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Comparative Study of Energy Balance of a Single-Phase Power Supply for Magnetron

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ABSTRACT

The objective of this work focuses on the comparative study of energy balance of conventional single-phase power supply for magnetron using different methods. The energy balance study already performed on the classical single phase power supply currently used by most industrial ovens was not experimentally validated. In this article the detailed study of different powers (primary power of the transformer, output power of the transformer and input power of the magnetron) was performed, each of these powers were compared with their corresponding powers obtained experimentally.

Keywords: *Magnetron, Energy Balance, Modeling, Matlab-Simulink.*

1. INTRODUCTION

The energetic characteristics of the magnetron require an average input power of 1200W with this power the magnetron can delivers full useful power 800W. In this article we will perform an original comparative study on the balance of obtained power by simulation using Matlab-Simulink and that by experiment.

In the first part, we will remind the modeling of the classical power supply for one magnetron with MATLAB-SIMULINK code. The results of currents and voltages waveforms obtained from the experimental setup will be compared with those obtained by simulation using MATLAB in the nominal operation.

The second part will be devoted for the powers involved calculation, we will calculate the input power of the transformer by calculating the product point by point of the current and the voltage, thereafter and following the same steps we will calculate the output power of the transformer, and finally the magnetron input power, which must be of the order 1200W (cited in the operating instructions of the magnetron) for full power operation. The different obtained powers by simulation with electrical model will be validated by those obtained experimentally.

2. MODELING OF SINGLE-PHASE POWER SUPPLY FOR MAGNETRON (REMINDER)

Figure 1 shows the schema π quadruple model of the single power supply [1],[2]. We note that each one of the three storable inductors is a function of its own reluctance. This model shown in the same figure 1 was successfully verified [3]. Each nonlinear inductance model is linked to a specific part of the magnetic circuit of the transformer, which allows to easily translating this model in Matlab-Simulink code [4], [5].

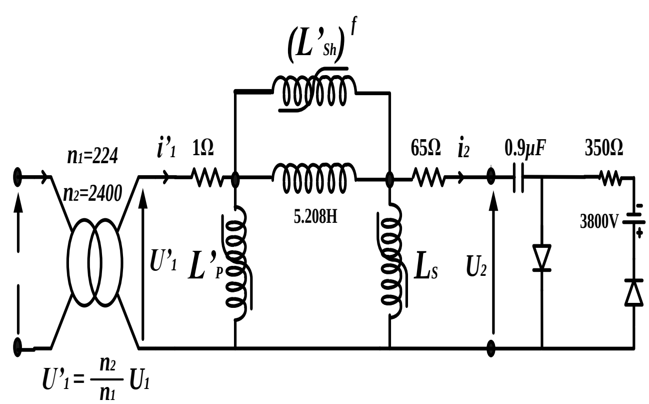

Fig. 1. Global Model of the Power Supply for one Magnetron.

The obtained simulation results of currents and voltages presented in the figures 2.a and 3.a are compared with those experimentally (figure 2.b and 3.b) obtained in the same conditions [6]. We see that the results of simulation and experiment are in good agreement [7].

