ANNALS OF THE FACULTY OF ENGINEERING HUNEDOARA
2004, Tome II, Fascicole 1

THE FUNCTIONING SIMULATION OF AN ELECTRICAL INSTALLATION AFFERENT TO A CRUCIBLE INDUCTION FURNACE, BY USING THE PSCAD - EMTDC PROGRAM

[1]IAGĂR Angela, PĂNOIU Caius, ABRUDEAN Cristian

[1,2] University „POLITEHNICA" TIMIŞOARA, Faculty of Engineering HUNEDOARA

ABSTRACT

The paper presents the simulation of the functioning process of an electrical installation afferent to a crucible induction furnace, supplied to an industrial frequency. The simulation being presented by using the PSCAD-EMTDC program.

KEYWORDS: *induction furnace, industrial frequency, simulation*

1. INTRODUCTION

In this paper the electrical installation of an electromagnetic induction furnace, with crucible, is being analysed. The capacity of the furnace being 12.5 tones cast iron.

The furnace is supplied by using a three-phase transformer (f = 50 Hz). The transformer has the rated output Sn = 2625 kVA, the connexion Δ/Δ, $3\times6/1.2$ kV, and the voltage control in steps (4 primary steps and 8 secondary ones). The balancing of the three-phased network is made through a Steinmetz symmetry diagram, with coil and capacitors, while the compensation of the power factor of the furnace is made through a battery of capacitors.

The purpose of the paper is the simulation of the functioning process of an electrical installation afferent to a crucible induction furnace, by using the PSCAD-EMTDC program. The simulation results have been compared with the experimental data obtained by measurements made in the lower voltage part of the electrical installation of the furnace.

2. EXPERIMENTAL RESULTS

For measuring the electrical quantities of the studied installation, there has been used a data acquisition system.

The measured electrical quantities (high voltages and currents) have been transformed, by using an adapting block, into voltages that have a compatible range with the used acquisition board (ADA 3100). The acquisition data frequency had the value 12.5 kHz. The acquisition time has been 400 ms, each signal having 20 periods which can be selected by the program. The time between the two consecutive data windows has the value 5 s.

The measured electrical quantities (the secondary voltages, the currents absorbed by the installation of the furnace from the three-phased network and the currents that pass through the inductor) are presented in Fig. 1.

