Improved Optimization of the Nominal Functioning Of a High Voltage Power Supply N=2 Magnetrons for Microwaves Generator

A. Belhaiba*, N. Elghazal*, M. Chraygane*, M. Ferfra, B. Bahani*, M. Ould Ahmedou****
* MSTI Laboratory, ESTA, Technologie Higher School Agadir Ibn Zohr University
** Power electronics Laboratory, EMI,Mohammadia Engineering school Mohamed V University

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ABSTRACT

This work deals with the energetic validation of a new optimized high voltage power supply for micro-waves generators with N=2 magnetrons that are used as an energy source in industrial applications. In this article, we will apply an optimization strategy that aims at improving the nominal functioning of the optimized power supply with N=2 magnetrons. Unlike research work already done an this topic, this article treats the correct energetic functioning of the two magnetrons. An equivalent scheme in π of the transformer model is presented with the geometrical parameters taken as reference. This model has been tested with the help of the simulation software Matlab-Simulink close to nominal operation. The theorical results compared to the experimental measures are in good conformity. Following that, we will define a strategy that aims to minimize the volume of the transformer, while taking into account the energy characteristics imposed by the manufacturers, this by calculating the average power that must be identical to that treated for the reference case.

Corresponding Author:

A.Belhaiba,
Ibnou Zohr University Agadir, Morocco
e-mail: a.belhaiba@gmail.com

1. INTRODUCTION

The study of the nominal energetic functioning of the optimized HV power supply with two magnetrons used in the various industrial applications has never been done, despite the existence of a theory [1],[2],[3] on the modeling and optimized implementation of the transformer. This article deals with the energetic study of a new optimized power supply with N = 2 magnetrons, this optimization is based essentially to study the modelling of its special transformer with magnetic shunts.

This work is divided in two parts, In the first part, we present the equivalent model of the transformer retained (with the geometrical parameters taken as a reference (see appendix)) which will be integrated into the overall scheme of the power supply that will be suitable for the modeling and optimization of the whole device [4],[5],[6],[7],[8], with the help of the numerical simulation software Matlab-Simulink code. The experimental measurements allow to validate the simulated results of this model. Subsequently, we will establish the calculation of the power obtained by simulation so as to highlight the stabilizing effect of the current in each magnetron.

The second part will be devoted to improving optimization of the new transformer with N=2 magnetrons, We will highlight the influence of each geometric parameters on the electrical functioning of the new power supply with N=2 magnetrons, . Based on the geometric parameters corresponding to the new selected solution, we will validate the nominal functioning of the new transformer. This latter with the saving of weight and volume, makes the new power supply more economical. The new transformer derived from the optimization study must release an average power around 2400Watts=2*1200Watts for each magnetron. Finally, we will check the current regulation process in each magnetron.

2. MODELLING THE NEW POWER SUPPLY WITH N=2 MAGNETRONS

2.1 Description of the model

We will triy to incorporate the model of the transformer in the circuit of the new HV power supply from the source to the magnetrons figure1 [9], which we will represent each microwave tube by its equivalent circuit deduced from its electrical characteristic it is similar to that of a diode with dynamic resistance $R=\Delta U/\Delta I$ Ohm and threshold voltage E. Each storable inductance of π model [10], of section *S*, and average length *l*, presents a characteristic $\Phi(i)$ that we can determine on the basis of the *B(H)* curve of the material used and the geometric parameters, by the relations $\Phi(i)=B*S$ and $i=(H*l)/n_2$.

