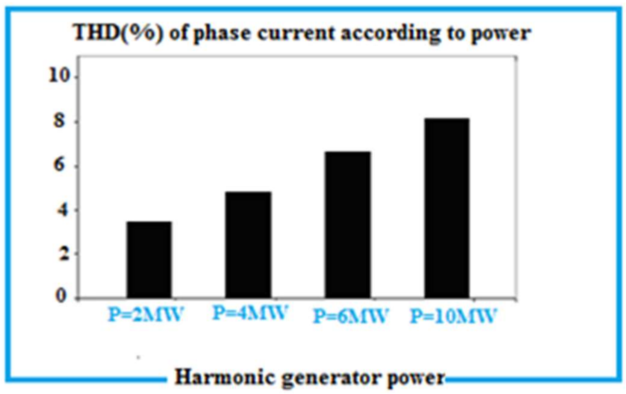

Figure 4. Increase of THD% of the current according to the power of the harmonic generator

Note that for a power of the harmonic generator P=2MW, the rate of harmonics of the current (current THD) has an average value of 3.45%, this factor (THD) increases and reaches a value of 4.83% if the power of the harmonic generator P=4MW, this factor also increases by a value of 6.44% for the power of the harmonic generator of 6MW as shown in the figure fig.(10) If the nuclear power reaches 10MW, the THD increases to 08.02%[10].

IV. HARMONIC MODELS CREATED USING ETAP

By exploiting the measurements previously carried out at our industrial installation, we were able to obtain a specific harmonic model entitled (TEST-FACTORY), this model thus introduced into the ETAP software, this harmonic model contains the harmonic rates of different load powers (H-2MW, H-4MW, H-6MW, H-10MW), harmonic analysis tests were performed for the IEEE 9-node network system[11].

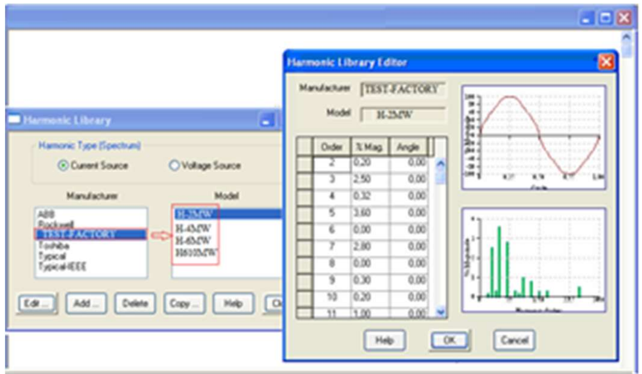

Figure 5. Created harmonic model (PH=2MW).

If we click on the harmonic model (H-2MW), we obtain the data of the harmonic model (Amplitude of each harmonic order, the curve of the harmonic model and the histogram of this one).

For a harmonic power of 4MW as shown in the following figure(5), and so on for the powers of the harmonic source 6MW and 10MW.

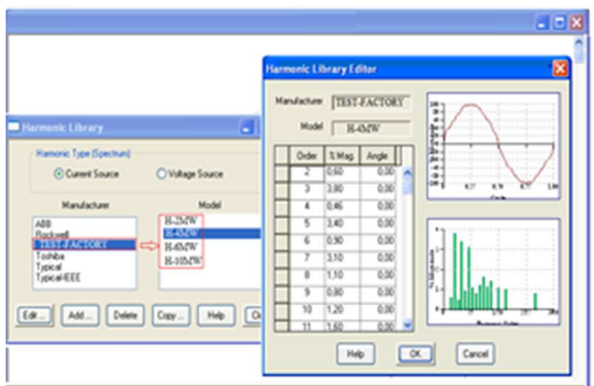

Figure 6. Created harmonic model (PH=4MW).

V. TEST NETWORK SYSTEM

In this part we tried to connect the harmonic model that we created , what we call harmonic generator on bus 6 of our 9-node IEEE network system [12] that we want to study to make simulations of analysis of the propagation of harmonics on the buses of our network with a power level of the harmonic source (P=2MW, P=4MW, P=6MW, P=10MW), by representing the harmonic spectrum in the different nodes systems using the ETAP software [13].

