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Modeling of New Three-phase High Voltage Power Supply for Industrial Microwave Generators with One Magnetron Per Phase

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ABSTRACT

This original work treats the feasibility study of a new HV power supply with a three-phase character, supplying a magnetron 800 Watts-2450 MHz per phase, for industrial microwave generators from the modeling with the EMTP code of a single-phase HV power supply for one magnetron. The exploitation of the modeling, with EMTP code, of the power system for one magnetron is to use, essentially, the developed model of its transformer, which is a π quadruple, consisting of saturable inductances able to translate the non-linear phenomena of saturation, while guaranteeing the stabilization process of the magnetron current. Using the new power supply device with a three-phase character and the EMTP code, the feasibility study, in nominal mode, of the three-phase power supply was performed satisfactory. The analysis of the results obtained helped to confirm the possibility of functioning of this new system without interaction between magnetrons, which provides, relative to the current device, gains of size, volume, cost of implementation and maintenance and makes this new system more economical, while guaranteeing the regulation process of the current in each magnetron.

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1. INTRODUCTION

Nowadays, to supply one magnetron, the current single-phase power supply of the tube microwave generator uses a HV transformer with magnetic shunts by magnetron [1]-[11]. To contribute to the development of the technological innovation in the manufacturing industry of the power supply for magnetrons of microwave ovens for domestic or industrial use, this work is part of the development of a new type of HV power supply with a three-phase character for microwave generators with several magnetrons. This has multiple benefits in terms of reducing weight, volume, electrical wiring and cost during the implementation and maintenance of such a new device.

The tendency towards the new device of power supply will be considered a different version of the single-phase model currently manufactured at the manufacturers of domestic or industrial microwave ovens,. It may comprise either a single-phase [12]-[15], three-phase (Figure 1) or six-phase transformer supplying several magnetrons per phase and not the present case a single-phase transformer by magnetron.

The modeling of this new generation of power supply for magnetrons passes obligatory by the modeling and the dimensioning of its new own HV transformer with shunts.

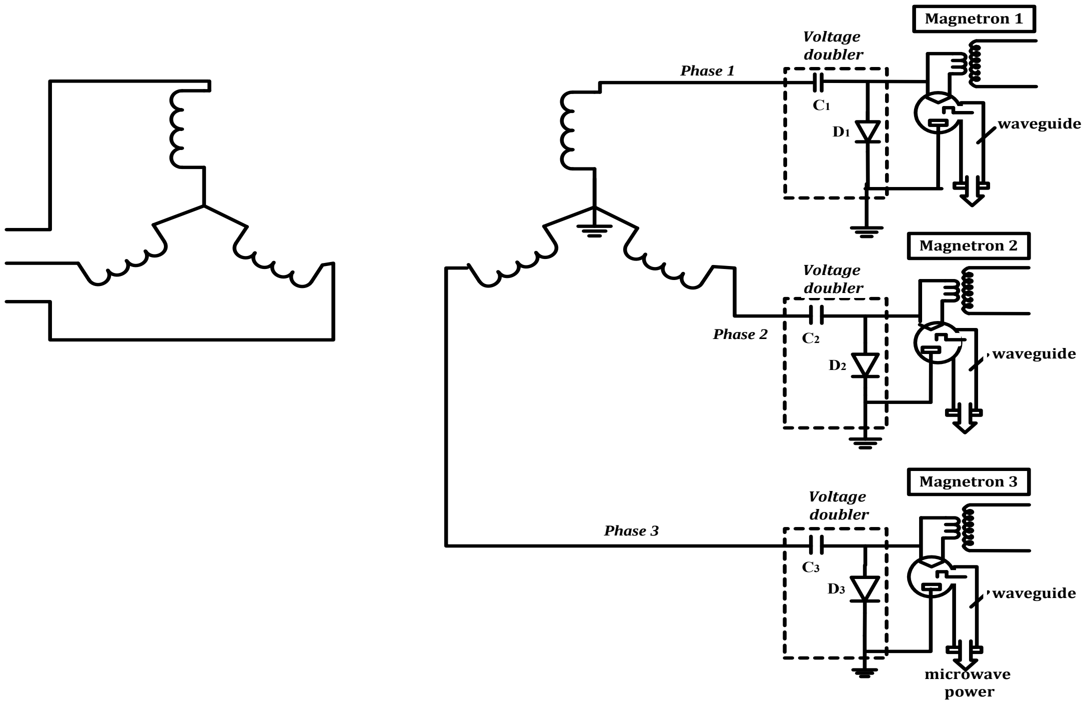

Figure 1. Three-phase power supply for magnetron by phase (Amperex Type)

