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ENERGY BALANCE OF OPTIMIZED THREE-PHASE HIGH VOLTAGE POWER SUPPLY FOR MICROWAVES GENERATORS WITH N MAGNETRONS BY PHASE (TREATED CASE N=1)

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ABSTRACT

This original work deals with the calculation of the power and the performance of optimized three-phase high voltage power supply for industrial microwaves generators with N magnetrons by phase (Treated case N=1). The design of this power supply is composed of three π quadruple models equivalents of new three-phase transformer with magnetic shunts of each phase; 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. In this work we will validate under Matlab Simulink the functioning of this new three-phase power supply and we will calculate its performance .The results obtained from this simulation compared with those obtained by experimental and simulated of conventional power supply using a single phase transformer for one magnetron are in good conformity. Following that, we will apply an optimization strategy that aims to reduce the volume of the three-phase transformer while respecting the constraints recommended by the manufacturer concerning the current flowing in each magnetron (Imax <1.2 A, $I_{Av} \approx 300$ mA). Based on the selected solution from optimization, we will validate the functioning of the power supply by calculating its performance that must be identical to that treated for the reference case.

Keywords: *Optimization, Power Supply, Performance, Modeling, Energy Balance, Average Power*

1. INTRODUCTION

The new three-phase high voltage power supply for industrial microwaves generators with one magnetron by phase represented in the Figure 1 is composed of a three-phase transformer with magnetic shunts. Each phase supplies at its output a voltage doublers cell composed of a capacitor and a diode that in its output supplies only one magnetron. This new power supply will be considered a different version of a single-phase power [1-14]; currently manufactured at the manufacturers of microwave ovens.

This paper treats the calculation of the power and the performance of optimized three-phase high voltage power supply for industrial microwaves generators with N magnetrons by phase (Treated case N=1). This optimization is based essentially on the modeling with Matlab Simulink of its own three-phase transformer.

This work is divided in two parts. First, we treat the modeling of the new three-phase high voltage power supply for one magnetron by phase. Then we will simulate the nominal electrical behavior of this New Three-Phase Power Supply circuit by using Matlab-Simulink code. The results obtained from this simulation will be compared with those obtained by the conventional power supply using a single phase transformer for one magnetron. Secondly, using Matlab-Simulink code, we will define a strategy for optimizing the new three-phase transformer. This optimization is based on the study of the influence of each geometric parameter of the transformer on the electric functioning of the power supply. Then we will validate the nominal functioning of the new power supply on the basis of the selected solution from optimization.

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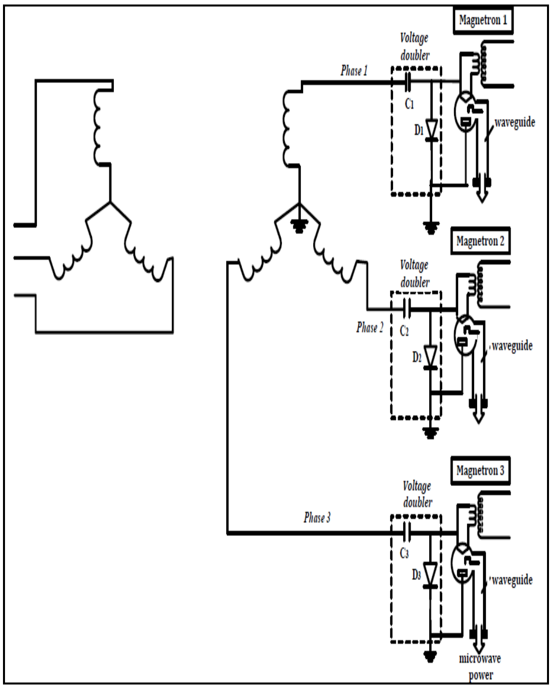

Figure 1: Three-Phase Power Supply For Magnetron By Phase (Amperex Type)

2. MODELING AND ENERGY BALANCE OF THE NEW THREE-PHASE HIGH VOLTAGE POWER SUPPLY FOR ONE MAGNETRON BY PHASE

The modeling of this new three-phase power is already developed [15]-[16]-[17]-[18] and it's based on the modeling of its own new three-phase HV power transformer with magnetic shunts. This transformer is a combination of three single-phase transformers (figure 2).