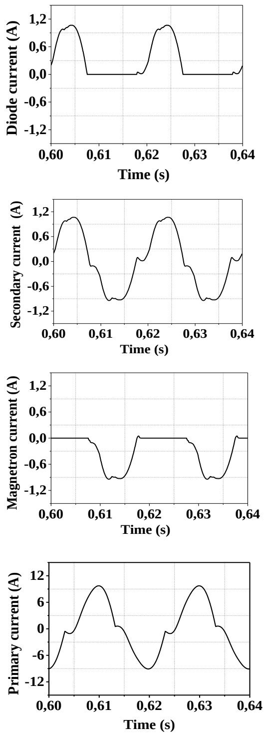

Fig. 2.a. Obtained results of currents with Matlab

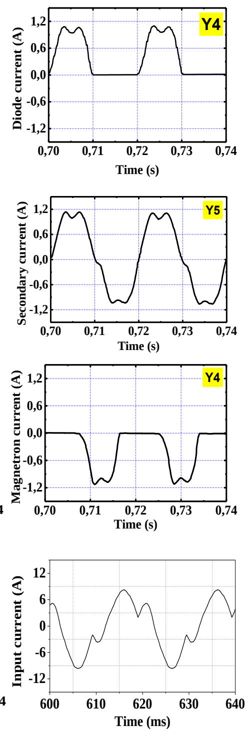

Fig. 2.b. Obtained results of currents with experiment

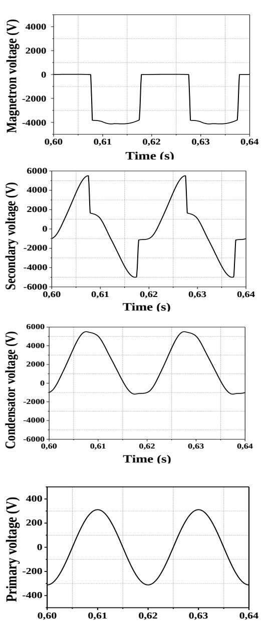

Fig. 3.a. Obteined results of voltages with MATLAB

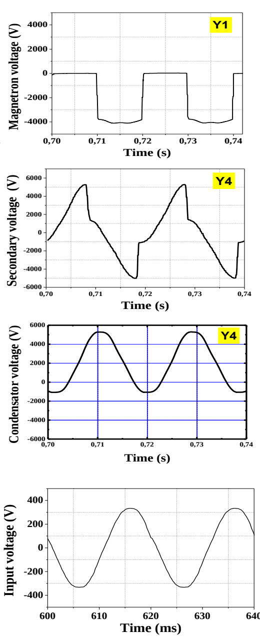

Fig. 3.b. Obtained results of voltages experimentally

3. ENERGY BALANCE OF HIGH VOLTAGE POWER SUPPLY FOR MAGNETRON

3.1 Involved powers: experimental method

This assessment includes determining the input and output power of the power supply from the experimental determination of the following powers:

- Input power of the transformer.
- Output power of the transformer.
- Input power of the magnetron or anodic power.

The power measurements were performed according to the assembly of figure 4. The voltage measurement is performed with a potentiometric divider (1/100 for primary and 1/1000 for the secondary) and the current measuring with sufficient power resistor. All of these two parameters are stored on digital oscilloscope and then transferred to the calculator for the power calculation. The power is determined over a period. The computer makes a data acquisition with the voltage curves (U) and currents (I) stored in digital oscilloscope. After that, the calculator sums the products U * I point by point over a period for the instantaneous power and divide on the number of points over a period to get thus the value of the average power in Watts.

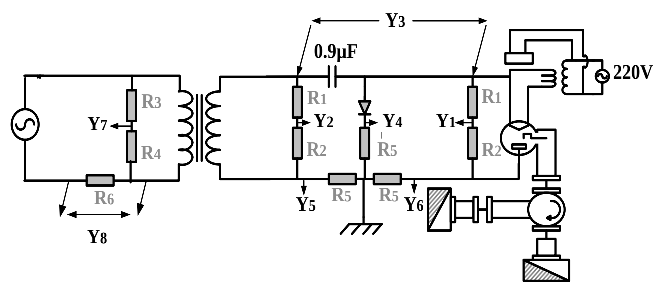

Fig. 4. Experimental setup used for voltage and currents measurements

- **Input power of the transformer**: The product point by point, of the two measured curves (Figure 2.b and 3.b) of primary current (Y8) and primary voltage (Y7) from the assembly of figure 4, allowed to get the instantaneous input power of the transformer (figure 5).