Our objective in this paper is on the one hand; to treat the modeling of the single-phase power supply currently designed to supply normally, in nominal mode, one magnetron which is from Moulinex mark. On the other hand, basing on this power supply, to treat the feasibility study of a new type of HV power supply with three-phase character for a magnetron per phase (N=1). The paper is organized as follows:

Firstly, we discuss the modeling of the single-phase power supply currently used in the microwave generators with N = 1 magnetron. The modeling with EMTP of this power supply uses the model, developed by Mr. Chraygane, of its transformer which is a π quadruple. The results will be compared with those obtained experimentally.

Secondly, before developing the real modeling of the three-phase HV power system for N=1 magnetrons per phase (Figure 1), we found it useful to treat, previously, the feasibility study of the nominal operating of a new HV power supply with three-phase character for one magnetron per phase (N=1), from the modeling with EMTP (ElectroMagnetic Transients Program) [16]-[26] of a single-phase HV power supply for a magnetron.

Thirdly, we treat the possibility of the functioning of this new system in case of breakdown of one or two magnetrons, which provides relative to the current device gains of size, volume, cost of implementation and maintenance and makes this new system more economical while guaranteeing the process of regulating the current in each magnetron.

2. MODELING OF THE CURRENT POWER SUPPLY FOR ONE MAGNETRON

The modeling already developed [1]-[11] of a single-phase HV power supply for one magnetron 800Watts-2450 MHz (Figure 2) is to model essentially the special HV transformer with magnetic leakage which ensures the stabilization of the means anodic current in the magnetron.

The equivalent model of the selected transformer will be integrated into the overall scheme of power supply to be adapted to the modeling of the whole system with EMTP [16]-[26] which able to take into account the geometry and the non linear magnetic properties of materials.

The equivalent circuit should translate the behaviour of the whole power including the magnetron and the transformer with shunts. The simultaneous solution of the electric and magnetic equations of the whole system is too complex and the solution can be only digital (EMTP) that analytical, with the possibility to study the choice of materials and dimensions of the transformer with possible optimization. In addition, the EMTP has the benefit of considering the non-linearity in the system by accepting the data relating to the saturable inductance and the global used model operates this facility, which allows as well making account the stabilizing effect of this power.

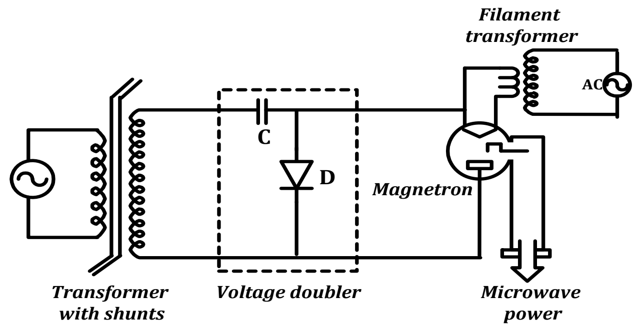

Figure 2. Current power supply for one magnetron (Amperex technology)