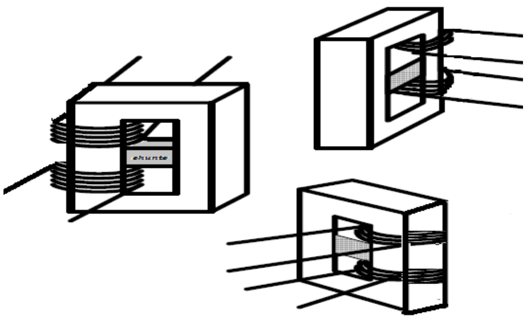

Figure 2: Equivalent Circuit Of Three-Phase Transformers With Magnetic Shunts

These three single-phase transformers can be combined in order to create a single central column consequently (figure 3). Each phase of the three-phase transformer behaves as a single-phase transformer. The design of the new three-phase transformer with magnetic shunts is an armored tetrahedral structure, which will undoubtedly help to reduce the volume of the new device and makes it more economical.

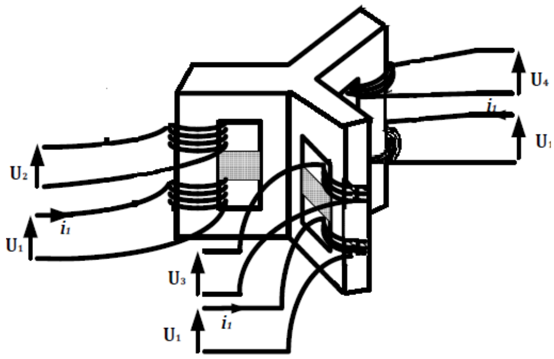

Figure 3.Form Of Magnetic Circuit Diagram Tetrahedron Type Of The New Three-Phase Transformer With Magnetic shunts

The figure 10 included in the appendix shows the integration of the equivalent model in π [19]-[20]-[21] of the transformer in the power supply from the source to the magnetron. Everything happens as if each phase of the three-phase HV transformer with magnetic shunts is composed of three ideal transformers; each one supplying a quadruple π composed of five inductive elements.

The five nonlinear inductors studied in Figure 10 (see Appendix) depend on the reluctance of the magnetic circuit portion with a section S and average length l. Each one is represented by its characteristic Φ(i) derived from the relation L(i)=(n2 Φ (i) / i) determined from the magnetization curve B (H) of the material used and the geometrical dimensions of the transformer used as reference (see Appendix) using the relation: n2*Φ(i)=n2*B*S and i=(H*l)/n2.

2.1 Simulation Results of the Nominal Functioning of the New Three-Phase Power Supply for one Magnetron by Phase.

The implementation of each nonlinear inductance in MATLAB-SIMULINK code was performed using the following blocks (figure 4):

- An integrator to convert the voltage in flow.
- A (lookup table i= Φ(i)) function, which accepts a large number of N points relating to the currents.
- An imposed current source.

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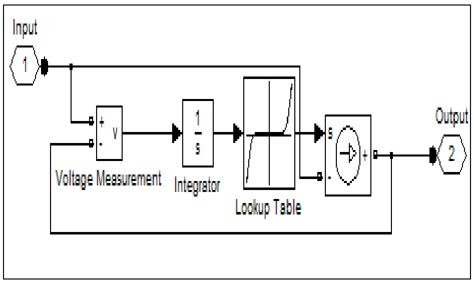

Figure 4: Diagram Block Of One Non-Linear Inductance

The five blocks of the nonlinear inductances will be integrated in the overall scheme of the new power supply (figure 10) to be suitable for the modeling and optimization of the whole device.

By using Matlab Simulink code, we have simulated under the nominal voltage 220V/380V and 50 Hz, the nominal electrical behavior of this New Three-Phase Power Supply circuit with one Magnetron by Phase used as reference. Figure 5(a) and figure 5 (b) shows the electrical signals obtained from this simulation (current in magnetrons (M**1**, M**2**, M**3**), voltages across each magnetron (M**1**, M2, M**3**), current in the capacitors (C**1**, C**2**, C**3**), voltages across the secondary of the model of the transformer (U**2**, U**3**, U**4**), voltages across each capacitors (C1, C2, C3) and currents in the diodes (D**1**, D2, D**3**)).

