

Modeling of a New High Voltage Power Supply for Microwave Generators with Three Magnetrons

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ABSTRACT

This original work treats the modeling of a new type of HV power supply with several magnetrons (treated case $N=3$ magnetrons). The design of this new power supply uses a new single-phase high voltage transformer with magnetic shunts supplying three doublers voltage cells, each one composed of a capacitor and a diode. Each cell supplies in its turn one magnetron. The π equivalent model of the transformer is developed taking account the saturation phenomena and the stabilization process of each magnetron current. The model of the transformer is based on the determination of the analytical expressions of the non linear inductances that can be stored from the fitting of the magnetization curve $B(H)$ of material used. The resulting model will be implemented under Matlab-Simulink code. The simulation results are in good agreement with the experimental measurement for one magnetron, thus provides, relative to the current device, gain of volume, weight and cost of all power supply with respecting the conditions recommended by the constructor of magnetron current: $I_{peak} < 1.2$ A, $I_{mean} \approx 300$ mA.

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1. INTRODUCTION

The new HV power supply for $N = 3$ magnetrons represented in the Figure 1 composed magnetic HV transformer supplying three cells voltage doublers and current stabilizers [19], [4], [3], [2], [17], [8]. The electrical characteristics laid down by the constructor of the magnetron [19], [16] require a special power supply. The trend toward the new power supply device with several magnetrons will therefore be a different version of the single-phase model currently used for domestic microwave ovens and industrial applications. The new device composed essentially of a single-phase transformer (Figure 1) [9], [15] supplying three identical magnetrons. The modeling of this new generation of power supply for several magnetrons necessarily passes by the modeling and the dimensioning of its own new HV transformer with magnetic shunts. This later ensures the stabilization of the current in each magnetron. Contrairely to conventional transformers, the leakage flux in the shunt is of the same order of magnitude that the primary and the secondary fluxes.

From the modeling [21], [7], [11] and the knowledge of the nominal operation of the current HV power supply for a magnetron 800 Watts-2450 MHz, this paper fits into the development of a new generation of HV transformer supplying $N = 3$ magnetrons. That will have multiple advantages as regards the reduction of weight, volume, electrical wiring, and thus the cost of realization and maintenance of the total device. Our

interest in this work is firstly, to develop a new model of the transformer supplying $N=3$ magnetrons. And secondly to verify the regulation process of the voltage and the magnetron current.

This work is organized as follows: Firstly, we will establish the π model representative of the transformer with $N = 3$ magnetrons. Its saturable inductances are able to translate the nonlinear saturation phenomena. Each one of them in this model is characterized by the nonlinear relation between current and flux. The determination of characteristics is directly obtained from the geometric parameters and the magnetic circuit quality represented by the magnetization curve $B(H)$.

Secondly, we will implement and validate this model of transformer with magnetic shunts under Matlab-Simulink code. This tool has allowed us to introduce an unlimited number of points of the magnetization curve $B(H)$. After that, we will present the simulated curves of voltages and currents obtained by Matlab-Simulink of this new power supply with $N = 3$ magnetrons.

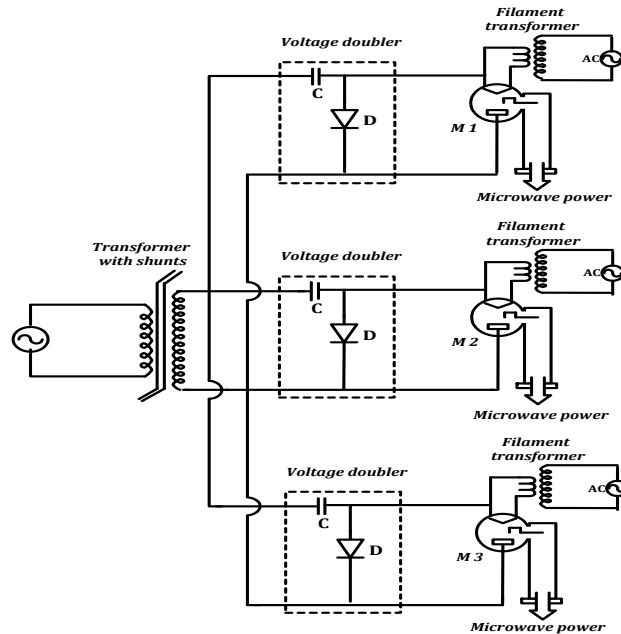


Figure 1. New HV power supply for microwave generator with $N=3$ magnetrons

2. MODELING OF THE NEW HV POWER SUPPLY OF MICROWAVE GENERATOR WITH $N=3$ MAGNETRONS

The modeling [19], [5], [10], [1], [18], [13], [14], [6], [12] of the HV power supply for three magnetrons 800 Watts-2450 MHz, leads essentially to the modeling of its special HV transformer with magnetic shunts. This transformer ensures the stabilization of the average anodic current in each magnetron. It is suitable for modeling the whole by a powerful tool for the numerical calculation of Matlab-Simulink.