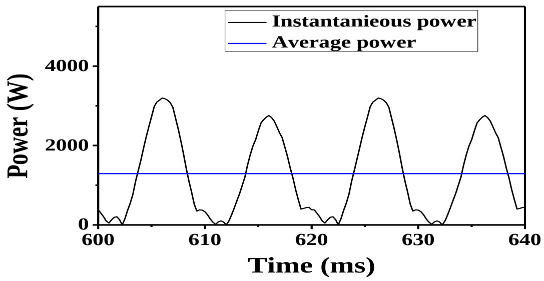

Fig. 5. Input power of the transformer (Average power and instantaneous power)

- **Output power of the transformer:** The product point by point, the both measured curves (figure 2.b and 3.b) of secondary current (Y5) and secondary voltage (Y2) from the practical mounting figure 4, led to obtain the instantaneous output power of the transformer (figure 6).

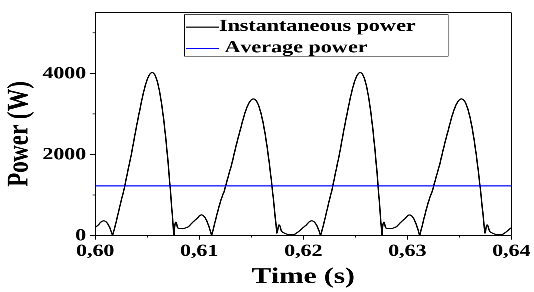

Fig. 6. Output power of the transformer (Average power and instantaneous power)

- **Input power of magnetron or Anodic power :** The product point by point, of the two measured curves (Figure 2.b and 3.b) magnetron current (Y6) and magnetron voltage (Y1) from the same practical mounting figure 4, allowed to find the instantaneous input power curve of the magnetron figure 7 [8], [9], [10], [11].

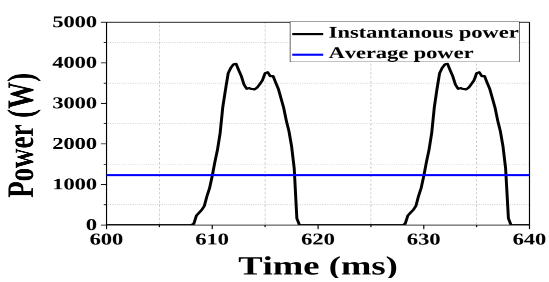

Fig. 7. Intput power of the magnetron (Average power and instantaneous power)

The various average powers found are then:

- 1360W in the input of the transformer from the experimental measurement of the primary voltage and the primary current.
- 1220W at the high voltage output of the transformer from the experimental measurement of secondary voltage and secondary current, in which we must add 40W for heating the filament of the magnetron cathode (13A under 3,15V). The overall power output of the transformer is therefore 1260W.
- 1200W input of the magnetron.

We can deduce the power supply efficiency:

$$\eta_{Experiment} = \frac{1200+40}{1360} = \frac{1260}{1360} = 0{,}91$$

3.2. Involved powers: simulation method under (Matlab- Simulink)

From the model of the transformer under Matlab-Simulink (figure 8) we have succeeded to get the following powers:

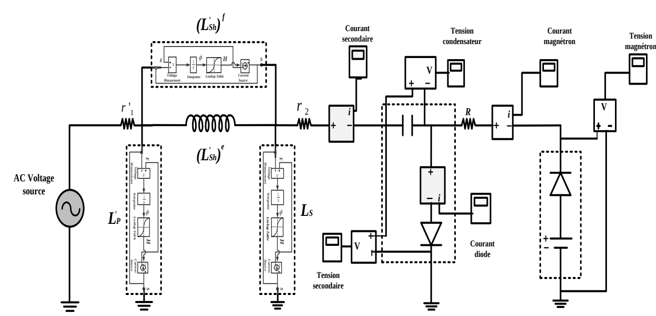

Fig. 8. Power supply model under Matlab-Simulink

- Input power of the transformer (figure 9):

