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GLOBAL MODELING OF A NEW THREE PHASE HV POWER SUPPLY FOR MICROWAVES GENERATORS WITH N MAGNETRONS BY PHASE (TREATED CASE N=1) UNDER MATLAB SIMULINK CODE

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ABSTRACT

In the industrial installations of microwave generators, the current single phase power supply uses a single-phase HV power transformer with magnetic shunts for each magnetron. Based on the encouraging results obtained from the modeling of a new generation of single-phase HV power supplies for industrial microwaves generators with N magnetrons, we performed a feasibility study for a new three-phase HV power supply with N magnetrons per phase. In this paper, we present an original conception of a new three-phase of HV power supply for microwaves generators with N magnetrons per phase (treated case N = 1). The modeling of this new generation of power supply for magnetrons passes obligatorily by modeling and dimensioning of its own new three-phase HV power transformer with shunts. This modeling of the new three-phase HV power supply of one magnetron by phase, consists to exploiting the model of new three-phase HV power transformer with shunts by MATLAB-SIMULINK code. This model, resulting from the diagram of the armored magnetic circuit tetrahedron type equivalent of this transformer with magnetic shunts, is a π quadruple model with saturable inductances able to translating the saturation phenomena. The electrical signals obtained (currents and voltages) are variable magnitude curves, periodic and non-sinusoidal dephased 2π / 3 between them. These signals have the same form as those of experimental of a cla '(ssical power supply containing one transformer by magnetron. That presents multiple advantages in terms of reducing weight, volume, electrical wiring and cost during the implementation and maintenance of such a new device.

Keywords:- *High Voltage (HV), Generators, Magnetrons, Matlab, Microwaves, New Modeling,- Power Supply, SIMULINK, Three Phase Transformer*

NOMENCLATURE

The upper and lower case letters represent respectively the primary and secondary quantities.

r_A, r_B, r_C, r_a, r_b, r_c : are respectively the primary and secondary resistances of phases A, B, C.

i_A, i_B, i_C, i_a, i_b, i_c : are respectively the currents traversing the primary and secondary windings of phases A, B, C.

u_A, u_B, u_C, u_a, u_b, u_c: are the primary and secondary windings voltages of phases A, B, C.

Φ_A, Φ_B, Φ_C, Φ_a, Φ_b, Φ_c, Φ_{Sh}: are respectively the primary, secondary and shunts fluxes by turn in each phase.

n_1, n_2: the number of primary and secondary turns for each phase.

R_A, R_B, R_C, R_a, R_b, R_c, R_{Sh},: magnetic circuit reluctances of primary, secondary and shunts of each phase, traversed respectively by the fluxes Φ_A, Φ_B, Φ_C, Φ_a, Φ_b, Φ_c, Φ_{Sh}.

R_{COM}, Rcom: the common reluctances between the three phases traversed by the common fluxes Φ_{COM}, Φ_{com}.

1. INTRODUCTION

This paper treats the modeling of a new three phase HV power supply of industrial microwaves

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generators with N magnetrons (type 800 Watts at 2450 MHz) by phase (treat case of N=1). Currently to supply only one magnetron, the industrial installations of single phase HV power supply for microwaves generators use a HV power transformer with magnetic shunts by magnetron [2]-[3]- [10]-[11]. To contribute to the development of technological innovation in industry of manufacturing of power supplies of magnetrons for microwave ovens for domestic or industrial use, this work is part of the development of a new type of three-phase HV power supply for generators microwave with several magnetrons. The new power supply device considered will be thus a different version of the single phase model currently manufactured by the constructors of microwave ovens. It may comprise either a single phase transformer [6]-[8]-[9] or three-phase (Fig.1), or six-phase supplying several magnetrons by phase and not as the current case of a single-phase transformer by magnetron. The modeling of this new generation of power supply of magnetrons passes necessarily by the modeling and dimensioning of its own new three-phase HV power transformer with shunts.

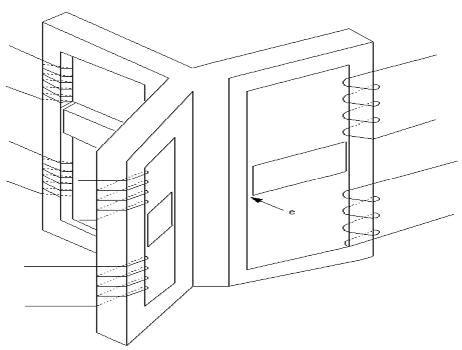

Figure.1. Form Of Magnetic Circuit Diagram Tetrahedron Type Of The New Three Phase HV Transformer With Magnetic Shunts

Moreover, in our previous work, we have made a preliminary study, with EMTP code, dealing with the feasibility [19] at the nominal operation of a new HV power (3x800 Watts at 2450 MHz) three-phase character with one magnetron by phase. In this new HV power supply with three phase character system, we have connected in star three identical π quadruple models of three identical single phase HV transformers with magnetic shunts. These models are supplied by a three-phase system. Encouraged by conclusive results obtained we have undertaken the study of a real and original three-phase transformer newly conceived. It will be dimensioning in this paper and modeled as an equivalent electrical circuit. The new conception of the new three-phase HV power transformer with magnetic shunts uses an armored structure tetrahedron type (Fig.1) to represent its equivalent magnetic circuit. That will undoubtedly allow to reducing the size, volume and makes this new device more economical while ensuring the regulation process of each magnetron current. For this reason, the new design is more advantageous than the combination of three identical single-phase models connected in star [19]. We have exploited the model of the new three phase HV power supply system of one magnetron by phase with MATLAB-SIMULINK code. It is a π quadruple model derived from diagram of the armored structure magnetic circuit tetrahedron type equivalent of the three phase HV power transformer with magnetic shunts. This model is composed of saturable inductances capable to translating the nonlinear saturation phenomena. Each inductance of this model is characterized its analytical expression, which reflects its non-linear relationship "flux-current". The principle of determination of this relationship has the advantage to be simple and directly obtained from the geometrical parameters of construction of the new three phase transformer.