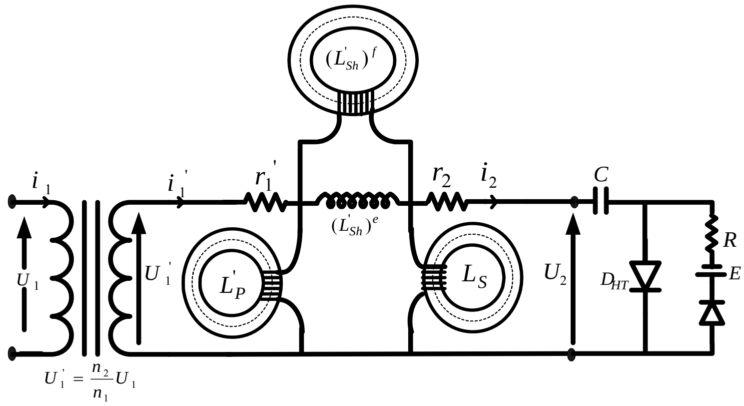

Figure 3. Π quadruple model of the transformer leakage referred to secondary

The figure 3 shows the incorporation of the π equivalent circuit of the transformer in the power supply resulting from the electric and magnetic equations of its operation. The advantage of this model is in its single-phase equivalent circuit referred to the secondary, which seems more comfortable to study the operation of the transformer with EMTP. This model is called natural because each inductance, with iron core, is based on the reluctance, therefore the permeability of a very specific part of the magnetic circuit supposed fictitiously closed on which are coiled n_2 turns (secondary). The immediate relevance of this model is to assign at each inductance a nonlinear relation "flow-current" of the form from the geometric parameters of a specific portion of the magnetic circuit, allowing translating its real operation in nonlinear mode.

To perform this modeling [1]-[4] we have sought to integrate the model of the transformer in the power circuit from the source to the magnetron (Figure 3), where we represented the microwave tube by its equivalent circuit deduced from its electrical characteristic that is formally similar to that of a diode with dynamic resistance of 350Ohms and threshold voltage E≈3800 volts.

The elements of the model, in particular nonlinear inductances, were determined from the magnetic characteristics of plates and the geometrical dimensions of the transformer. Each element of a saturable portion of the magnetic circuit, of section S and of medium length l, is represented by its inductance $\mathbf{L(i)=n_2\Phi(i)/i}$ where the quantity $\mathbf{n_2\Phi(i)}$and its corresponding current$\boldsymbol{i}$ can be determined from the curve B(H) of the material used and the geometrical elements using the relations:

$n_2 * \Phi = n_2 * B * S \ \& \ i = (H * \ell)/n_2$

To validate this model, we have carried out tests on a microwave generator 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 =100Ω, secondary resistance r_2=65Ω, number of primary turns: n_1=224, number of turns in the secondary n = 2400).
2) A condenser with a capacity C=0, 9 μF and a high voltage diode DHT.
3) A magnetron designed to function under an approximately voltage ≈4000 V.

To obtain its nominal power, it needs an average intensity I_{mean}≈300 mA, but without exceeding the peak value of its current (I_{peak}<1,2 A). In addition, the data from the manufacturer made it possible to extract the values E=3800V and R = 350Ω.

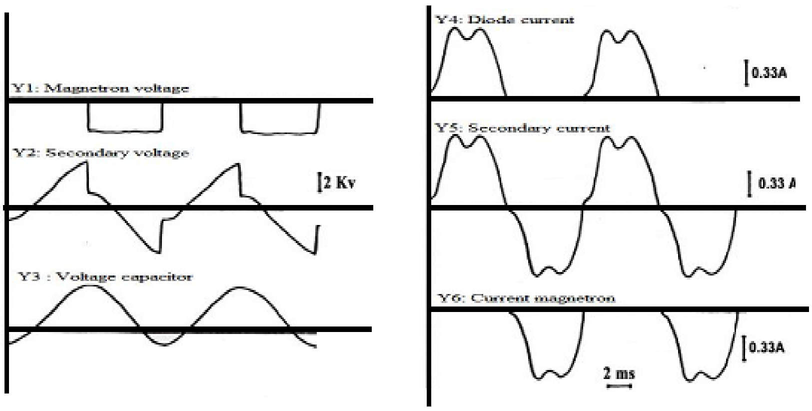

Figure 4(a). Concordance of the experimental waveforms of currents and voltages (nominal mode)

The Figure 4(a) and 4(b) show that in nominal operation (U_1=220 V and f= 50Hz) the results of the simulation by EMTP of the device, in non linear regime, are in concordance with the forms of the experimental waves observed in these same conditions. Indeed, between values peak to peak, the relative differences will never exceed 4%.