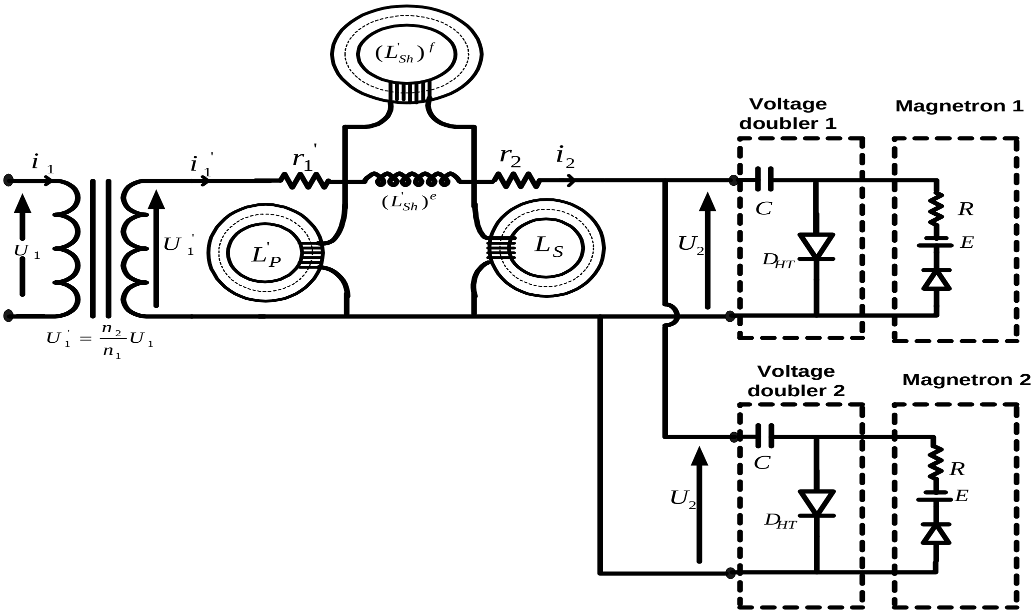

Figure 1. π quadrupole model of the transformer supplying two magnetrons

2.2 Simulation of the nominal functioning of the new power supply with N = 2 magnetrons by Matlab-Simulink code

We will try to present in Matlab-Simulink code each nonlinear inductance of the model with a block in which we introduce the points of the magnetization curve of the used material , this block is composed of the following elements figure2:

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

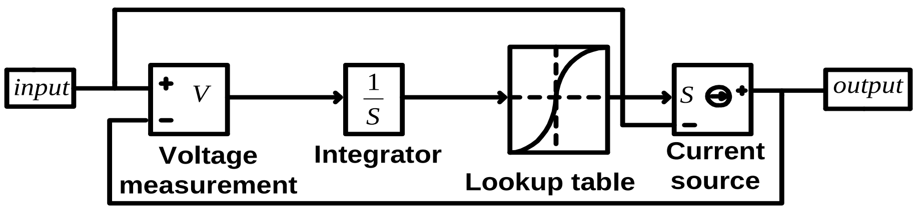

Figure 2. Block diagram of a nonlinear inductance of the model

After that, we will collect the three blocks of the nonlinear inductances and introduce then using Matlab-Simulink code, in the overall scheme of the power supply with N=2 magnetron Figure3.