The equivalent diagram must translate the behavior of the whole, including the three magnetrons and the transformer cannot be separated from the external circuits. The analytical processing is too complex, the solution, thus can be only numeric using suitable software (Matlab-Simulink).

The Figure 2 shows the integration of the model of the new transformer in the circuit of the new HV power supply from the source to the magnetrons.

Each inductance of this model is a function of the reluctance of the portion of the magnetic circuit that it represents. The simulation by Matlab-Simulink, in non linear regime related to the saturation of magnetic circuits, is possible. Then each non linear inductive element is represented by its characteristic, depending on the relation:

$$n_2 * \Phi = n_2 * B * S$$

$$i = (H * \ell) / n_2$$

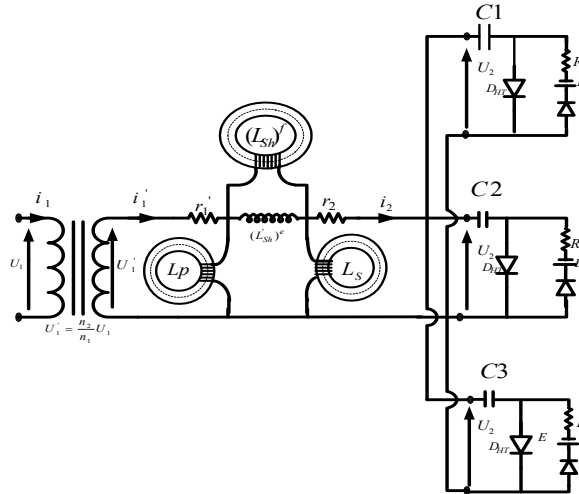


Figure 2. Equivalent circuit of new power supply for N = 3 magnetrons

Under matlab-Simulink each inductance is represented by a block diagram (Figure 3) and its elements are the following:

1. An integrator allows us to deduced the flux from the voltage.
2. A function called Lookkup table: this is a block which the input-output relation is defined by the user. In the dialog box, which is created when you click on the icon of the LUT. It determines point by point the relation input-output of the couple values (i, Φ) deduced from those (H, B) and the geometrical data for the three inductances.
3. An imposed current source.

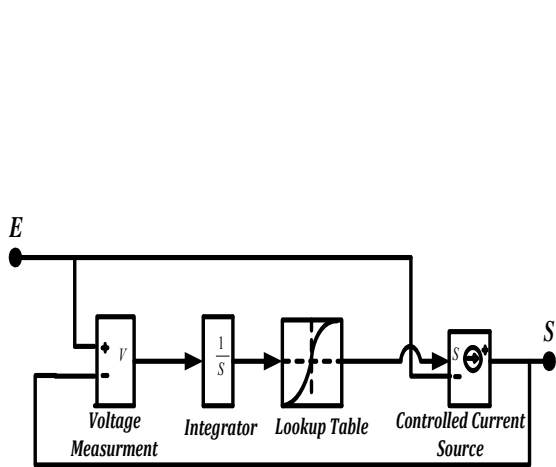


Figure 3. Block Diagram of a non-linear inductance under Matlab-Simulink

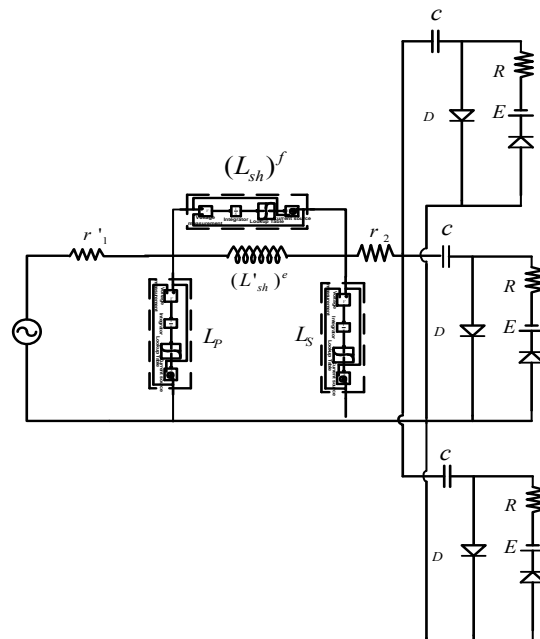


Figure 4. Circuit of the new HV power supply for N = 3 magnetrons simulated using Matlab-Simulink code in nominal mode (non-linear regime)

Thus, the Figure 4 shows the overall scheme of the HV power supply for three magnetrons simulated, using the software Matlab-Simulink.