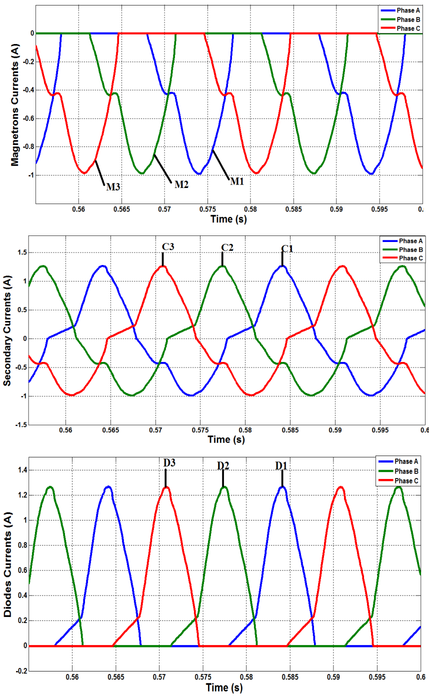

Figure 5 (A) Simulation With Matlab-Simulink: Forms Of Currents Waves

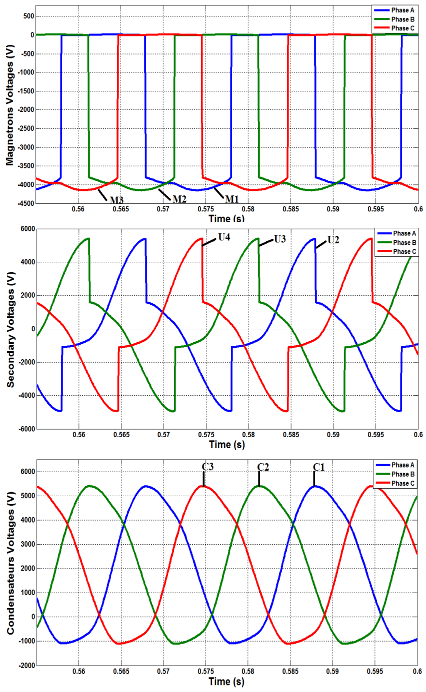

Fig.5 (B) Simulation With Matlab Simulink: Forms Of Voltages Waves

From the figure 5(a) and figure 5 (b) we note that the signals obtained from this simulation have the same form as those of experimental and simulated of conventional power supply using a single phase transformer for one magnetron[1]-[3]-[5]-[21]-[22]. These signals are curves of various sizes, periodic and non-sinusoidal dephasing by ($2\pi/3$) between them, which confirms the absence of interaction between magnetrons.

2.2 Energy Balance of the New Three-Phase Power Supply for one Magnetron

Unlike the research done in this topic, we have validated the nominal functioning of this new three-phase power supply by the power calculation. In this part we have calculated the value of instantaneous power curve from the temporal curves of voltages at terminal of each magnetron and the currents passing in each one. This leads to determine the average power curve, which equals during a period P_{ave}=3433 Watts. That is to say there will be 1144 Watts for each magnetron (figure6).

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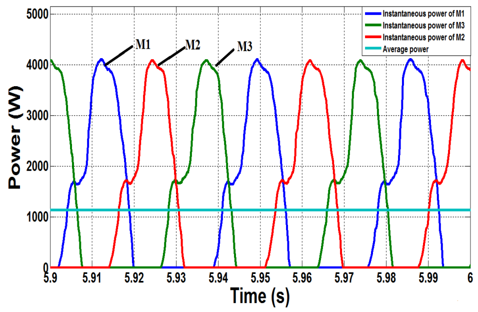

Figure 6: Instantaneous And Average Power Curves Of Each Magnetron

Thereafter we can deduce the performance of this new three-phase power supply, which is 84%, namely.

$$\eta_{reference} = \frac{Ps}{Pe} = \frac{3433}{3*1650*0.825} = 0.84$$

3. *OPTIMIZATION OF THE NEW THREE-PHASE HV POWER SUPPLY ONE MAGNETRON BY PHASE*

3.1 Strategy of Optimization

In this part, we will present an optimization strategy [23]-[24]-[25] of the new transformer that maintains a minimum volume of the transformer. To do this, we perform a set of simulations in which we seek the following objectives. Firstly, we will study the influence of each geometric parameter of the construction of the transformer on the magnetron current. The geometric parameters of the transformer considered variables are:

- The size of the magnetic circuit a (mm)
- The number of secondary turns n2
- The size of the shunts materialized by n3
- The width of the air gap e (mm).
- The quality of magnetic plates

Secondly, we will define a strategy based on the study of the simultaneous influence of more than one parameter, which aims to reduce the volume of the transformer.

3.2 Influence of different geometric parameters

By using Matlab-Simulink code and varying the reference parameters geometric in precise intervals. $15 \leq a \leq 25$, $2300 \leq n2 \leq 2500$, $10 \leq n3 \leq 18$, $0.55 \leq e \leq 0.95$, for each simulation we observe the shape of the current magnetrons, noting each time the maximum and average value (Figure11-see appendix)

The results obtained in figure 11 included in the appendix shows that the variation of the geometric parameters changes the electrical behavior of the circuit high voltage power. Therefore it is possible to reduce the volume of the transformer without exceeding the limits recommended by the manufacturer and without incurring damage to the magnetrons tubes.