2. PRINCIPLE OF MODELING

The conception of this new HV power transformer with magnetic shunts was based on the diagram of the armored structure of its magnetic circuit tetrahedron type Fig.1. A magnetic shunt serves to divert an important part of flux circulating between the primary and secondary windings of each of three phases. The primary and secondary fluxes of the three phases respectively, are added together to cross the Common reluctances R_{COM} and Rcom (Fig. 2). The sum of these fluxes is zero if the three-phase system is equilibrated. Other hand, taking into account the air-gaps dimension and the magnetic state of saturation, the magnetic fluxes of air dispersion are negligible compared to one through the shunts. Hereafter, we consider the new three-phase transformer without iron losses (hysteresis loss and eddy current). And to simplify the study, we consider the Star Star (Yy) coupling between the primary and secondary windings.

2.1 Mathematical Equations and Dimensioning

- **Electrical Equations**

Once the new three-phase transformer with shunts is supplied, the turns of primary and secondary windings of each phase, which are respectively traversed by fluxes ΦA, ΦB, ΦC, Φa, Φb, Φc, are thus the seat each one of an electromotive force of auto-induction. Applying of Ohm's law provides the six electrical equations of

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the new three-phase transformer with shunts, and considering the general case where the three phase system is not necessarily equilibrated:

$$u_A = r_A . i_A + n_1 . \frac{d\Psi_A}{dt} \quad (1)$$
$$\text{Or} \quad \Psi_A = \Phi_A + \Phi_{COM}$$

Φ_A: is the own flux of phase A and Φ_{COM} the common flux of primary side of this phase.

$$u_B = r_B . i_B + n_1 . \frac{d\Psi_B}{dt} \quad (2)$$

$$u_C = r_C . i_C + n_1 . \frac{d\Psi_C}{dt} \quad (3)$$

$$u_a = -r_a . i_a + n_2 . \frac{d\Psi_a}{dt} \quad (4)$$
$$\text{Or} \quad \Psi_a = \Phi_a + \Phi_{com}$$

$$u_b = -r_b . i_b + n_2 . \frac{d\Psi_b}{dt} \quad (5)$$

$$u_c = -r_c . i_c + n_2 . \frac{d\Psi_c}{dt} \quad (6)$$

Such as the leakage fluxes in the air are negligible, and by writing each total flux in the form: $n\Phi = Li$, and considering the currents in the inductances and L_{COM} Lcom corresponding to the common reluctances between phases R_{COM} and Rcom, the previous equations become:

$$u_A = r_A . i_A + \frac{d}{dt}(L_A . i_A) + \frac{d}{dt}(L_{COM} . i_{COM}) \quad (7)$$
$$\text{Or} \quad i_{COM} = i_A + i_B + i_C$$
$$u_B = r_B . i_B + \frac{d}{dt}(L_B . i_B) + \frac{d}{dt}(L_{COM} . i_{COM}) \quad (8)$$
$$u_C = r_C . i_C + \frac{d}{dt}(L_C . i_C) + \frac{d}{dt}(L_{COM} . i_{COM}) \quad (9)$$
$$u_a = -r_a . i_a + \frac{d}{dt}(L_a . i_a) + \frac{d}{dt}(L_{com} . i_{com}) \quad (10)$$
$$\text{Or} \quad i_{com} = i_a + i_b + i_c$$
$$u_b = -r_b . i_b + \frac{d}{dt}(L_b . i_b) + \frac{d}{dt}(L_{com} . i_{com}) \quad (11)$$
$$u_c = -r_c . i_c + \frac{d}{dt}(L_c . i_c) + \frac{d}{dt}(L_{com} . i_{com}) \quad (12)$$

- **Magnetic Equations**

From the diagram of the equivalent magnetic circuit of the new three-phase transformer with shunts Fig.2 (see Appendix a), and applying the magnetic circuit formulas, we can write the magnetic equations for each phase of the new three-phase transformer for new three-phase HV power supply for microwaves generators. The dimensions of the magnetic circuit of the Fig.2 are identified by the letters A, B, C, D, E, F which are relative to the average line of magnetic flux of various magnetic circuit portions.

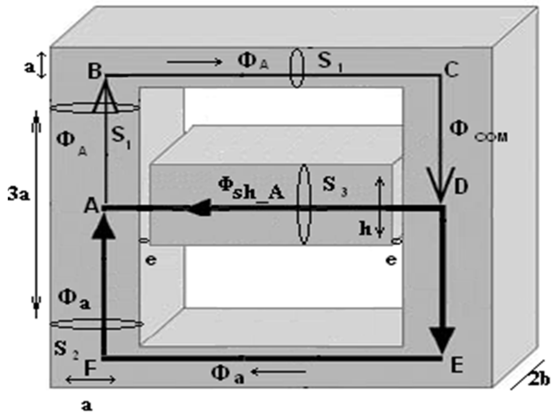

Figure.2: Diagram Of The Equivalent Magnetic Circuit Of One Phase (Phase A As Example) Of The New Three-Phase Transformer With Magnetic Shunts

We take the phase A as example:

1. For the path ABCDA :

$$R_A . \Phi_A + R_{COM} . \Phi_{COM} + R_{sh\_A} . \Phi_{sh\_A} = n_1 . i_A \quad (13)$$

2. For the path ADEFA

$$-R_{sh\_A} . \Phi_{sh\_A} + R_{com} . \Phi_{com} + R_a . \Phi_a = -n_2 . i_a \quad (14)$$

With, Φcom and Φ_{COM} are the sum respectively of fluxes Φa, Φb, Φc and Φ_A, Φ_B, Φ_C traversing the common reluctances Rcom and R_{COM}.