We validate this model by comparing the results of simulations with those obtained from the tests already made [19], [21] on a generator microwave composed of the following elements:

1. A HV transformer with magnetic shunts characterized by: $f=50$ Hz, $S=1650$ VA, $U_1=220$ V, and $U_2=2330$ V (resistance of the primary referred to the secondary $r'_1=100\Omega$, secondary resistance $r_2=65\Omega$, number of primary turns: $n_1=224$, and number of turns in the secondary $n_2 = 2400$).
2. Three voltage doublers which each one is composed of a condenser with a capacity $C=0.9 \mu\text{F}$ and a high voltage diode DHT.
3. Three identical magnetrons which each one is designed to operate under voltage about 4000V. For its nominal power, it needs an average intensity $I_{\text{means}}=300\text{mA}$, but without exceeding the peak current may destroy it ($I_{\text{peak}}<1.2$ A).

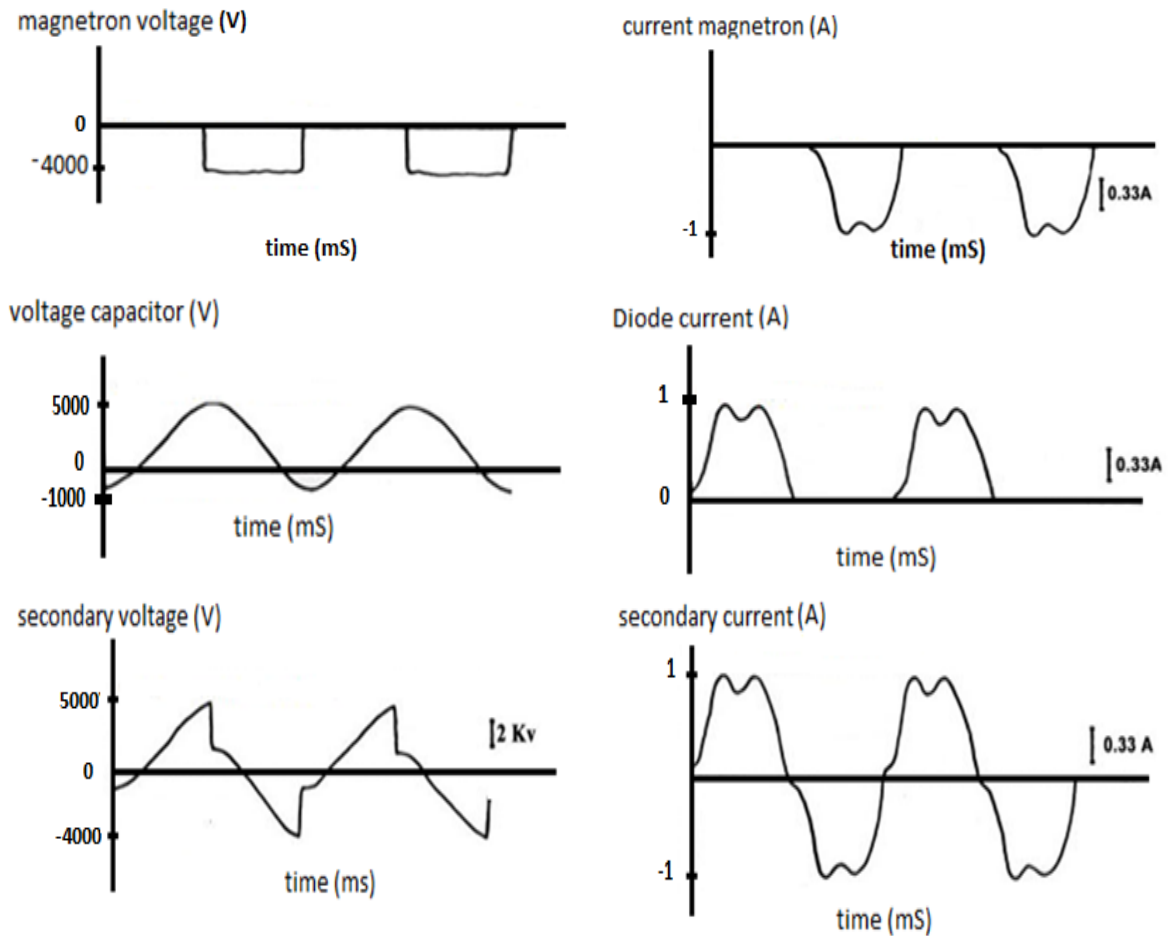


Figure 5. Experimental waveforms of currents and voltages for HV power supply with one magnetron(nominal mode)