3.3 Optimization of the New Three-Phase Transformer With Magnetic Shunt

The results obtained in previous paragraph shows the influence of each geometric parameter on the electrical behavior of the power supply especially on the magnetrons currents. This will lead to define a strategy that aims to reduce the volume of the transformer. This strategy is based on the study of the simultaneous influence of more than one parameter, by minimizing in the same time the width of the core unwound 'a', number of secondary turns 'n2', number of stacked sheets of each shunt 'n3' and thickness of the air-gap 'e'

Table 1: Variation Range of the Parameters

Name of Parameter	Range Value
a: width of the core unwound(mm)	$15 \leq a \leq 25$
n2:number of secondary turns	$2300 \leq n2 \leq 2500$
n3:number of stacked sheets of each shunt	$10 \leq n3 \leq 18$
e:thickness of the air-gap(mm)	$0.55 \leq e \leq 0.95$
B(H):magnetic quality of the material	SF19,S91,AFK502

Using Matllab-Simulink code and the quadruple model, we simulated the electrical behavior of the three-phase HV power of different possible configuration of parameters (figure 12-see appendix).

The Table 2 included in the appendix summarizes the solutions that can give the best operation of magnetrons. These solutions respect the criteria imposed by the manufacturer and allow the best functioning at nominal state of the new three-phase HV power supply for one magnetron by phase. The choice of the optimal solution must be validated by calculating the volume (Iron + Copper) of the transformer.

From the table 2 included in the appendix we see that the D solution presents simultaneously

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a minimum volume of iron and copper of the transformer and the best operation of the magnetron. We note that the solution C presents a minimum volume but it does not allow a functioning of the magnetron in full power (Imax=0.98(A) and Iav=230(mA)). The simulation by MATLAB-SIMULINK code of this optimized solution, shows that the waveforms of currents and voltages in nominal operation at 220 V in each magnetron do not present any oscillations affecting magnetrons tubes and respects the constraints recommended by the manufacturer (Imax <1,2 A, Imoy ≈ 300 mA).

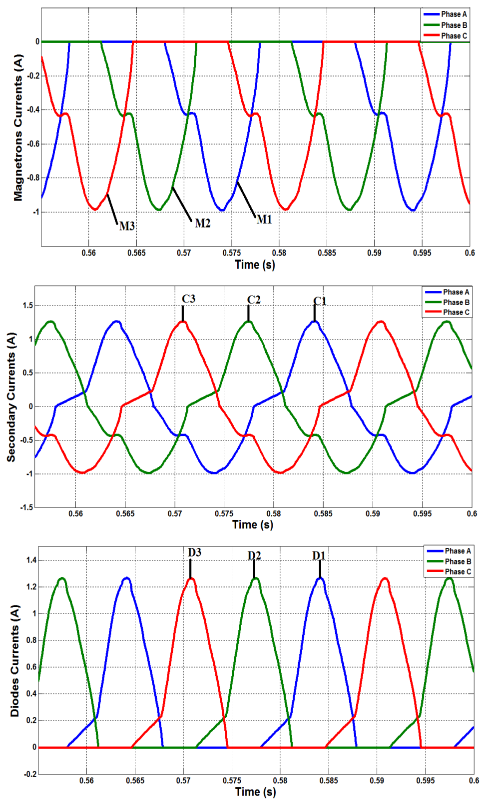
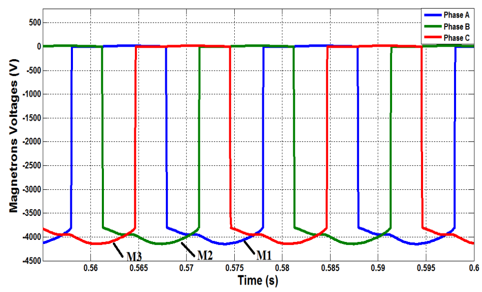