3. For the path BCEFB :

$$R_A . \Phi_A + R_{COM} . \Phi_{COM} + R_{com} . \Phi_{com} + R_a . \Phi_a = n_1 . i_A - n_2 . i_a \quad (15)$$

The equations (13) to (15), are complemented by the additional relations translating the fluxes conservation law for each phase:

$$\Phi_A = \Phi_a + \Phi_{sh\_A} \quad (16)$$
$$\Phi_B = \Phi_b + \Phi_{sh\_B} \quad (17)$$
$$\Phi_C = \Phi_c + \Phi_{sh\_C} \quad (18)$$

Such as: Φsh_A, Φsh_B and Φsh_C are respectively, total fluxes traversing the shunts of phases, A, B and C. We obtain thus, the complete system of electric and magnetic equations representing the operation of the new three-phase HV transformer with magnetic shunts of the new three phase HV power of magnetrons.

2.2 Equivalent electrical circuit of the new three-phase transformer with shunts

- ***π* quadruple model by phase referred to secondary**

We take always the phase A as example:

$$u_A = r_A . i_A + n_1 . \frac{d\Phi_A}{dt} + n_1 . \frac{d\Phi_{COM}}{dt} \quad (19)$$

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$$u_a = -r_a.i_a + n_2.\frac{d\Phi_a}{dt} + n_2.\frac{d\Phi_{com}}{dt} \quad (20)$$

Multiplying equation (19) by (n_2/n_1) and writing the quantities ($n_1\Phi_A$) and $n_1\Phi_{COM}$ in the form: $n_1.\left(\frac{n_2}{R_A}\right)\left(\frac{R_A}{n_2}\right)\Phi_A$

We obtain:

$$u'_A = r'_A.i'_A + n_2.\frac{d\Phi_A}{dt} + n_2.\frac{d\Phi_{COM}}{dt}$$
$$= r'_A.i'_A + \frac{d}{dt}\left(\frac{n_2^2}{R_A}\frac{R_A}{n_2}\Phi_A\right)$$
$$+ \frac{d}{dt}\left(\frac{n_2^2}{R_{COM}}\frac{R_{COM}}{n_2}\Phi_{COM}\right)$$

With: $r'_A = \left(\frac{n_2}{n_1}\right)^2 r_A$, $i'_A = \left(\frac{n_1}{n_2}\right) i_A$, $u'_A = \left(\frac{n_2}{n_1}\right) u_A$

By posing the inductance (n_2^2/R_A)=L'p_A and the electric current ($R_A\Phi_A/n_2$) = i'p_A, the above equation become:

$$u'_A = r'_A.i'_A + \frac{d}{dt}\left(L'_{p\_A}.i'_{p\_A}\right)$$
$$+ \frac{d}{dt}\left(L'_{COM}.i'_{COM}\right) \quad (21)$$

We replace $n_2\Phi_a$ and $n_2\Phi_{com}$ in the equation (20) by $n_2\Phi_a = \left(\frac{n_2^2}{R_a}\right)\left(\frac{R_a}{n_2}\right)\Phi_a$ and by posing the inductance (n_2^2/Ra)=Ls_a and the electric current (RaΦ a/n_2) = is_a, we obtain: $u_a = \frac{d}{dt}\left(L_{s\_a}.i_{s\_a}\right) + \frac{d}{dt}\left(L_{com}.i_{com}\right) - r_a.i_a$ (22)

The development of the auto-induction force expression $n_2.\frac{d\Psi_A}{dt}$ can lead to the following relation:

$$n_2.\frac{d\Psi_A}{dt} = \frac{d}{dt}\left(\frac{n_2^2}{R_a}\right)\left(\frac{R_a}{n_2}\right)\Psi_a$$
$$+ \frac{d}{dt}\left(\frac{n_2^2}{R_{sh\_A}}\right)\left(\frac{R_{sh}}{n_2}\right)\Phi_{sh\_A}$$

By posing (n_2^2/R_{sh_A})=L'_{sh_A} and ($R_{sh\_A}.\Phi_{sh\_A}/n_2$) = i'_{sh_A} :

$$n_2.\frac{d\Psi_A}{dt} = \frac{d}{dt}\left(L_a.i_a\right) + \frac{d}{dt}\left(L'_{sh_A}.i'_{sh_A}\right) \quad (23)$$

The equations (21) to (23) respond to the single phase equivalent circuit reduced to secondary of three-phase transformer with shunts of Figure.2. All occurs as so for each phase of this new three-phase HV transformer with shunts tetrahedron type, was composed of three perfect transformers, each one supplies a π quadruple composed of the inductive elements L'p and L_{COM} on the primary side, L_S and L_{com} on the secondary one and L'_{HS} on the shunt side. These inductances are respectively traversed by currents i'p, i_{COM}, is, icom and i'_{Sh}.

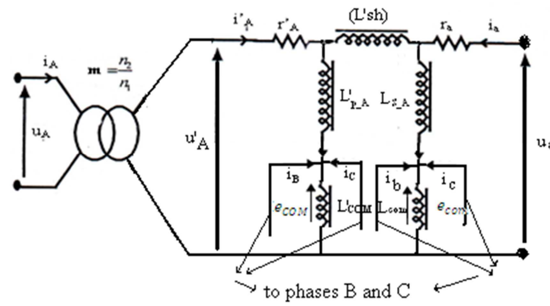

Fig. 3. Π Quadruple Model Of Saturable Inductances Referred To Secondary Equivalent Of New Three-Phase HV Transformer With Magnetic Shunts

In perfect transformer input of phases A, B, C, we have the currents i_A, i_B, i_C and the voltages u_A, u_B, and u_C. And in its outputs, we find the voltages $u'_A = (n_2/n_1)\ u_A$, $u'_B = (n_2/n_1)\ u_B$ and $u'_C = (n_2/n_1)\ u_C$ and the currents $i'a = (n_1 / n_2).\ i_A$, $i'_B = (n_1/n_2)\ i_B$ and $i'_C = (n_1/n_2)\ i_C$. Finally we obtain to the output terminals of these quadruples the real voltage of output of three-phase transformer with shunt u_a, u_b, u_c.