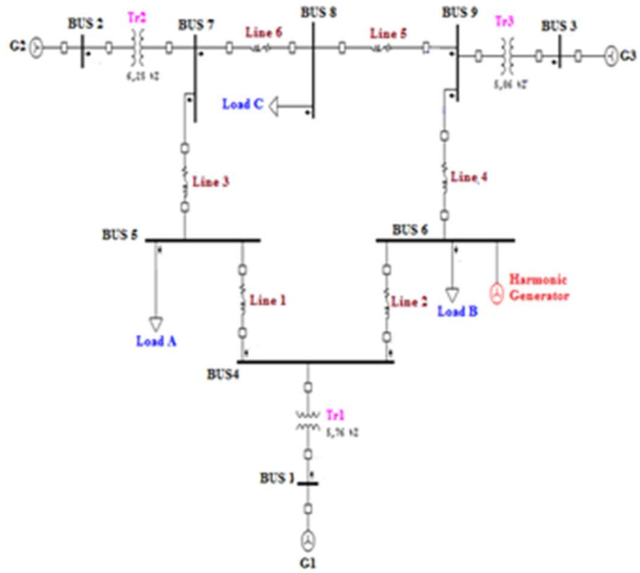

Figure 7 . IEEE 9 Bus Network System

In this case the harmonic generator is connected to bus 6 of our network, see figure (7), we have presented the voltage harmonic spectrum of the network connection bus with the harmonic generator for different values of power from the harmonic load.

V.1. The power of the harmonic generator (P=2MW)

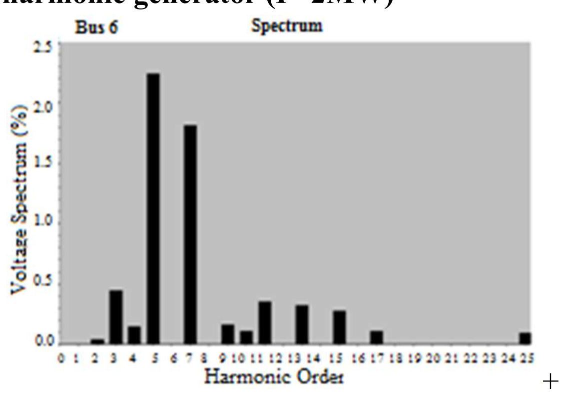

Figure 8. Harmonic spectrum of Bus 6

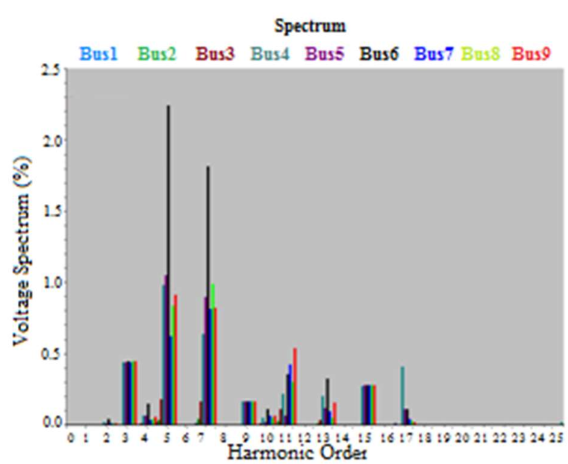

Figure 9. Harmonic spectrum of Bus 1, 2, 3, 4, 5, 6, 7,8 and 9.

For a 2MW harmonic power with a current harmonic rate of 3.45%, the peak of the voltage harmonic spectrum at the connection node of the harmonic generator with our network (bus 6) is around 2.2%

V.2. The power of the harmonic generator (P=4MW)