Fig.7 (a) Waveforms of currents corresponding to the chosen solution D



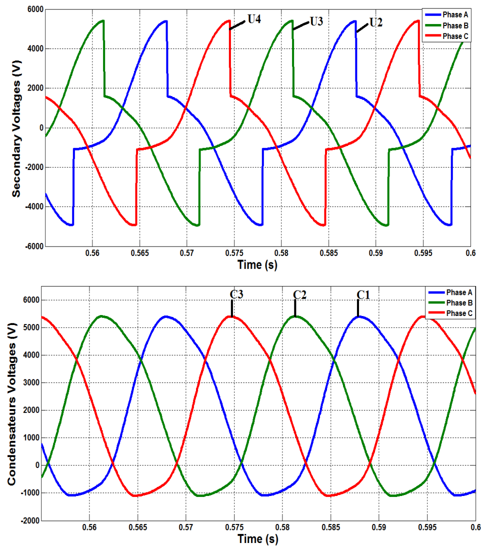


Fig.7 (B) Waveforms Of Voltages Corresponding To The Chosen Solution D

From figure 7(a) and figure 7 (b) we observe that the waveforms corresponding to the solution D are in perfect accordance with those obtained by the reference case.

3.4 Energy Balance of Optimized New Three-Phase Power Supply for one Magnetron

By using the geometric parameters of the transformer of the adapted D solution we will validate the nominal functioning of the power supply by the power calculation. The instantaneous and average power curves for each magnetron (figure 8) have the same form of those obtained by that treated for the reference case.

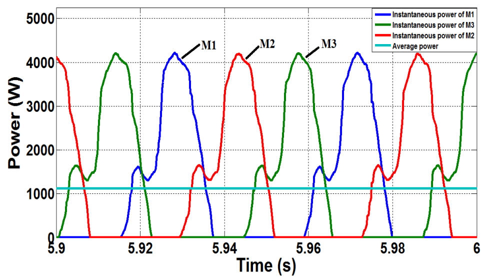


Figure 8: Instantaneous Power Ana Average Power Of Each Magnetron Coresponding To The D Solution

The performance of this new optimized three-phase power supply of microwave generator is around 83%, namely

$$\eta = \frac{Ps}{Pe} = \frac{3365}{3*1650*0.825} = 0.83$$

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4. CONCLUSION

The originality of this paper resides in the calculation of the power and the performance of the three-phase high voltage power supply for industrial microwaves generators with one magnetron by phase resulting from the optimized solution.

For industrial application the new transformer presents relative to that studied for the reference case, the gain of volume and weight. This will reduce the cost of the power supply and make it more economical while preserving the same performance.

As perspectives, this work can be extended for modeling and optimization of new three-phase or six-phase power supply for several magnetrons by phase.

REFRENCES:

[1] M.Chraygane, "Modeling and optimization of a transformer with shunt of the high voltage power supply for magnetron used as microwave generators2450MHz 800W for industrial applications", *Thesis of doctorate*, Claude Bernard University-Lyon I, France, n° 189 (1993).

[2] David Greene J., Gross C,A, "Non linear modeling of transformers", *IEEE Transactions on Industry Applications*, NO 3, 24 may/June (1998).

[3] 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

[4] Dorgelot E.G., Philips, *Technishe Rundschau*, Vol. 21934 (1980) 103-109

[5] M. Chraygane, M. Ferfra, M.El Haziti, A.Zatni, M. Bour, M. Lharch, "Modélisation et simulation du fonctionnement nominal d'une nouvelle alimentation HT monophasée pour générateurs micro-ondes industriels à N=3 magnétrons ", *communication, Télécom'2009 et 6ème JFMMA*-Agadir. Comm., (2009) 77-78.

[6] Chraygane M, Teissier M., Jammal A. et Masson J.P, "Modélisation d'un transformateur à shunts utilisé dans l'alimentation H.T d'un générateurs micro-ondes à magnétron", *publication, journal de physique III*, France, (1994) 2329-2338

[7] Teissier M., Chraygane M., Jammal A. et Masson J.P, "Leakage Flux Transformer Modelling", *Communication, International Conference on Electric Machines, ICEM'94*, Paris, (1994)

[8] M. Chraygane, M. Ferfra, M. El Khouzaï, B. Hlimi, "Vérification expérimentale de la loi de conservation des flux du transformateur à shunts d'une alimentation pour générateurs micro-ondes à magnétron destinés aux applications industrielles", *RNJCP4-*Casablanca, Comm, (2003) 6-7.

[9] 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", *J. of PCN*, 22 (2005) 65-74.

[10] 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.

[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", *J. of PCN*, 27, (2006) 31-42.

[12] 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", *J. of PCN*, 40 (2008) 51-61.

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

[14] M. Chraygane, A. Zatni, M. Ferfra, B.Hlimi & S. Bidar, "Modélisation d'une nouvelle alimentation HT monophasée pour générateurs micro-ondes industriels à N=2 magnétrons", *Télécom'2007 et 5ème JFMMA*–Fès. Comm., (2007) 420-424.