2.3 Analysis of transformer model

The advantage of the armored type tetrahedron structure used for the new three-phase transformer with magnetic shunts, is that each phase is supplied by a simple voltage 220 volts.

The distribution of primary, secondary and shunts fluxes in each phase, is the same as that one of single-phase HV transformer with shunts, which ensures the stabilization of the current in the classical HV power for microwaves generators. This leads us to two important points:

- Deduce the geometry of the magnetic circuit of the new three phase HV transformer from that of single-phase transformer with magnetic shunts. Geometrical parameters are namely: the width of the core unwound **a**, sections of different cores **S_1**, **S_2** and **S_3**, the thickness of the air-gaps **e**.
- Validate this model of the new three-phase HV transformer with magnetic shunts by the comparison between the curves from this model with those simulated and experimental of single-phase HV transformer with magnetic shunts presented in [8]-[11]-[12].

3. MODELING OF NONLINEAR INDUCTANCES OF NEW MODEL

Each inductance of the studied model is a function of the reluctance, of the portion of magnetic circuit supposed as fictively closed on which is wound n_2 turns, and thus the magnetic permeability µ. This one depends in a complex way

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of state saturation, consequently of the variable current at every moment. Under these conditions, there is no proportionality between the voltage and current of each inductor, since the latter varies with these quantities.

To be able exploit with MATLAB-SIMULINK code, the study in the nonlinear regime of phenomena related to the saturation of each inductance, it is necessary to represent each nonlinear inductive element by its analytical expression deduced from fitting of magnetization curve of material used by constructors (SF_{19}) [8]-[21]. The total flux $n_2\Phi$ (i), (Φ (i) is the flux per turn) as a function of current i is given by the relation:

$$L = \frac{n_2.\Phi(i)}{i} = \frac{n_2^2.B.S}{H.l} = \frac{n_2^2.S}{l}.\frac{B}{H(B)} \qquad (24)$$

We therefore admit that any saturable part of the armored magnetic circuit investigated, has a characteristic form which is given in appendix Fig.2. And in the following, we consider only the effects of saturation; hysteresis effects and eddy currents are neglected. For determining the characteristic of each inductance from the geometrical parameters of construction of the considered magnetic circuit portion of this transformer, we use the fitting of the magnetization curve B (H) of the material used. We translate therefore the variation law of flux $n_2\Phi$ (i) as a function of i for each inductance.

3.1 Characteristic of each inductance

- **Characteristic $n_2\Phi_p$(i'p) of the primary inductance L'p**

For the calculation and simulation, we remember that the nonlinear inductance of each branch is replaced by the analytical expression of the instantaneous current as a function of flux passing through this inductance. We mention also that the reluctance R of a homogeneous magnetic circuit portion has as length l, section S and permeability μ, is given by the equation R = (l / μ s). From Figure 2 and the proposed model in paragraph 2.2, the primary inductance is the inductance of a ferromagnetic circuit supposed as fictively closed, corresponding to the path ABC (Fig.2) length lp and section S_1. On this last path, we consider wound n_2 turns traversed by the current i'p. From the fitting of the magnetization curve that gives the expression of the magnetic field H as a function of magnetic induction B [8] and the values of n_2, S_1, lp, as recorded in Appendix c , we arrive at the $n_2\Phi$p (i) law using the relationship:

$$i_p = \frac{l_p}{n_2}H(B) \qquad (25)$$

And as we use the flux Φ as input to this model from a simple integration of the voltage (Appendix Fig.2), we must replace the induction B in equation (25) by the flux through the relationship: $B = \Phi/S$

- **Characteristic $n_2\Phi$(i) of inductances commons L_{COM} and L_{com}**

The common inductances between the three phases L_{COM} (primary side) and Lcom (secondary side) are inductances of circuits ferromagnetic corresponding to CD and DE paths (Fig.2) its lengths respectively l_{COM} and lcom and section S_1. On these CD and DE paths, we consider wound n_2 turns traversed by the currents i_{COM} and icom. The characteristics of these inductances are therefore given by the relations:

$$i_{COM} = \frac{l_{COM}}{n_2}H(B) \text{ and } i_{com} = \frac{l_{com}}{n_2}H(B) \qquad (26)$$

- **Characteristic $n_2\Phi$(i) of the secondary inductance Ls**

Considering the symmetry of the magnetic circuit armored compared to the axis AD (Fig.2) and using relations similar to the preceding, we obtain, by posing l_S the average length corresponds to the path AFEA and the secondary section S_2 ($S_2 = S_1$), the equations of the form:

$$i_s = \frac{l_s}{n_2}H(B) \qquad (27)$$

- **Characteristic $n_2\Phi_{Sh}$ (i'_{Sh}) of inductance L'_{Sh}**

Lsh is the inductance of an assumed magnetic circuit supposed as fictively closed, corresponding to path DA (Fig.2) and of width l_{SH}-2.e_{Sh}, of section S_3 (S_3 = h. (2b)), see Appendix .c). Lsh is in series with two narrow air gaps of length e each one (e_{sh} = 2e is the global length of a shunt), on which we consider wound n_2 turns which is traversed by the current i'_{Sh}.