3. MODELING OF THE POWER SYSTEM WITH THREE-PHASE CHARACTER FOR ONE MAGNETRON PER PHASE

The three-phase transformer must be considered as the assembly of three single-phase transformers. Each column represents a transformer having n_1 turns in primary and n_2 turns in secondary (Appendix). So to achieve this type of the transformer, we can associate three single-phase transformers (Figure 5).

All three transformers can be combined in order to create a single central column (Figure 6). Consequently, everything that was said about the single-phase transformer is applied to each phase of the three phase transformer.

The feasibility study of the operating, in nominal mode, of this new system (Figure 7) was undertaken. It is to highlight if it is possible to supply several magnetrons per phase (case treated: a magnetron per phase), using the single-phase model of the HV power supply for a single magnetron 800Watts-2450MHz.

The three-phase HV transformer, not yet so far modeled or made, is represented by three identical models of a power supply for a magnetron connected in a star and supplied respectively by three-phase voltages dephasing by 2π/3 between them. The output of each model supplies, per phase, its own cell voltage doubler and voltage stabilizer, composed of a capacitor and a diode which in turn supplies a single magnetron.

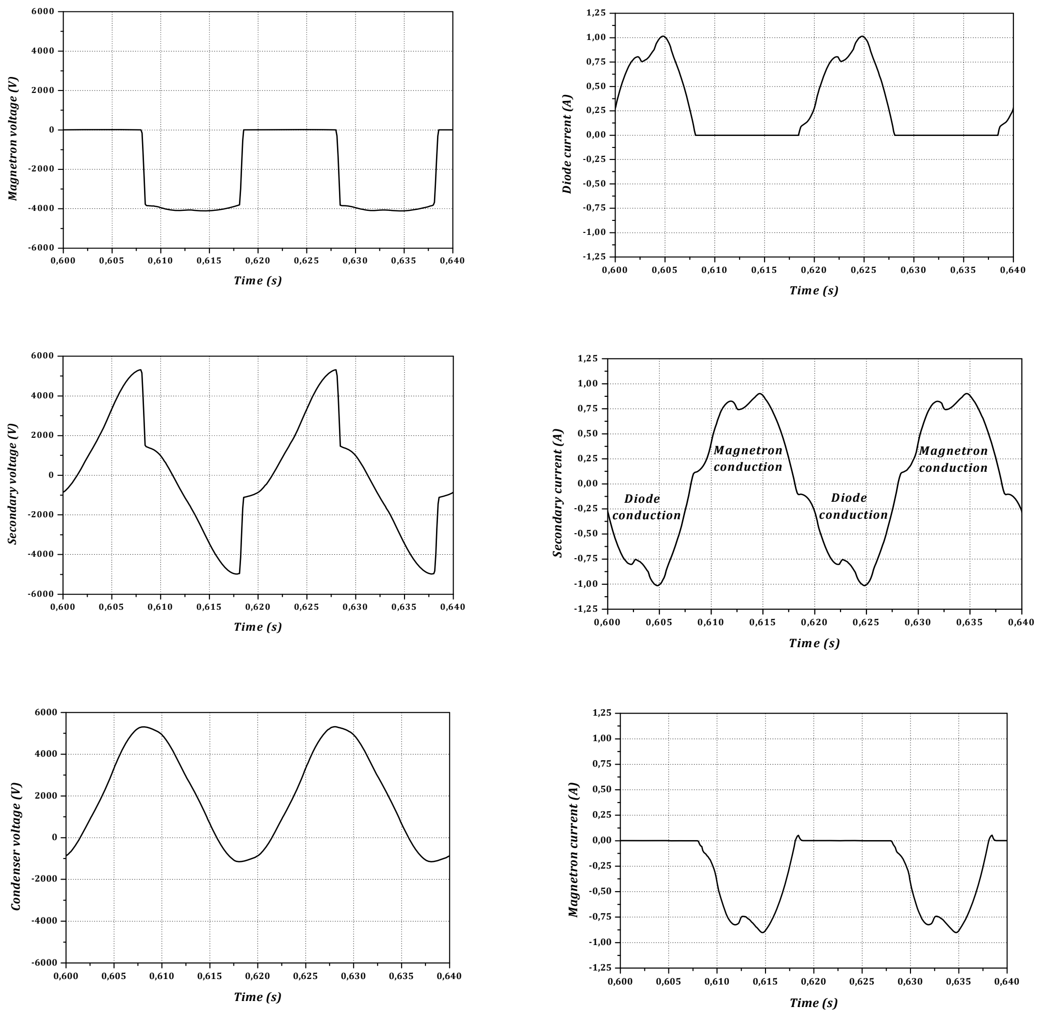

Figure 4(b). Concordance of the theoretical waveforms of currents and voltages (nominal mode)