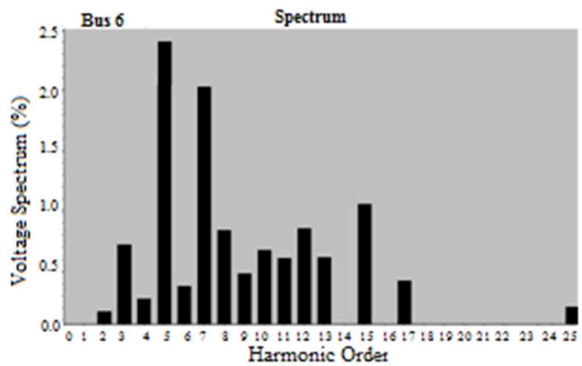

Figure 10. Harmonic spectrum of Bus 6

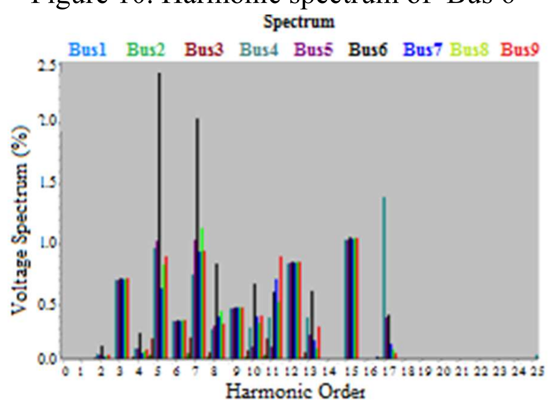

Figure 11. Harmonic spectrum of Bus 1,2, 3, 4, 5, 6, 7, 8 and 9

For a 4MW harmonic power with a current harmonic rate of 4.83%, the peak of the voltage harmonic spectrum at the connection node of the harmonic generator with our network (bus 6) is around 2.4%.

V. 3. The power of the harmonic generator (P=6MW)

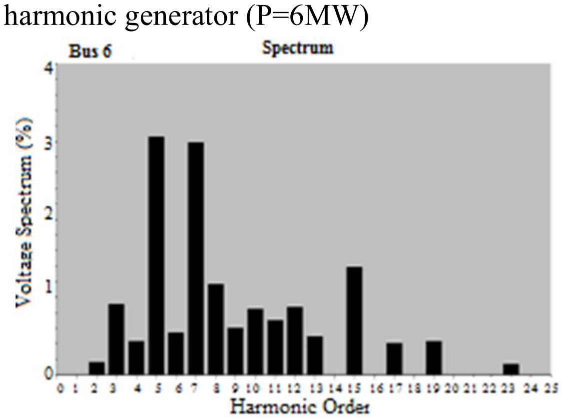

Figure 12. Harmonic spectrum of Bus 6

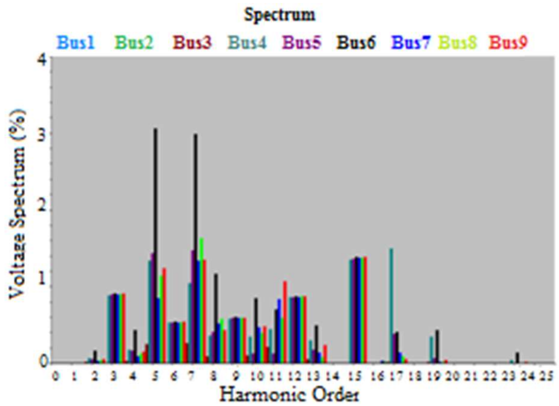

Figure 13. Harmonic spectrum of Bus 1,2, 3, 4, 5, 6, 7, 8 and 9

For a 6MW harmonic power, with a current harmonic rate of 6.44%, the peak of the voltage harmonic spectrum at the connection node of harmonic generator with our network (bus 6) is around 3.1%.

V.4. The power of the harmonic generator (P=10MW)

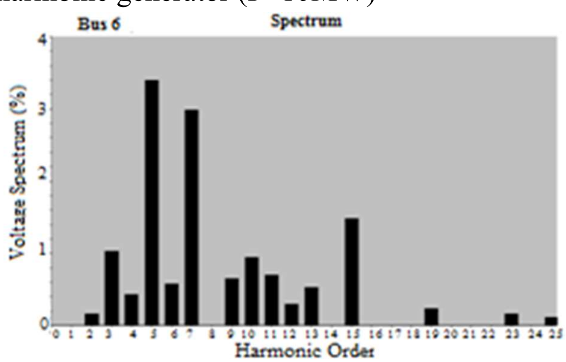

Figure 14. Harmonic spectrum of Bus 6

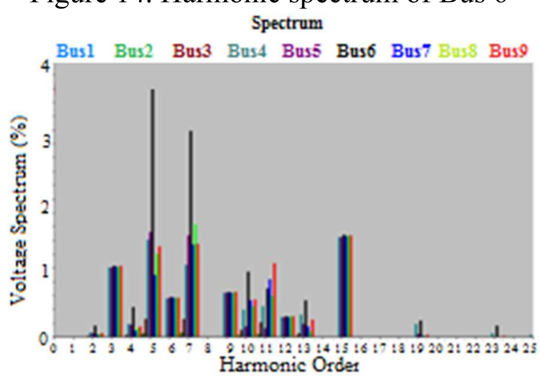

Figure 15. Harmonic spectrum of Bus 1,2, 3, 4, 5, 6, 7, 8 and 9

Through the tests we made for a 10MW harmonic source power with a current harmonic rate of 08.02%, the peak of the voltage harmonic spectrum at the connection node of the harmonic generator with our network (bus 6) is around 3.4%.