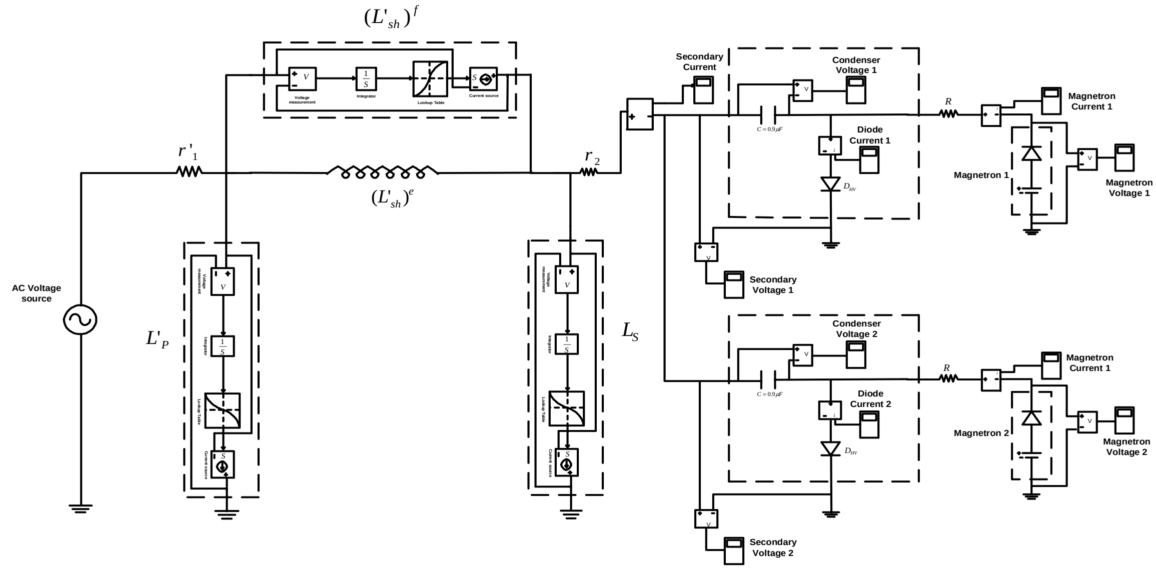

Figure 3. The scheme of the entire model of the power supply with N=2 magnetrons in Matlab-Simulink

To validate this model we perfomed a tests [11], we have used a microwaves generator composed of the following elements:

- High voltage transformer with shunts has the following characteristics:f=50 Hz, S=1650 VA, U_1=220V, and, vacuum U_2=2330 V (primary resistance view from secondary in r_1'=100Ω, secondary resistance r_2=65Ω, number of primary turns n_1=224,
- Two voltage-doublers each of which is composed of a condenser with capacity C = 0.9 µF and a high voltage diode D_{HV}.
- Two identical magnetrons each one designed to operate at a voltage of approximately 4000 V, for its nominal power, the microwave tube needs a average intensity I_{avg} = 300mA, but without exceeding the peak current may destroy the magnetron (I_{max}<1,2A). In addition, the data from manufacturer led to extract the values E=3800 V and R=350 Ω.

The geometrical dimensions of the transformer allows us to determine the parameters L'_p , L_s ,L_{sh}^f , and by exploiting the characteristics of sheet type SF_{19}, this will allow to find the value of $(L'_{sh})^e$=3.551 H. On the basis of the non-linear characteristics already established of each inductor and by using the model developed in Matlab-Simulink code, we will simulate the electrical behavior of the HV power supply circuit with N=2 magnetrons.