[15] Ould.Ahmedou M, " Contribution à l 'limentation des Générateurs micro-ondes à N Magnétrons par des Transformateurs Monophasés et Triphasés", *Thesis of doctorate*, Mohammadia's School of Engineering.

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

Mohamed V University, Rabat, Morocco, n° 189 (2012).

[16] Ould.Ahmedou.M, Bassoui.M, Ferfra.M, Chraygane.M, Belhaiba.A, Elghazal.N, Bahani.B " Global Modeling of New Three Phase HV Power Supply For Microwaves Generators With N Magnetrons by Phase (Treated Case N=1) Under MATLAB SIMULINK code "*accepted for publication in Journal of Theoretical and Applied Information Technology* (E-ISSN 1817-3195 / ISSN 1992-8645) (2013).

[17] Naama El Ghazal, M. Chraygane, M. Ferfra, A. Belhaiba, M. Fadel, B. Bahani," Modeling of New Three-phase High Voltage Power Supply for Industrial Microwave Generators with One Magnetron Per Phase " *International Journal of Electrical and Computer Engineering (IJECE),* Vol. 3, No. 2, April 2013, pp. 270~278

[18] M. Bassoui, M. Ferfra, M. Chraygane, M. Ould Ahmedou, N. Elghazal, A. Belhaiba" Optimization of a New Three-Phase High VoltagePower Supply for Industrial Microwaves Generators with N Magnetrons by Phase (Treated Case N=1)", *International Conference on Modeling and Simulation*, 06/07 November Paris-France

[19] 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.

[20] Ahmedou, M.Ould. Ferfra, M. Nouri, R. Chraygane, M. "Improved π Model of the Leakage Flux Transformer Used for Magnetrons", *2011 International Conference on Multimedia Computing and Systems - Proceedings* , art. no. 5945710. 7April 2011 through9 April 2011 Ourzazate, Morocco.

[21] M.Ould.Ahmedou, M.Ferfra, N.EL Gazal, M.Chraygane,M. Maaroufi "Implementation and Optimization Under Matlab Code of a HV Power Transformer For Micowave Generators Supplying Tow Magnetrons", *Journal of Theorical and Applied Information Technology* 30 November 2011, Vol. 33 No.2

[22] M.Ould.Ahmedou, M.Ferfra, A.Belhaiba, M.Chraygane, "Optimization of a HV Power Transformer for Microwave Generators Supplying Two Magnetrons", *International Workshop on Information Technology and communication* WOTIC Casa-Blanca 13 – 15 October 2011.

[23] A.Belhaiba, M.Ould.Ahmedou, M.Chraygane, M.Ferfra, N.Elghazal 'Energy balance of optimized high voltage power supply for microwaves generators used in various industrial applications' *International Review of Modeling and Simulation (IREMOS)*, 2012, Vol. 2, N.4, August 2012, pp: 1460-1469.

[24] 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 mangnetrons for microwaves generators".*International Journal of Electrical and Computer Engineering(IJECE)*,Vol.2, No.5,October 2012,pp.708-716

[25] Naama El Ghazal, 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*. Vol. 46 No.1. 15th December 2012.

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APPENDIX:

a. Geometry of the transformer

In this work, we have taken as reference the following geometrical dimensions of the three-phase transformer HV with magnetic shunts:

- The width of the non-wound core: a = 20 mm
- The width of the magnetic circuit: b = 120 mm
- Number of stacked sheets of the shunt: n3 = 18
- Number of turns in the primary: n1 = 224
- Number of secondary turns: n2 = 2400
- Height of the sheet stack of shunts: h = 0.5 n3.
- Surface of the core: S1 = S2 = a.b
- Surface of shunt: S3 = b.h
- Thickness of the air gap: e = 0.75 mm

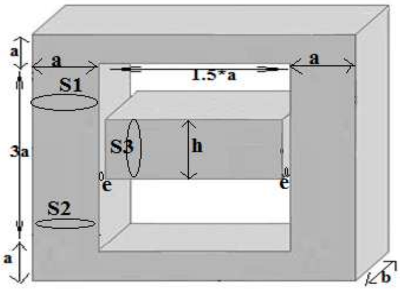

Figure 9: geometry of transformer with magnetic shunt

b. New quadruple model of three-phase transformer supplying one magnetron by phase