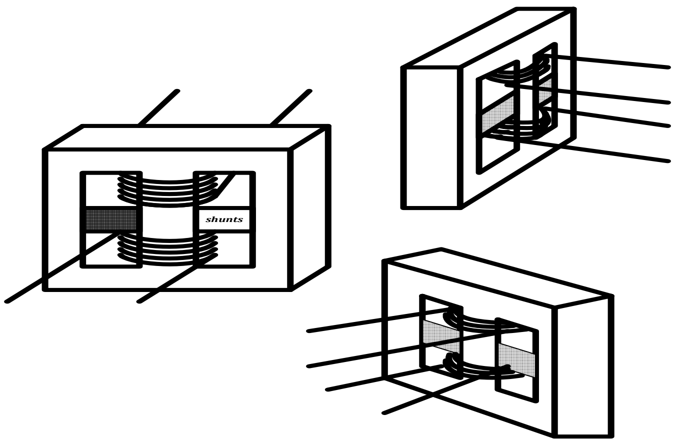

Figure 5. Equivalent circuit of three-phase transformers with magnetic shunts

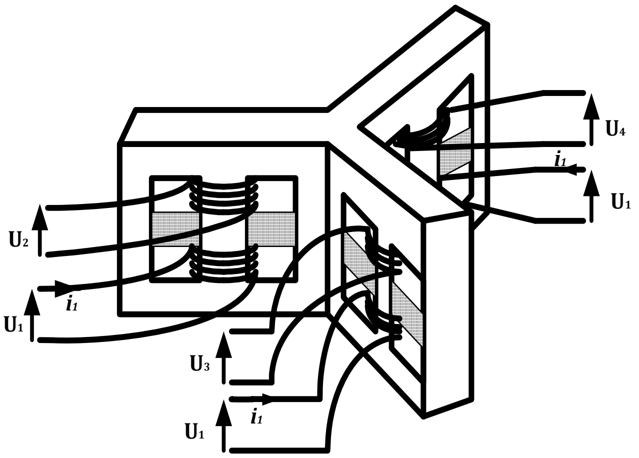

Figure 6. Block diagram of the three-phase HV transformer

The assembly in Figure 7 was simulated to account for the operation of three-phase power supply for microwave generator with a single magnetron per phase can each deliver under 220 volts the full power 800 Watts useful at 2450MHz. Each of the three identical models corresponds to that of a single phase power supply designed currently to power normally one magnetron which is, remember, of Moulinex brand having on the nameplate the characteristics 220/2200V, 50Hz, 1650 VA.

By supplying the primary, connected in star, of the new studied power system (Figure7), under the nominal voltage 220V/380V 50 Hz, the simulations with EMTP have helped to raise the temporal waveforms of voltages and currents (Figure 8).