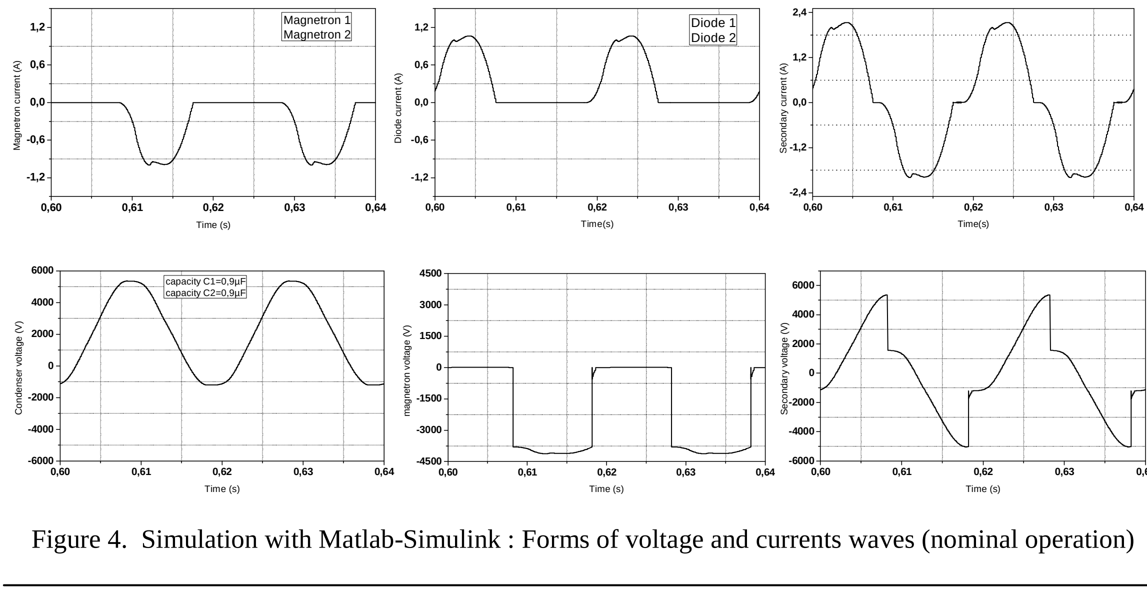

Figure 4. Simulation with Matlab-Simulink : Forms of voltage and currents waves (nominal operation)

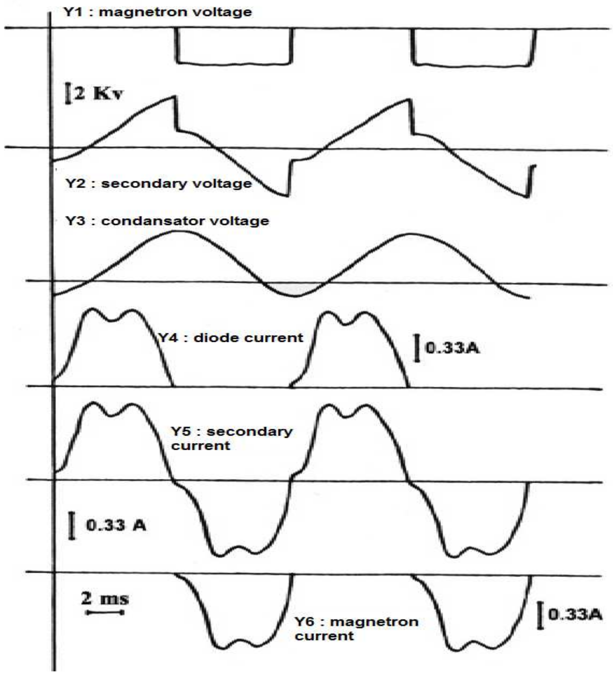

Figure 5. Experimental waveforms of currents and voltages (nominal mode)

The nominal electrical functioning of the new power supply with two magnetrons was simulated with the help of Matlab-Simulink software, by using a HV transformer with shunts suitably sized to supplying two magnetrons. We see that the signals from the figure4 have the same form of the signals obtained by experience with conventional power supply comprising a HV transformer for a single magnetron figure5, this confirms the lack of interaction between the powered magnetrons. The operating points of the magnetrons are not disturbed, this is essential for a stabilized current of the power supply.

The curves from the figure4 thus confirm that each magnetron can operate properly in nominal operation (U_1=220 V et f=50 Hz), to debit full microwave power (I_{mean}=300mA, I_{max}=1A), which makes the simulation of this model satisfactory. On the other hand, the stabilizing effect of the current in each magnetron, has been conclusively verified figure6, by observing, with Matlab-Simulink code, the evolution of the current in each magnetron relative to the variations of primary voltage ±20V .

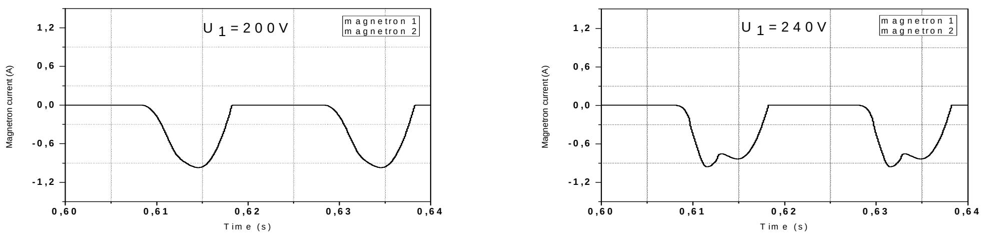

Figure 6. Stabilization of the magnetron current in each magnetron relative to the variations of section voltage of ±10% of the nominal voltage