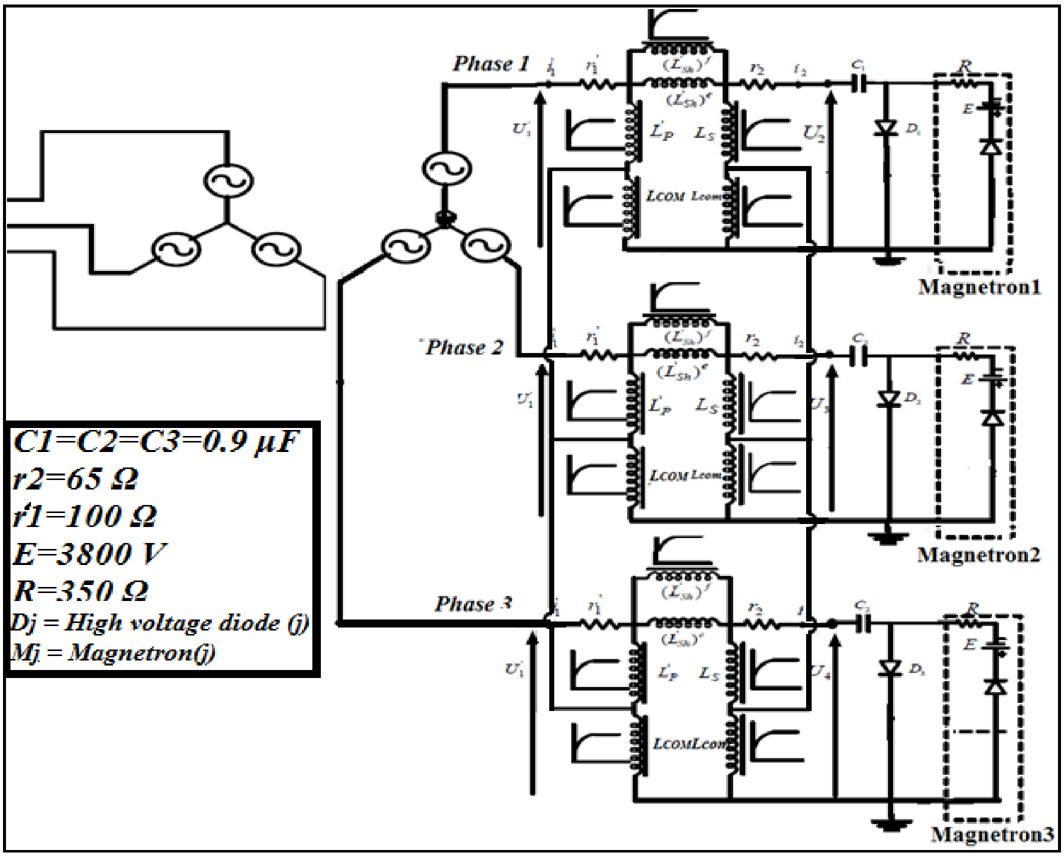

Figure 10: New Quadruple Model Of Three-Phase Transformer Supplying One Magnetron By Phase

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c. Simulation results of the magnetron current according to geometric parameters of the transformer

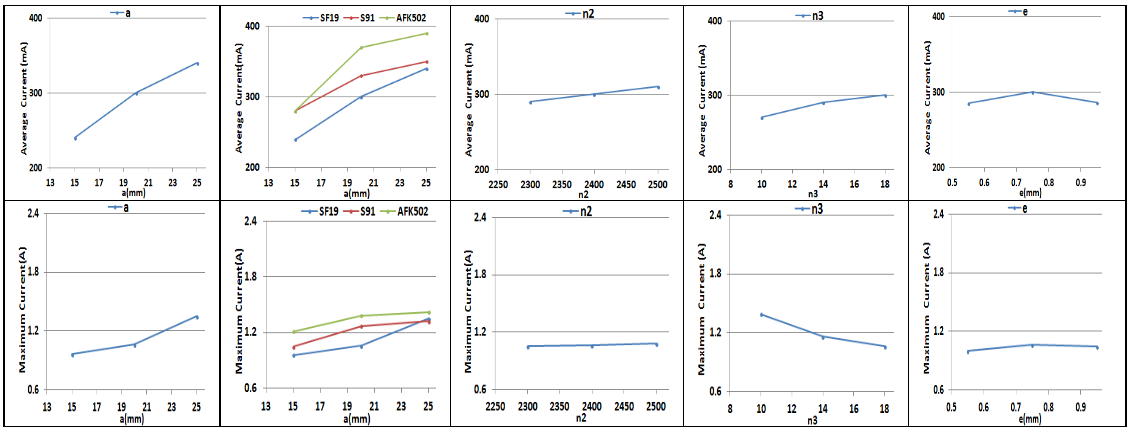

Figure 11: Simulation Results Of The Magnetron Current According To Geometric Parameters Of The Transformer