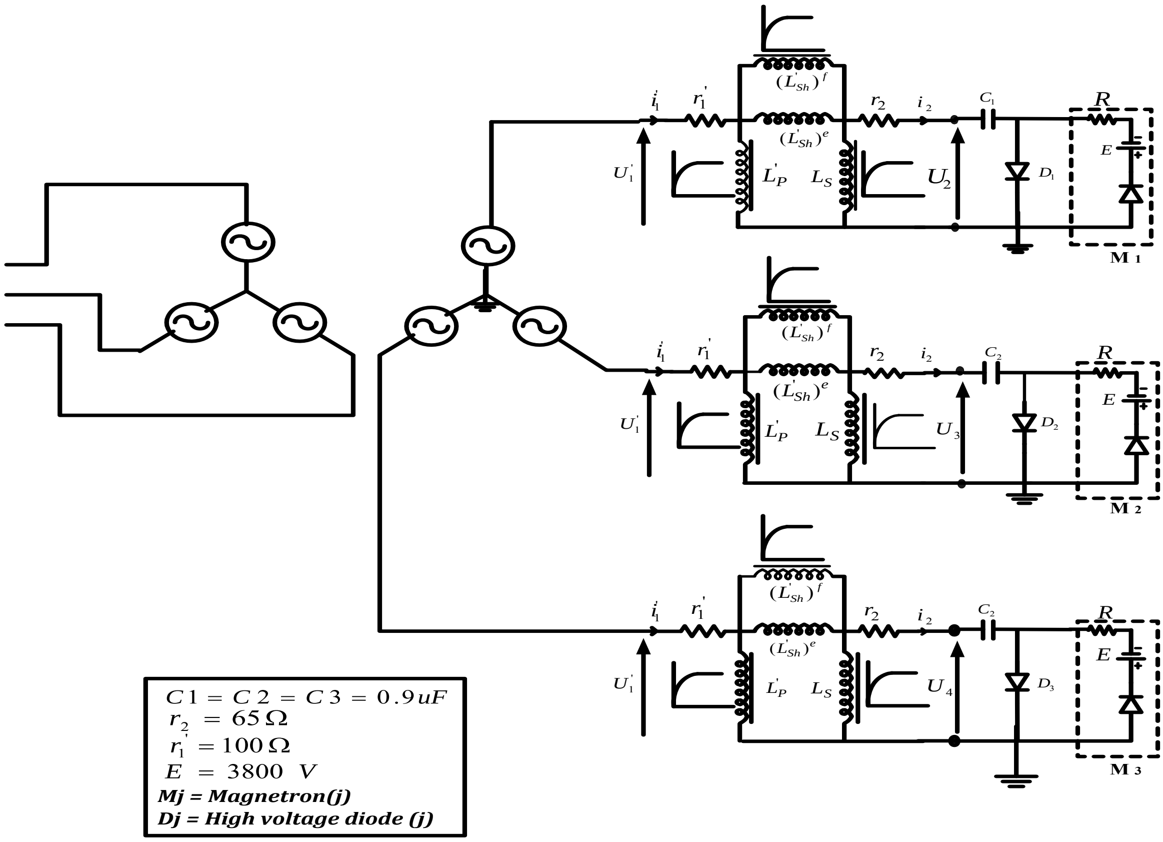

Figure 7. Three-phase assembly diagram simulated with EMTP (a magnetron per phase)

In the first remark, we note that the obtained electrical signals (currents in the diodes (D_1, D_2, D_3), current in magnetrons (M_1, M_2, M_3) current in the capacitors (C_1, C_2, C_3), tension (U_2, U_3, U_4) across the secondary of the model of the transformer and the voltages across each magnetron (M_1, M_2, M_3)) are curves of various sizes and non-sinusoidal periodic dephasing of 120 degrees between them.These signals have same form as those of a conventional power supply with a single transformer by magnetron. The dephasing of 120 degrees between them confirms the absence of interaction between magnetrons. The points of operation of these magnetrons are therefore no longer disrupted, which crucial for a stabilized power supply in current. Moreover, the failure of any magnetron does not affect the operation of magnetrons remaining. Just replace the magnetron off by a magnetron nine.