2.3 Energetic validation of the new power supply with N = 2 magnetrons taken as reference

In this part we will validate the nominal functioning of the new power supply by the power calculation. The temporal curves of voltages $U_m(t)$ at terminal of each magnetron and the currents $I_m(t)$ passing in each one [12], will allow sampling of the values of voltages and currents, which will lead to computing the value of the instantaneous power curve [13]. This same curve will allow thereafter, to establish the average power curve during a period figure7. This indicates that the transformer delivers an average power equal to 2400Watts. That is to say there will be 1200Watts for each magnetron. This confirms full power operation of the new power supply with N = 2 magnetrons.

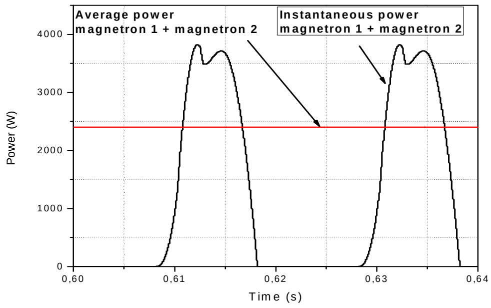

Figure 7. Instantaneous power and average power of two magnetrons

3. IMPROVED OPTIMIZATION OF THE TRANSFORMER WITH N = 2 MAGNETRONS ON THE BASIS OF ITS MODELING

3.1 Influence of different geometric parameters

By exploiting the Matlab-Simulink code and varying the reference parameters in precise intervals. 30 < a < 50, 2050 < n_2< 2750, 10 < n_3< 18, 0,45 < e < 1,05, we noted for each simulation the maximum current values and the average current, the figure7 shows the results of variation of the average and maximum current values according to the parameters of the transformer.

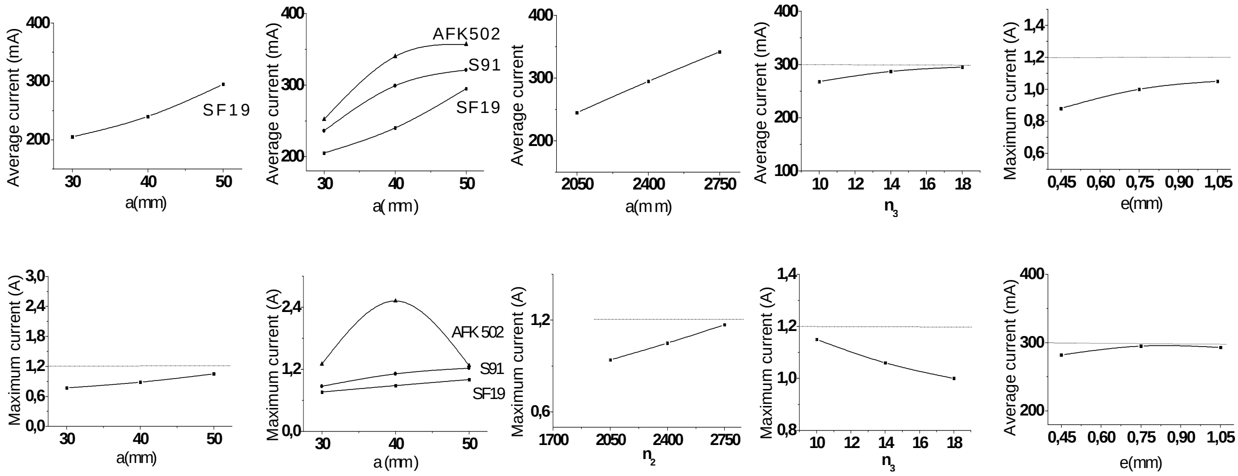

Figure 8. Simulation results of the magnetron current according to geometric parameters of the transformer

The simulation results shown in figure8 illustrate that the variation of the geometric parameters change the nominal operating of power supply, this will lead to define a strategy that aims to minimize the volume of the transformer while respecting the recommendation imposed by the manufacturer.