Applying the magnetic circuit's law in this ferromagnetic field with air gaps, we obtain:

$$\left(\frac{1}{\mu}.\frac{l_{sh}-e_{sh}}{S_3}+\frac{1}{\mu_0}.\frac{e_{sh}}{S_3}\right)\Phi_{Sh} = n_2.i'_{sh}$$

If R_{Sh} designates the reluctance of this portion, It corresponds to the reluctance of the ferromagnetic part $(R_{SH})^f$ and reluctance constant $(R_{SH})^e$ caused by the air of the air gap, hence:

$$R_{Sh} = R^f_{Sh} + R^e_{Sh} \qquad (28)$$

With: $R^f_{sh} = \frac{1}{\mu}.\frac{l_{sh}-e_{sh}}{S_3}$ and $R^e_{sh} = \frac{1}{\mu_0}.\frac{e_{sh}}{S_3}$

We know that the inductance ($L'_{Sh} = n_2^2/R_{Sh}$) traversed by the current i'_{Sh} obeys the law :

$$n_2\Phi_{sh} = L'_{sh}i'_{sh}$$

By writing the expression of the L'_{Sh} according to $(R_{SH})^f$ and $(R_{SH})^e$, it comes:

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$$L'_{sh} = \frac{n_2^2}{R_{sh}^f + R_{sh}^e} = \frac{\frac{n_2^2}{R_{sh}^e} \cdot \frac{n_2^2}{R_{sh}^f}}{\frac{n_2^2}{R_{sh}^e} + \frac{n_2^2}{R_{sh}^f}}$$

That we can put in a more convenient form: by posing

$$(L'_{sh})^e = \frac{n_2^2}{R_{sh}^e} \text{ The air gap inductance and}$$

$$(L'_{sh})^f = \frac{n_2^2}{R_{sh}^f} \text{ Inductance of ferromagnetic part}$$

We obtain thus:

$$L'_{sh} = \frac{(L'_{sh})^e * (L'_{sh})^f}{(L'_{sh})^e + (L'_{sh})^f} \qquad (29)$$

Other hand, the current expression i'_{Sh} becomes:

$$i'_{sh} = \frac{R_{sh}}{n_2}\Phi_{sh} = \frac{R_{sh}^e}{n_2}\Phi_{sh} + \frac{R_{sh}^f}{n_2}\Phi_{sh}$$

by posing: $(i'_{sh})^e = \frac{R_{sh}^e}{n_2}\Phi_{sh}$ and $(i'_{sh})^f = \frac{R_{sh}^f}{n_2}\Phi_{sh}$

$$n_2\Phi_{sh} = (L'_{sh})^e * (i'_{sh})^e + (L'_{sh})^f * (i'_{sh})^f \qquad (30)$$

From equations (28) (29) (30), we find thus that the inductance L'_{Sh} is equivalent to two inductances $(L'_{Sh})^e$ and $(L'_{Sh})^f$ in parallel. The inductance $(L'_{Sh})^e$ is supposed as fictive winding n_2 turns wound in the air of section S_3 traversed by the current i'_{sh}.

At the inductance $(L'_{Sh})^f$, we associate a ferromagnetic circuit corresponding to the path AD of length l_{SH}-e_{sh}. The π quadruple model of the three phase transformer with shunts in figure 3 is slightly modified, it becomes equivalent to that of Fig.4.

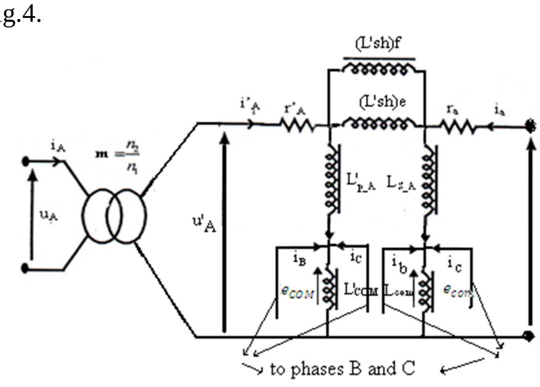

Figure.4: New Π Quadruple Model Of Three-Phase Transformer With Shunts

We see that to translate the relationship $n_2\Phi_{Sh}$ (i) of the inductance L'Sh, it is enough to find the relationship $n_2\Phi_{Sh}$ (i'_{Shf}) of the inductance $(L'_{SH})^f$, because the inductance (L'Sh)e is constant. From the expression of the instantaneous current passing through this inductance derived from the B(H) curve fitting and the values of n_2, L'_{SH}, S_3 and e_{sh},. We arrive at the $n_2\Phi_{Sh}(i'sh^f)$ law using the relations:

$$(i_{sh})^f = \frac{l_{sh-}e_{sh}}{n_2}H(B) \qquad (31)$$

4. SIMULATION RESULTS

The study of the operation under nominal state of this new system in Figure 5 was undertaken. The mounting of Fig.5 was simulated by MATLAB-SIMULINK code, to reflect the operation of the three-phase HV power for microwaves generator with one magnetron by phase able to delivering under 220 V its full power 800 Watts useful at 2450 MHz. All three identical models supplies normally at nominal state one magnetron type 800 Watts at 2450 MHz. Figure 5 shows the equivalent diagram of mounting of three-phase HV power supply of a new generation of microwaves generators with N magnetrons by phase (case treated N = 1 by magnetron phase). It is composed of three π quadruple models equivalent of phases. Every one supplies at its output a voltage doubler cell composed of a capacitor and a diode that in its output supplies only one magnetron.