d. network of obtained curves

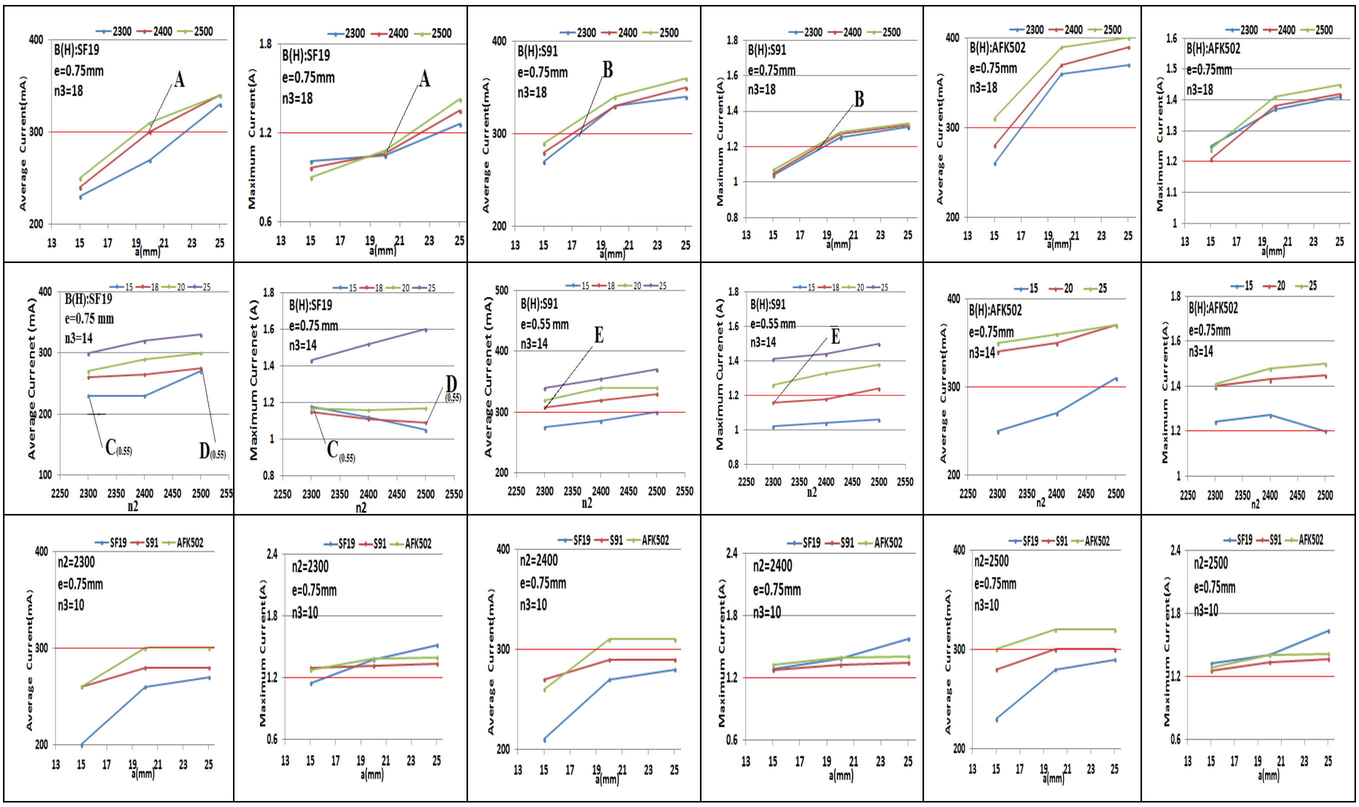

Figure 12: Network Of Obtained Curves

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e. Possible solutions of Parameter Settings That Respect the Norms Imposed by the Manufacturer

Table.2 Possible Solutions Of Parameter Settings That Respect The Norms Imposed By The Manufacturer

Name of solution	B(H)	a (mm)	n_2	n_3	e (mm)	V (cm^3)	Iav (mA)	Imax (A)
A(Ref)	SF19	20	2400	18	0.75	1509	228	0.99
B	SF91	20	2300	14	0.75	1487	280	1.17
C	SF19	15	2300	14	0.55	879.6	230	0.98
D	SF19	18	2500	14	0.55	1235	280	1.02
E	S91	18	2500	14	0.55	1235	308	1.16