3.2 Improved optimization of the transformer with shunt

The previous results highlight the influence of each parameter on the electrical behavior of the transformer and the magnetron current [14], which is of special interest to us. The algorithm studied in previous work mainly aims to minimized the volume of the transformer, regardless of the nature of materials or the electrical power of the selected solution.

In this part we will apply a strategy that aims to minimize the volume of iron and copper of the transformer and therefore its cost, by studying the simultaneous influence of more than one parameter by minimizing at the same time the number of turns n_2, the width ‘’*a*’’ of the core unwound and the number ‘’n_3’’ of the sheets stacked of each shunts.

By using the Matlab-Simulink code and the π quadruple model, we will simulate, for different possible configurations, of the transformer parameters.

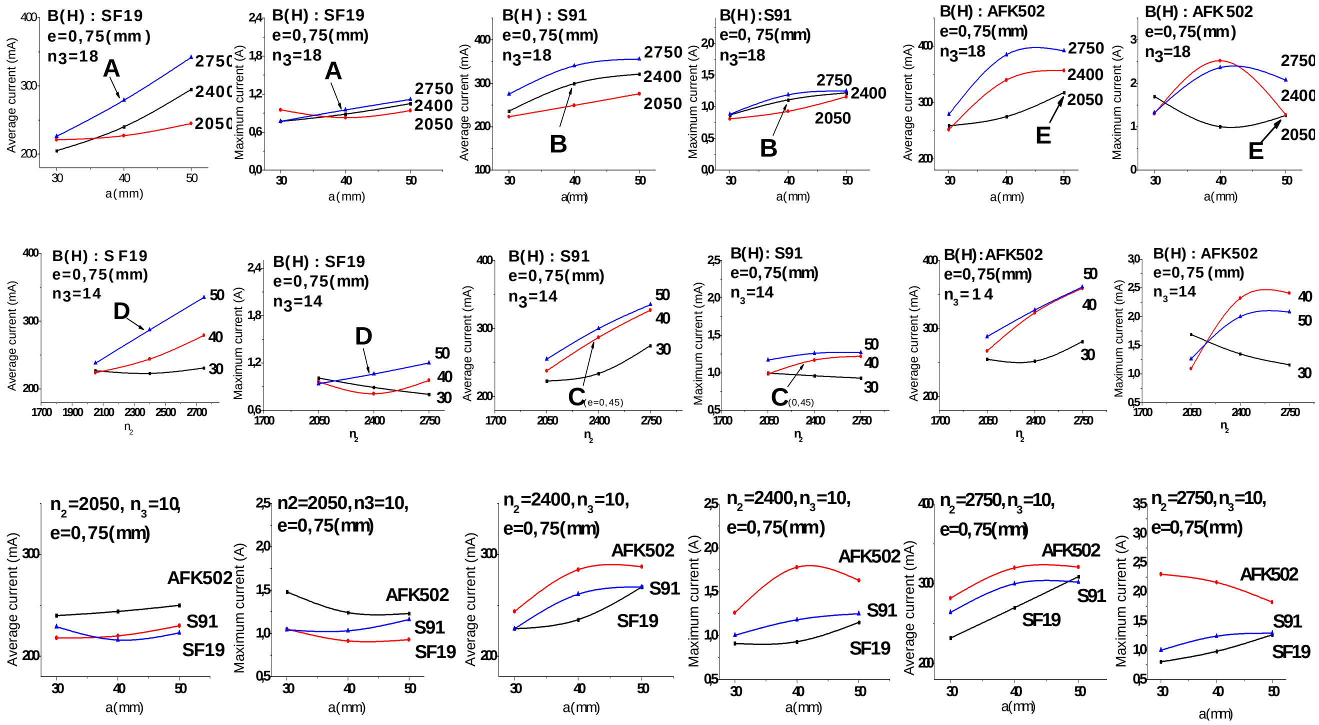

Figure 9. Network of obtained curves

Using the network of curves (Figure9) leads to draw an infinity of selected solution, that respond of the norm imposed by the manufacturer. Table 1 summarizes some solutions.