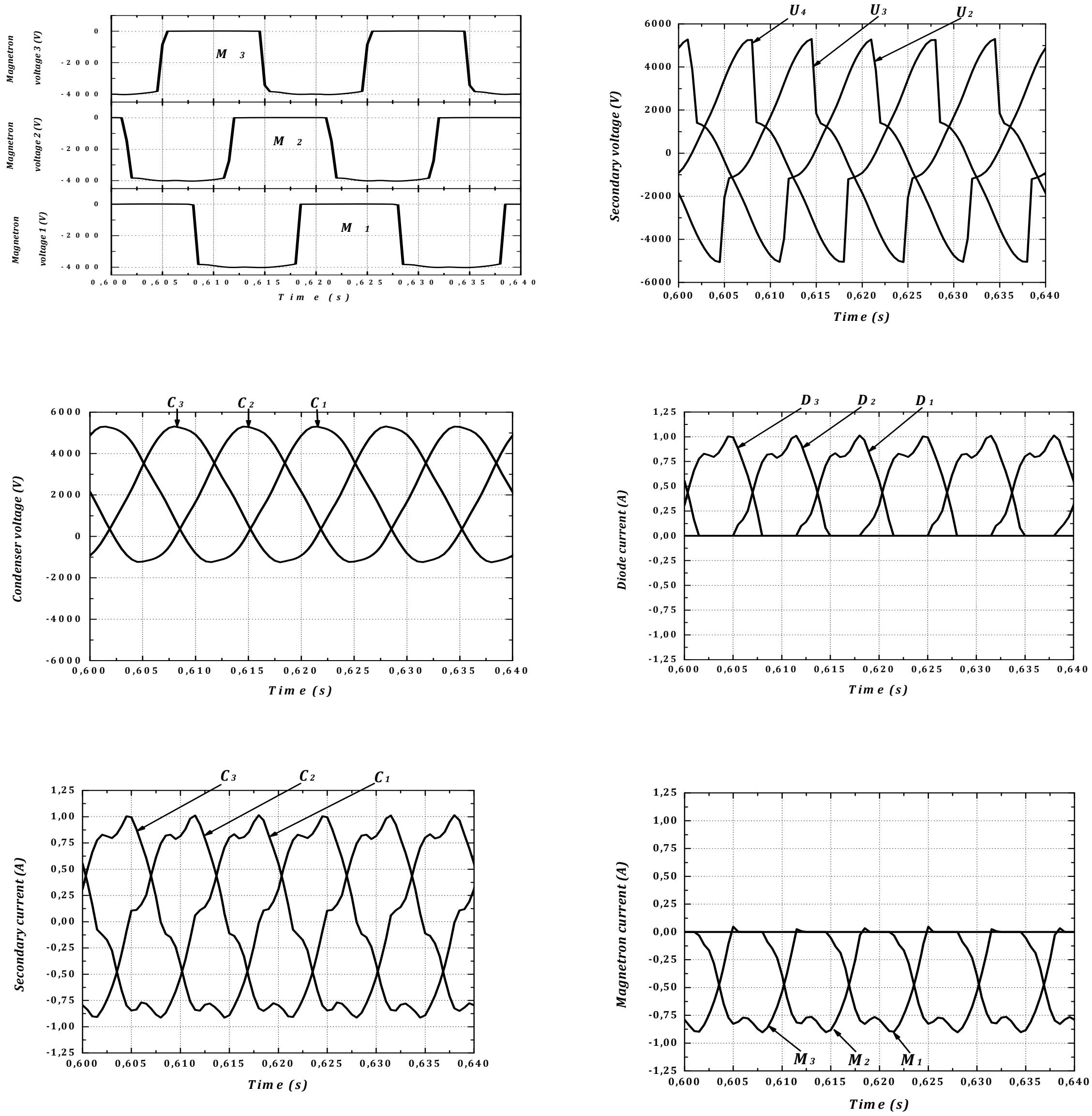

Figure 8. Simulation results of the new power system

4. CONCLUSION

The feasibility test of the operation at the nominal mode of the new power system with three-phase character for a magnetron by phase is conclusive. It can be extended without any problem to the case of the operation of the power supply for N magnetrons by phase in nominal scale. On the other hand, the failure of M from N magnetrons (M≤N) powered does not change the functioning of the (N-M) remaining magnetrons.

The positive feasibility study of the new three-phase power supply with three-phase character for one magnetron by phase will certainly encourage us to undertake the real study of the true three-phase power supply for several magnetrons per phase by modeling and dimensioning properly of its own three-phase transformer with shunts, which will probably help reduce the size, volume, weight and electrical wiring and therefore guarantee a lower cost of implementation and maintenance of microwave generators.

As perspectives, this work can be also performed in a similar manner to the case of the same type of HV power supply with three-phase or six-phase character for several magnetrons by phase of useful power everyone 1000 Watts or 1200 Watts-2450 Mhz. What contributes the development of the effective modeling of the new three-phase or six-phase power systems for several magnetrons 800 Watts, 1000 Watts or 1200 Watts at 2450 MHz for microwave generators using in industrial applications.

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