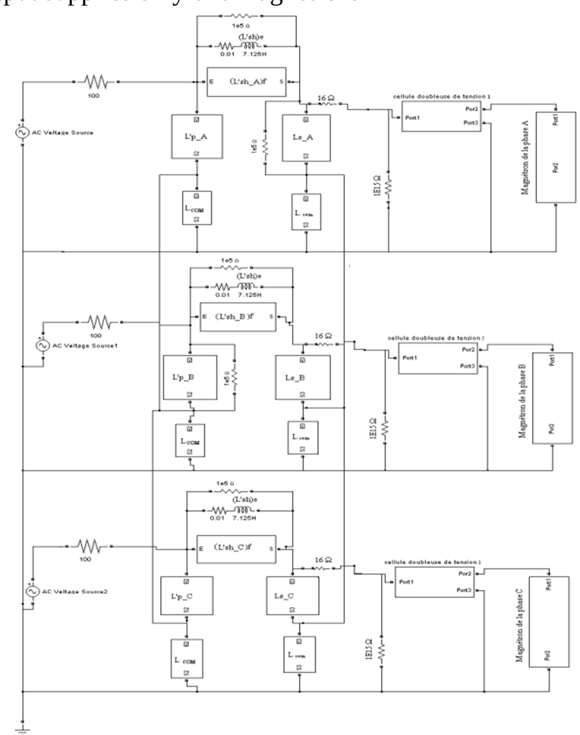

Figure.5. Equivalent Diagram Of The Mounting Of Three-Phase HV Power Supply For One Magnetron By Phase Simulated With The MATLAB-Code SIMULINK

This equivalent circuit reflects the behavior of the entire three-phase HV power supply including the magnetron and the three-phase transformer with shunts. The simultaneous solution of electric and magnetic equations of entire system is too complex.

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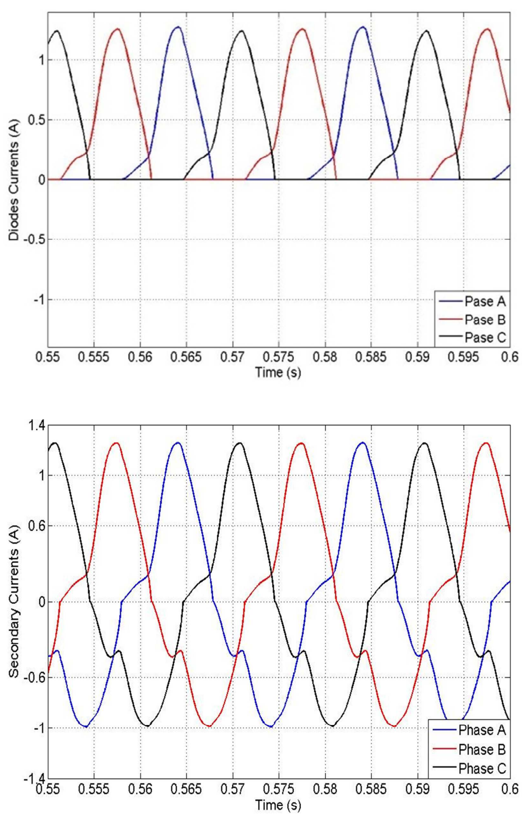
The solution can be only numerical (MATLAB-SIMULINK or other code). Based on the nonlinear characteristics already calculated by the above formulas of each inductance and using developed programs around the MATLAB-SIMULINK code, we simulated the circuit behavior of the new three phase HV power of microwaves generator with one magnetron per phase. Figure 6 shows the oscillograms obtained from this simulation. As first remark, we note that the electrical signals obtained (I_diode, I_secondary, I_magnetron, V_magnetron, V_secondary V_condensator) are curves periodic and non-sinusoidal dephasing 2π /3 between them(Fig.6). These signals have the same form as those of experimental and simulated of classic HV power supply having a single transformer by magnetron. The dephasing of 2π /3 confirms the absence of interaction between magnetrons.



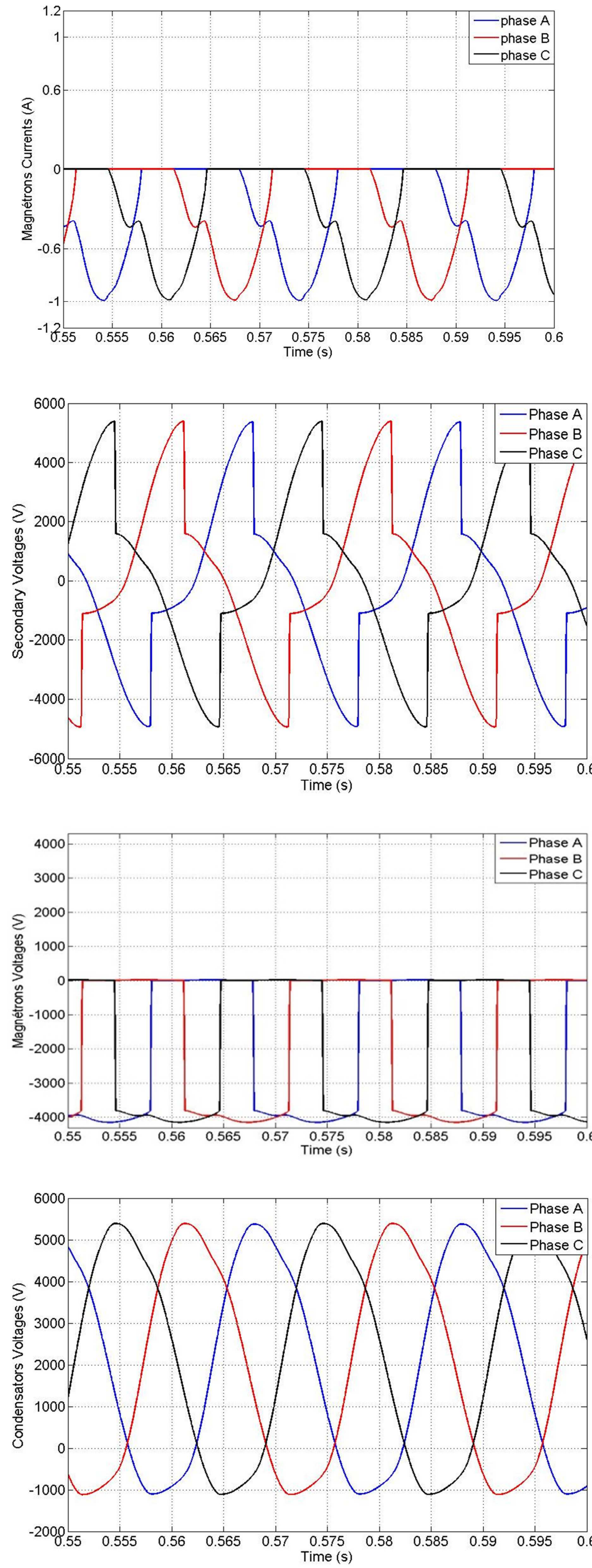


Figure.6. Waveforms Of Current And Voltage Of Simulation Of The New Three-Phase HV Power System For Magnetron.