Table 1. Possible solutions of parameter settings that respects the norms imposed by manufacturers

Name of solution	B(H)	n_3	*a*(mm)	*e* (mm)	n_2	V(cm^3)
A	SF_{19}	18	40	0.75	2750	1502
B	S_{91}	18	40	0.75	2400	1496
C	**S_{91}**	**14**	**40**	**0.45**	**2350**	**1486**
D	SF_{19}	14	50	0.75	2400	2217
E	AFK_{502}	18	50	0.75	2050	2229

From the table above we see that the C solution presents a better volume gain of iron and copper. And therefore the cost of the whole device.

3.3 Energetic validation of the selected solution

By using the geometric parameters of the transformer which corresponds to the selected solution adopted for the simulation of the model, We will simulate for this case the electrical behavior of the HV power supply circuit for N=2 magnetrons, The waveforms of voltages and currents are shown in figure10. From this latter we see that the waveforms from the C solution are in good agreement with those obtained in the first part, the C solution presents a simultaneous reduction of copper and section, as it respond to the specifications imposed by the manufacturer so that the magnetron operates in full power (I_{moy}=300mA, I_{max}=1A).

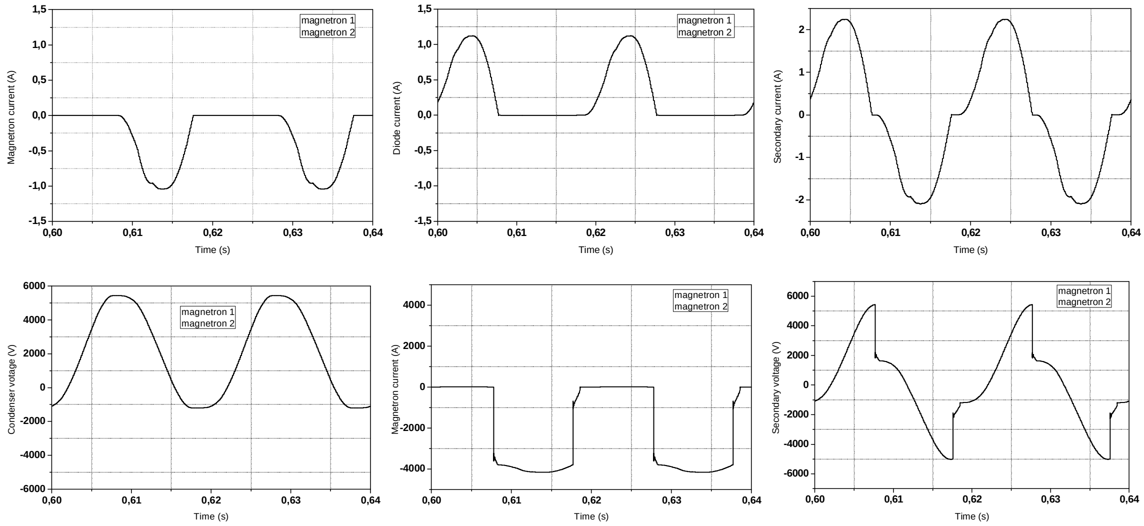

Figure 10. waveforms of voltages and currents for the configuration parameters of the transformer of selected solution

Figure11 shows the waveforms in the two magnetrons relative to the variations of primary effective voltage 200V and 240V. We note that the maximum amplitude of the current remains less than the admissible limit value recommended by the manufacturer (1.2A). With this configuration parameters, the control process of current is completely secured.