The following figure presents the harmonic spectrum of the connection node of our network with the harmonic generator which has been created for different values of the harmonic power.

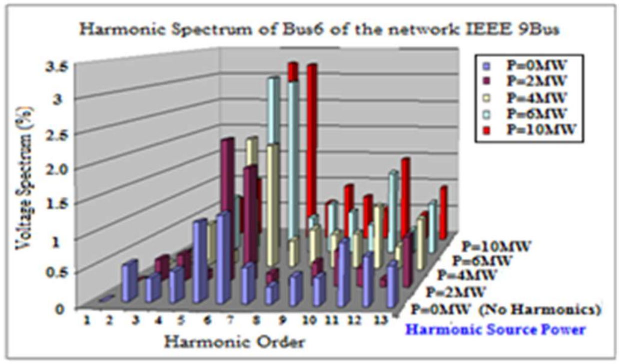

Figure 16. Harmonic spectrum of the network connection bus with the harmonic generator for different values of harmonic power.

VI. CONCLUSION

In this work, we discussed the problem of harmonics in electrical networks, first we defined the harmonics in voltage and current, the rate of harmonic distortion according to the standards. We then presented the harmonics measured in our industrial installation, and their models created in ETAP, which allows us to perform harmonic analysis simulations with a power level of the harmonic source (P=2MW, P=4MW , P=6MW , P=10MW) with the network systems studied: an IEEE 9-node network system, representing the harmonic spectrum in the different system nodes using the ETAP software.

If we compare the harmonic rate THD for the different values of the power of the harmonic generator, we observe that the variation of the current THD increases proportionally with the increase in the harmonic power see figures: figure (3) and figure (4), these results are logical since each time the electrical power of the harmonic source increases, this means that the electrical current consumed by the nonlinear loads in the installation increases, and consequently the current THD increases.

REFERENCES

[1] Hingorani N. G., Gyugyi L, ‘’Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems‘’, New York: IEEE Press, 2000

[2] T. Haryono, ‘’the effect of harmonic distortion to power factor‘’, University of Yogyakarta, 2007, Indonesia.

[3] H. Elkhatib, "Etude de la stabilité aux petites perturbations dans les grands réseaux électriques : optimisation de la régulation par une méthode métaheuristique," Université de PAUL Cézanne D'aix Thèse de Doctorat, 2008.

[4] Badis Mallem, ‘’ Modélisation, analyse et commande des grands systèmes électriques interconnectes‘’, docteur de ENS Cachan, France, 2010.

[5] S. M. Sadeghzadeh, ‘’Amélioration de la stabilité transitoire et de l’amortissement des oscillations d'un réseau électrique a l'aide de SMES et de SSSC‘’, Ph.D, Sharif University of Technology, IRAN, 1998.

[6] P. Kundur, ‘’Power system stability and control‘’, New York: McGraw-Hill, 1994.

[7] J. Machowski, J.W. Bialek et J.R. Bumby, ‘’Power system dynamics: stability and control‘’, 2nd Edition, John Wiley & Sons, Ltd, 2008.

[8] Roberto andres, ‘’Etude de la stabilité transitoire à l’aide de l’algorithme SIME’’,

maitrise en génie électrique, école de technologie supérieure, 2015, Montréal, Canada.
[9] Kundur P, ‘’Power System Stability and Control‘’, McGraw Hill Inc., 1994, ISBN 0-07-035958-X.
[10] Kamel Saoudi, ‘’Stabilisateurs intelligents des systèmes electro-energetiques‘’, thèse de doctorat U
[11] niversité Ferhat Abbas, Setif1, 2014, Algérie.
[12] M, Uzunoglu, ‘’Harmonics and voltage stability analysis in power systems including thyristor-controlled reactor’’, Yildiz Technical University, Electrical–Electronics Faculty, Electrical Engineering Department, 34349 Besiktas, Istanbul, 2004, Turkey.
[13] Kundur P., et al. Definition and Classification of Power System Stability. IEEE Trans. On Power Systems, Vol. 19, No. 2, pp.1387-1401, May (2004).
[14] http://www.etap.com