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The operating points of these magnetrons are no longer disturbed, which is essential for a stabilized current power supply. Moreover, the tests of the breakdowns of the magnetrons, which we carried out, confirm that the breakdown of N magnetrons does not modify the operation of the remaining magnetrons. It suffices to replace the magnetron off by a new one.

5. CONCLUSION

The study of operating at nominal state of new system of three phase HV power supply with one magnetron by phase has been conclusive. It can be extended without any problem in case of power supply operation of magnetrons by N phase at the nominal state. In the other hand, the breakdown of one or more of N magnetrons supplied does not change the operation of remaining magnetrons. The modeling of the new three phase HV power supply with one magnetron by phase, based on an appropriate dimensioning by magnetic circuit tetrahedron type of its own three-phase HV transformer with shunts has been done. That will certainly help undoubtedly to reduce size, volume, weight and electrical cabling and therefore guarantee a lower cost of implementation and maintenance of microwaves generators. This study can be extended for modeling a three-phase transformer with magnetic shunt with a armored-magnetic circuit type of three or five columns, able to supplying in its secondary N magnetrons by phase. This work can also be similarly performed to the case of the same type of three phase or six-phase HV power supply for several magnetrons by phase with useful power 1000 Watts or 1200 Watts for each one at 2450 MHz. Thus contributing to the development of new modeling systems of three-phase or six-phase of power supply with several magnetrons (800 Watts, 1000 Watts or 1200 Watts at 2450 MHz) by phase for microwaves generators for industrial applications. An optimization strategy of the new three-phase HV power supply can also be defined using optimization programs developed around the MATLAB-SIMULINK code, to reduce the installation cost and without damage the magnetrons tubes. The results of this optimization, allow us to realize the new three-phase HV transformer with shunt for a new generation of industrial microwaves generators. And this will contributes to technological innovation.

6. APPENDIX

a- Geometry of transformer with magnetic shunts

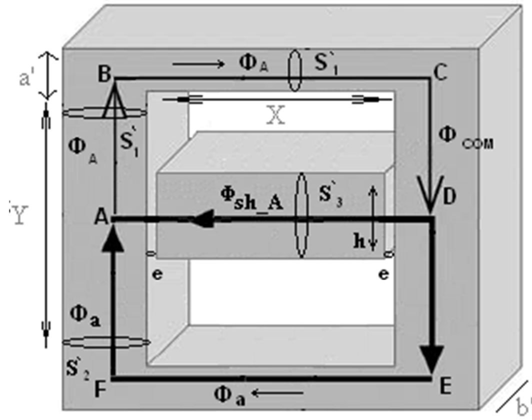

Fig.1

We have S'$_1$ that the section must be equal to the section of single-phase transformer with magnetic shunts S$_1$:

$S'_1=a'*b'$

$S_1==2*a*b$

Thus, we have two solutions for the geometry of this new three phase transformer with shunts:

1. a'=a and b'=2*b
2. a'=2*a and b'=b

As the section S'$_3$ must be the double of the section S$_3$.

$S'_3=h'*b'$

$S_3=h*b$

$S'_3=2*S_3$

From the above solution 1: a'=a and b' = b*2 is more realizable

X and Y calculated from the reluctances:

The primary and shunts reluctances that correspond to paths respectively ABCD and AD, must therefore be equal to those in case of single phase. That allows us to obtain the system of equations:

1) $\frac{1}{2}Y + 0.5 * a + 0.5 * a + +X + 0.5 * a + 0.5 * a + \frac{1}{2}Y = 6.5 * a$

2) $0.5 * a + X + 0.5 * a - 2 * e = 2.5 * a - 2 * e$

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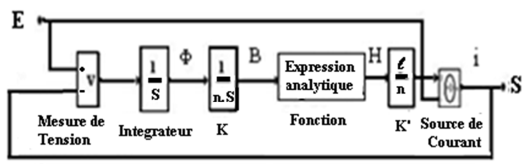
From this system we have:
X=1.5*a ; Y=3*a

b- Fig.2



c- Parameters

a'=a=0.02 m;
b=0.06 m
b'=0.12 m;
n2=2400;
s1=a'*b' m^2;
lp=4.5*a;
l_{COM}=2*a;
ls=4.5*a;
l_{com}=2*a;
e=0.00055 mm;
s3=0.00068*b*n3 m^2;
lsh=(2.5*a-2*e);

REFERENCES

[1] Muhammad Taher Abuelma'atti, Modeling of Magnetization Curves for Computer-Aided Design, IEEE Transactions On Magnetics, vol. 29, no. 2, march 1993.

[2] John C. Gallawa and Microtech Productions.''The Complete Microwave Oven Service'' Handbook v. 2011

[3] Aguili T & Chraygane M., Une alimentation originale pour générateurs micro-ondes, Revue Générale de l'Electricité - France, RGE 5 (1990) 49-51.

[4] M.Ferfra, M.Chraygane, M.Fadel, Ould Ahmedou. "Non linear modelling of an overall new high voltage power supply for N=2 magnetrons for industrial microwave generators" Physical and Chemical News 54, pp. 17-30, 2010.

[5] N. El Ghazal, M Chraygane, M.Ould Ahmedou, M. Ferfra, A Belhaiba, 'Modélisation d'une alimentation haute tension à caractère triphasé pour générateurs micro ondes industriels à un magnétron par phase', Conférence Méditerranéenne sur l'ingénierie Sûr des Systèmes Complexes MISC'11, ENSA, Agadir 27 – 28 Mai 2011, pp-281 – 2285.