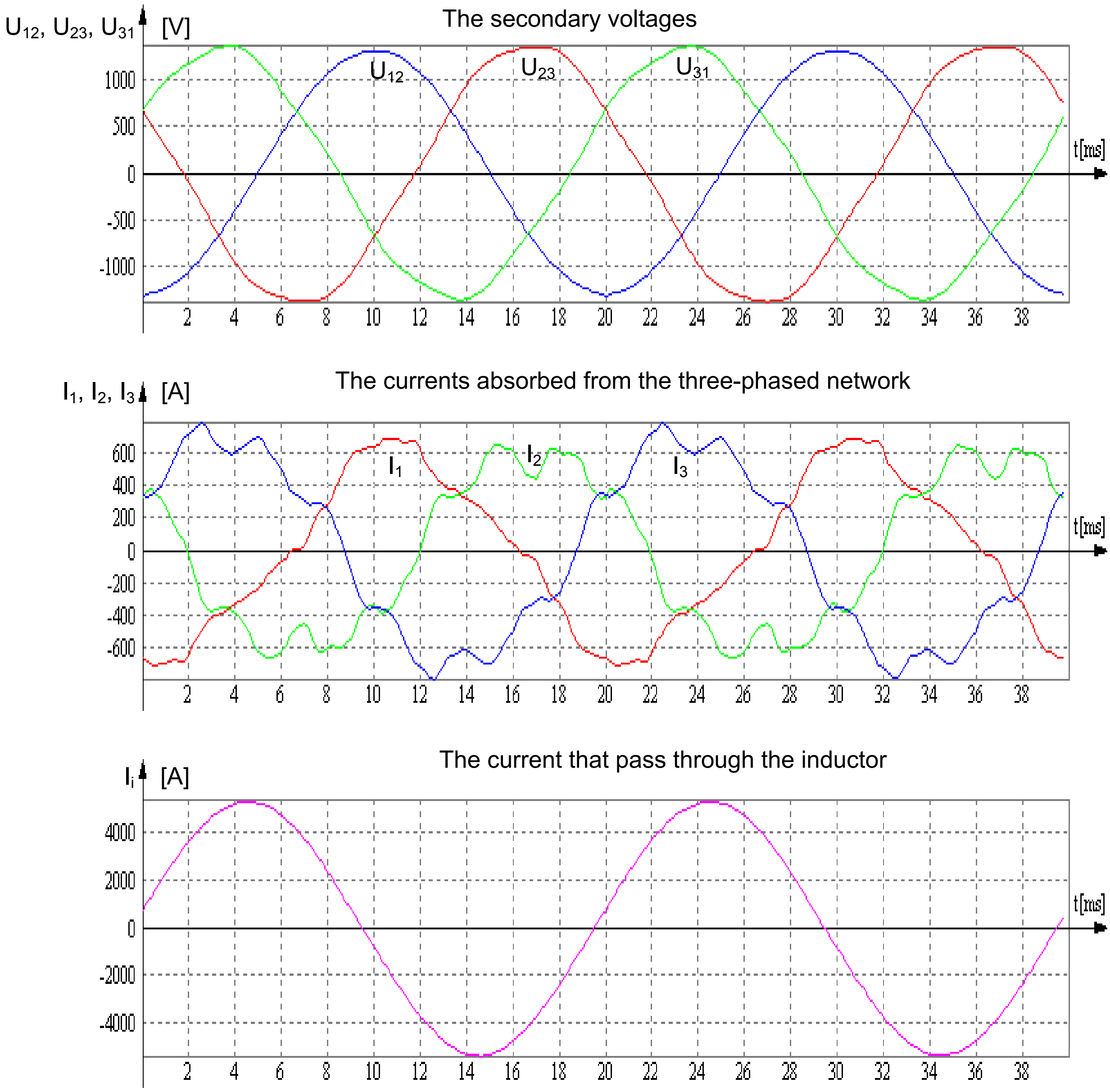

Fig. 1. *The electrical quantities measured in the lower voltage part of the studied electrical installation*.

There have been ascertained some electromagnetic disturbances in the currents absorbed by the installation of the furnace from the three-phased network; this indicates the non-linear characteristic of the components from the electrical installation of the analysed induction furnace.

Having this remark as a starting point, supposing, as well, that the coil (with magnetic core) from the symmetry installation is saturated, by using the PSCAD-EMTDC program, a simulation of the functioning process of the electrical installation has been obtained.

3. THE SIMULATION OF THE FUNCTIONING PROCESS OF THE ELECTRICAL INSTALLATION AFFERENT TO AN INDUCTION FURNACE OF INDUSTRIAL FREQUENCY BY USING THE PSCAD-EMTDC PROGRAM.

3.1. The modelling of the changing inductance of a symmetry coil

The saturation of the magnetic core of the symmetry coil can be mathematically modelled by using the relation (1). Formula (1) expresses the non-linear dependence of the magnetic induction from the coil, on the magnetic field strength and on temperature:

$$B = \mu_0 \cdot H + B_{s0} \cdot \frac{H_a + 1 - \sqrt{(H_a + 1)^2 - 4H_a(1-a)}}{2(1-a)} \cdot \left(1 - e^{\frac{T-T_c}{c}}\right), \qquad (1)$$

where $H_a = \dfrac{\mu_0 \cdot H(\mu_{ro} - 1)}{B_{s0}}$. (2)

In relations (1) and (2):

$\mu_0 = 4\pi \cdot 10^{-7}$ H/m represent the vacuum absolute permeability;

H [A/m] – is the magnetic field strength (the magnetic field is generated by the current from the symmetry coil);

T [°C] – is the temperature of the magnetic circuit of the coil;

T_c = 800°C is the Curie temperature characteristic to the material of the electrical steel, from which the magnetic circuit of the coil is made.

$a \in (0; 0,5)$; $c \in (20; 100)$

B_{s0} [T] – represent the saturation magnetic induction of the electrical steel at the temperature of T = 0°C;

μ_{r0} – is the initial relative magnetic permeability (T = 0°C).

Therefore the induction of the coil can be determined by the expression:

$$L = \frac{\Phi}{i} = \frac{B \cdot S}{i}, \text{ [H]} \qquad (3)$$

where: S [m^2] – is the quadrate section of the symmetry coil;

i [A] – the current through the coil.

Let a = 0,01 ; 0,49 and c = 100; 500; μ_{r0} = 1400; B_{s0} = 2T; T = 30°C; H = 1....10000 A/m, a MATLAB program has been created to implement the relations (1) and (2) in order to determine the curve B(H) for the magnetic circuit of the symmetry coil. In the Fig. 2 is presented the obtained curves B(H).