The Figures 5 and 6 respectively present the resulting obtained in practice and those from simulation of the device by Matlab-Simulink together are in a better accordance. The peak current magnetron obtained by Matlab-Simulink (-0.96A) remains close -1A [9], [19]; after practical results. Indeed, from peak to peak value, the relative differences never exceed 6%. The simulation was satisfactory by Matlab-Simulink.

3. VERIFICATION OF PROCESS REGULATION OF VOLTAGE AND CURRENT MAGNETRON

During the simulation of the model using Matlab-Simulink, we were able to observe the stability of the variation of the magnetron current compared to the variation of the voltage. The following figures show the waveform of the magnetron current in case 200V and 240V ($\pm 10\%$) of the rated voltage. We find that the maximum amplitude of the current is not exceeded the permissible value recommended by the constructor

($I_{max} = 1.2A$). We can say that with this model, the stabilization of the magnetron current is completely recovered.

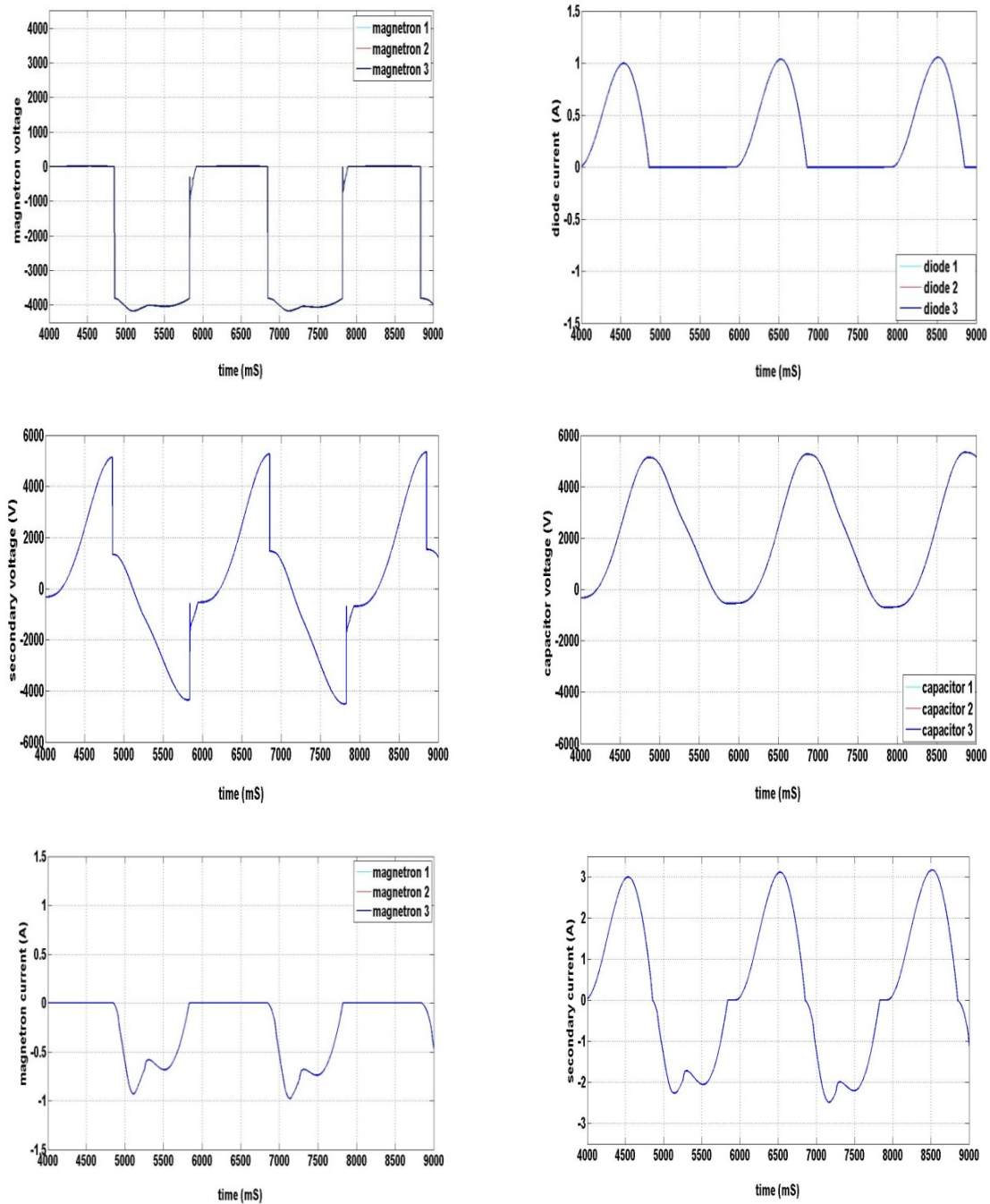


Figure 6. Simulation with Matlab-Simulink code: waveforms of voltages and currents of this new HV with N=3 magnetrons (nominal mode)