[6] M.Ould.Ahmedou, M.Ferfra, N.El Ghazal, M.Chraygane, M.Maaroufi, 'implementation and optimization under matlab code of a hv power transformer for microwave generators supplying two magnetrons',Journal of Theoretical and Applied Information Technology pp 227 - 238 Vol 33. No. 2 – 2011.

[7] J. R. Lucas, representation of magnetization curves over a wide region using a non-integer power series, international J. Elect. Enging. Edduc – vol. 25. pp. 335 – 340. Manchester U.P. 1988. Printed in Great Britais.

[8] 13-M.Ould.Ahmedou, M.Ferfra, R.Nouri, M.Chraygane "Improved π Model of the Leakage Flux Transformer Used for Magnetrons" International Conference on Multimedia Computing and Systems, IEEE Conference, Ouarzazat (Morocco) from 07 to 09 April 2011.

[9] 14- M.Ould.Ahmedou, M.Chraygane, M.Ferfra, "New π Model Validation Approach to the Leakage Flux Transformer of a High Voltage Power Supply Used for Magnetron for the Industrial Micro-Waves Generators 800 Watts". International Review of Electrical Engineering (I.R.E.E.), Vol. 5. n. 3. May-June.2010. pp. 1003-1011.

[10] M. Chraygane, M. Ferfra, B. Hlimi, "Détermination analytique des flux et des courants du transformateur à fuites d'une alimentation haute tension à magnétron pour générateurs micro-ondes industriels 800 Watts à 2450 Mhz", Phys. Chem. News, PCN, 40 (2008) 51-61.

[11] M. Chraygane, M. Ferfra, & B. Hlimi, Etude analytique et expérimentale des flux du transformateur à shunts d'une alimentation pour magnétron 800 Watts à 2450 Mhz, article, revue Physical and Chemical News, PCN, vol. 27,2006, pp. 31-42.

[12] M. Chraygane, M. El Khouzaï, M. Ferfra, & B. Hlimi, "Etude analytique de la répartition des flux dans le transformateur à shunts d'une alimentation haute tension pour magnétron 800 Watts à 2450 Mhz", *Physical and Chemical News, PCN*, 22 (2005) 65-74.

[13] Guanghao Liu, Xiao-Bang Xu, "Improved Modeling of the Nonlinear B–H Curve and Its Application in Power Cable Analysis", *IEEE Transaction on Magnetics*, vol. 38, NO. 4, July 2002

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[14] Chraygane M., ferfra M. & Hlimi B., "Modélisation d'une alimentation haute tension pour générateurs micro-ondes industriels à magnétron", *La Revue 3EI*, Paris, France, vol. 41, 2005, pp. 37-47.

[15] A. D. Theocharis · J. Milias-Argitis · Th. Zacharias, "Single-phase transformer model including magnetic hysteresis, and eddy currents", *Electr Eng* vol. 90, 2008, pp. 229–241.

[16] Satoru Hiwa, Tomoyuki Hiroyasu, Mitsunori Miki. "Hybrid optimization using DIRECT, GA, and SQP for global exploration". *IEEE Congress on Evolutionary Computation'2007*. pp.1709~1716.

[17] Gill, P.E., W. Murray, M.A. Saunders, and M.H. Wright, "Procedures for Optimization Problems with a Mixture of Bounds and General Linear Constraints" *ACM Trans. Math. Software*, Vol. 10, pp 282-298, 1984.

[18] M. Ould Ahmedou, M. Ferfra, M. Chraygane and M. Maaroufi, 'A New Modeling of the Non-Linear Inductances in MATLAB'

[19] N.El Ghazal, M.Ould Ahmedou, A.Belhaiba, M.Chraygane, M.Ferfra and Boubker Bahani, 'Feasibility study of a new three-phase HV power supply for microwaves generators supplying a one magnetron per phase under MATLAB code' *International Conference on Multimedia Computing and Systems, IEEE Conference, Tangier (Morocco) from 10 to 12 May, 2012*.

[20] A.Belhaiba, M.Ould Ahmedou, N. Elghazal, Mohamed Chraygane, Mohamed Ferfra and Boubker Bahani, 'Modeling the power Balance of microwave generator for one magnetron Under Matlab-Simulink code', *International Conference on Multimedia Computing and Systems, IEEE Conference, Tangier (Morocco) 10 to 12 May, 2012.*

[21] M. Ould Ahmedou, M. Ferfra, M. Chraygane, M. Maaroufi, 'A New Modeling of the Non-Linear Inductances in MATLAB', *book, Matlab–A Fundamental Tool For Scientific Computing And Engineering Applications" – Volume 1, chapter 13, pp 319 – 330, Edited by Vasilios N. Katsikis, Published by InTech*. 26 September 2012.

[22] A.Belhaiba. M. Ould Ahmedou. M. Chraygane. M. Ferfra. N. Elghazal, Energy Balance of Optimized Hight Voltage Power Supply for Microwaves Generators Used in Various Industrial Applications, *International Review on Modelling and Simulations (Vol. 5 N. 4) - August 2012 - Papers (Part A)*

[23] A. Belhaiba, N. Elghazal, M. Chraygane, M. Ferfra, B. Bahani, **M. Ould Ahmedou**, " Improved Optimization of the Nominal Functioning Of a High Voltage Power Supply N=2 Magnetrons for Microwaves Generator", *International Journal of Electrical and Computer Engineering (IJECE) Vol. 2, No. 5, October 2012, pp. 708~716*

[24] N. Elghazal, **M. Ould Ahmedou**, M. Chraygane, M. Ferfra, A. Belhaiba, „Optimization of High Voltage Power Supply for Industrial Microwave Generators for one Magnetron., *Journal of Theoretical and Applied Information Technology, pp 001 - 010 Vol. 46. No. 1 -- 2012*