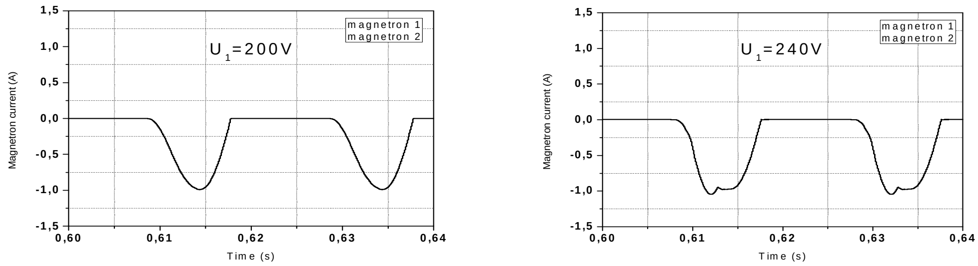

Figure 11. Stabilization of the magnetron current relative to variations ±10 % of the nominal voltage in primary for geometric parameters of the C solution

To validate the energetic functioning of the new optimized transformer with two magnetrons, we calculate the average power that must be in the order of 1200Watts.

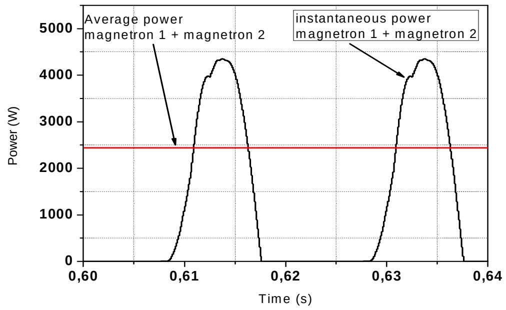

Figure 12. Instantaneous power and average power of two magnetrons of the C solution

We see from the figure12 that the new transformer with N = 2 magnetrons resulting from the C solution, has the same characteristics with that previously treated, the average and instantaneous power curves show a full-power operation P_{avg}=2400W, that is to say 1200Watts for each magnetron.

4. CONCLUSION

We have succeeded to define a proper strategy that aims to maximize the volume of the transformer with two magnetrons, while ensuring the proper functioning of each magnetron.

For industrial applications requiring the same power, the new optimized power supply presents relative to the present solution taken as a reference, the gain of volume and weight and the therefore the cost of the overall system, between the two systems, the transformer becomes more economical while preserving the full power functioning.

Appendix

During this work, we took as references the parameters of the model of the transformer with magnetic shunts.

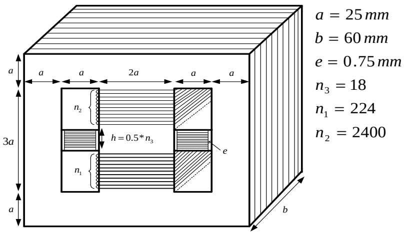

Figure 13. geometric parameters of the transformer (reference case)

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BIOGRAPHIES OF AUTHORS

Abderrahim.Belhaiba was born in Agadir, Morocco, in 06/12/1983; he received the Master in 2010 in instrumentation and Telecommunications from faculty of sciences (Ibn Zohr University) Agadir-Morocco, where he pursues his doctoral program.
His research is interested in the ‘’ Study of the energy balance of a new high voltage power supply N magnetrons per phase 800 Watts - 2450 MHz for microwave generators used in industrial applications’’.

Naama.Elghazal was born in Laayoune, Morocco, in 08/04/1984; he received the Master in 2010 in instrumentation and Telecommunications from faculty of sciences (Ibn Zohr University) Agadir-Morocco, where he pursues his doctoral program.
His research is interested in the ‘’ Study of the energy balance of a new high voltage power supply N magnetrons per phase 800 Watts - 2450 MHz for microwave generators used in industrial applications’’.

Mohammed Chraygane was born in Morocco in 1963, he received his thesis of doctorat from Claude Bernard University Lyon I in 1993 and his ‘doctorat d’état’ from Ibn Zohr University Agadir-Morocco in 2007. In 1994, he joined Technology Higher School Ibn Zohr University Agadir **Morocco** (ESTA). Since this date he has been a professor in MSTI Laboratory (ESTA School Ibn Zohr University Agadir Morocco Agadir). His field of interest is modeling a high voltage power supply used for industrial microwaves generators with magnetron.