3.2. The simulation results

In order to present the simulation of the functioning process of an electrical installation afferent to a crucible induction furnace, there has been used a PSCAD-EMTDC program. In the expressions (1) and (2) we notes:

$$c_{11} = \frac{T - T_c}{c}; \qquad (4)$$

$$c_1 = 1 - e^{\frac{T-T_c}{c}};\qquad (5)$$

$$c_2 = \frac{\mu_0(\mu_{r0}-1)}{B_{s0}};\qquad (6)$$

$$H_a = H \cdot c_2 = N \cdot I \cdot c_2,\qquad (7)$$

where N denotes the number of turns of the symmetry coil (N=72) and I denotes the current that passes through the symmetry coil;

$$H_{a1} = H_a + 1;\qquad (8)$$

$$H_{a2} = 4H_a(1-a);\qquad (9)$$

$$H_{a3} = \sqrt{(H_{a1})^2 - H_{a2}};\qquad (10)$$

$$H_{a4} = \frac{H_{a1} - H_{a3}}{2(1-a)};\qquad (11)$$

$$B_1 = \mu_0 \cdot H = \mu_0 \cdot N \cdot I;\qquad (12)$$

$$B_2 = B_{s0} \cdot H_{a4} \cdot c_1;\qquad (13)$$

$$B = B_1 + B_2.\qquad (14)$$

The simulation results are shown in Fig. 3.