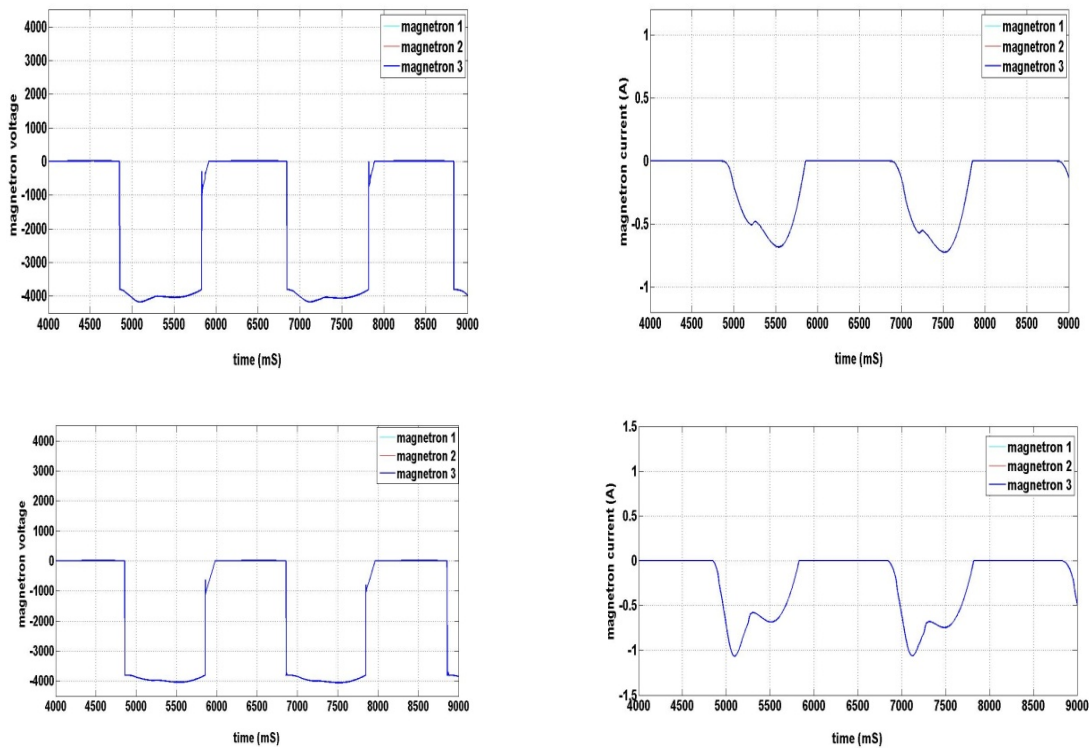


Figure 7. The stabilization of the anode current of the magnetron with respect to variations of supply voltage ($\pm 10\%$) of the rated voltage

4. CONCLUSION

The validation of the π model equivalent of the new HV transformer with magnetic shunts for $N=3$ magnetrons under Matlab-Simulink code in nominal mode is conclusive. The three magnetrons can operate without any problem of interaction between them. This new type of power supply can deliver up to $3 \times 800 = 2400$ Watts useful at 2450 MHz after his own adequately sized transformer with magnetic shunts.

The observations made using Matlab-Simulink code show an excellent agreement between the simulated and the experimental tests. This code has confirmed the validity of the model in the non linear mode. On the other hand, the failure of one of the three magnetrons doesn't affect the operation of the remaining magnetrons.

The future work will treat the possibility of functioning of HV single-phase power supply for $N > 3$ magnetrons which each one can deliver in nominal scale 800 Wts at 2450 MHz. On the other hand, we will treat the optimisation of this new system.

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