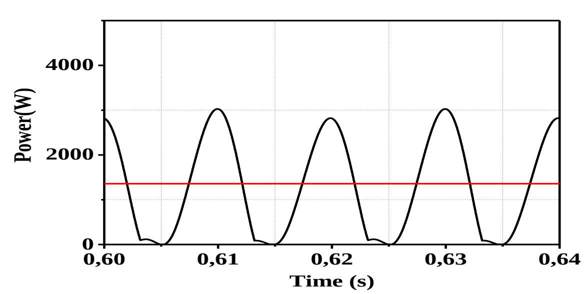

Fig. 9. Input power of the power supply

- Output power of the transformer (figure 10)

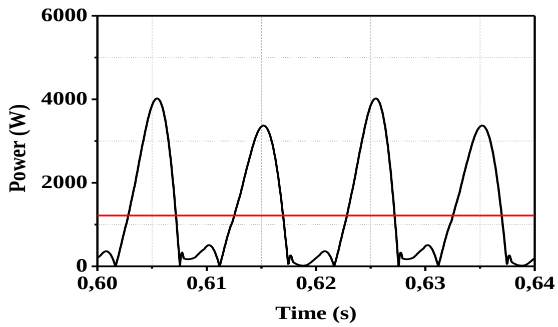

Fig. 10. Output power of the transformer

- Input anodic power of magnetron (figure 11)

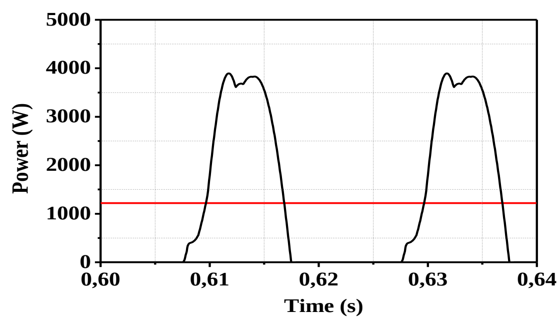

Fig. 11. Input anodic power of the magnetron

The various average powers found by simulation are then:

- 1357W in the input of the transformer from primary voltage and primary current obtained by simulation.
- 1217W in the output of the transformer, in which we must add 40 W for heating the filament of the magnetron cathode (13A under 3,15V). Thus the global output power of the transformer is 1257 W.
- 1198W across the magnetron

Thus we can deduce the performance obtained by simulation

$$\eta_{Simulation} = \frac{1198+40}{1357} = \frac{1238}{1357} = 0{,}911$$

On the other hand the transformer nameplate indicates an apparent power 1650VA with a power factor 0,825. Which corresponds to an active power at the transformer primary 1650*0,825=1361,25W. This is equal to the input power value found by the previous both methods (1360W and 1357W). This value is also confirmed by measuring the input power (1361W) using the experimental setup figure 12 indicated by reading the ferromagnetic power meter. The value of measured power found by the different described methods confirms that the mounting of the studied power supply operates under nominal conditions and the magnetron debits full microwave power.

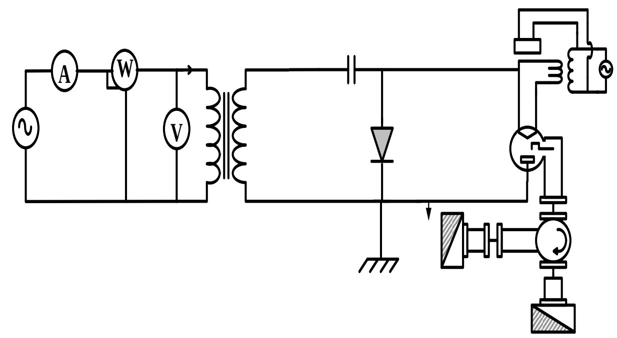

Fig. 12. Experiment setup : measuring input power

4. CONCLUSIONS

In this paper, the developed analytical study permits a comparative study of electrical operation for magnetron power supply. The obtained results under MATLAB are successfully validated with those found experimentally, this will allow to understanding the complex operating of this special transformer with shunts.
As perspective, the encouraging results of the electrical and magnetic functioning for magnetron power supply, will lead to dealing the energetic study but this time for the new three-phase power supply for single magnetron per phase.

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