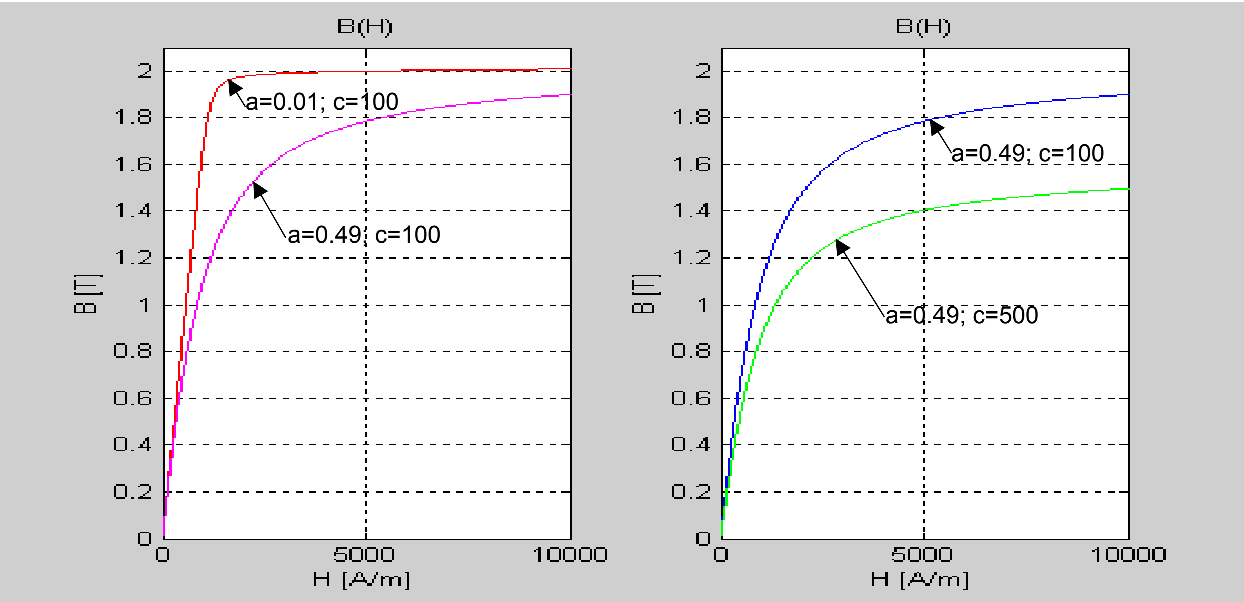

Fig. 2 *The dependence B(H) for the magnetic circuit of the symmetry coil.*

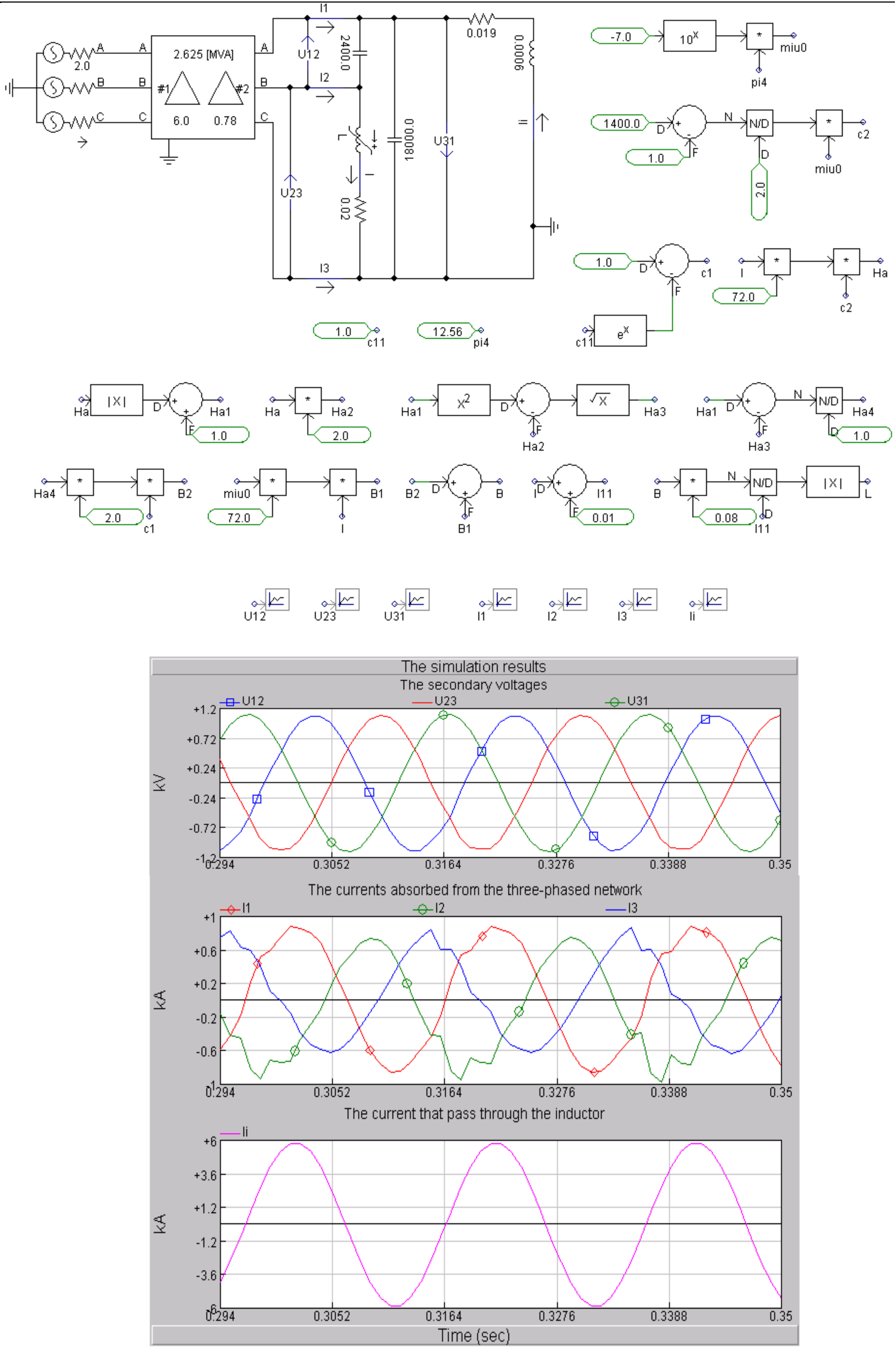

Fig. 3 *The simulation results by using PSCAD-EMTDC.*

4. CONCLUSIONS

The experimental measurements have proved the existence of some electromagnetic disturbances in the currents absorbed by the installation of the induction furnace (f = 50 Hz) from the three-phased network.

By using the PSCAD-EMTDC program and supposing that the coil (with magnetic core) from the symmetry installation is saturated, a simulation of the functioning process of the electrical installation has been obtained.

A good concordance between the experimental results and the simulation results obtained by using the PSCAD-EMTDC program can be observed; this indicates the that the saturation of the coil, from the symmetry installation, can be represent an explanation for the existence of the electromagnetic disturbances in the currents absorbed by the installation of the furnace from the three-phased network.

5. BIBLIOGRAPHY

1. A. Buta , A. Pană – *Simetrizarea sarcinii rețelelor electrice de distribuție,* Editura Orizonturi universitare, Timişoara, 2000.
2. Marilena Ungureanu, M. Chindris, I. Lungu – *Utilizari ale energiei electrice*, Editura Didactică şi Pedagogică, R.A. Bucureşti, 1999.
3. *** PSCAD-EMTDC – *User's guide, 2001.*