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COMPARATIVE STUDY AT VERY HIGH FREQUENCY BETWEEN THE TRADITIONAL DC/DC POWER CONVERTERS AND THE RESONANT CONVERTERS

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ABSTRACT
The study is to confront the results of experimental tests performed on a classical DC/DC power converter (Forward type) to results obtained with a DC/DC series resonance converter at high frequencies.

This comparative study concerns mainly the dynamic behavior, the static behavior, the energy efficiency, the echauffement of components and the quality of output voltages. This comparison allowed to highlight the deficiencies that remain to be filled by the classical power converters (hard-switching) to compete the resonant converters (soft-switching) at very high frequencies.

INTRODUCTION
The Using of the resonance principle has allowed to make a breakthrough in the DC power supplies. Advanced mainly due to the soft-switching in the switches it uses. This has contributed to the emergence of new generations of power supplies reaching very high operating frequencies never achieved before.

In this context, the classical switching power supplies (hard-switching) are increasingly excluded in favor of resonance power supplies at high frequencies. But now, there is a new situation which can, in turn, reverse the tendency of the balance. This is the breakthrough in the technology of the magnetic and electronic components. Technologies that achieve very high frequencies with better switching conditions. This is precisely what we are trying to prove through this work by comparing, at high frequencies, the experimental results of a resonant power supply and a classical switching power supply using this new generation of components.

This experimental comparison will concern, initially, the dynamic behavior, the static behavior, the energy efficiency and the heating of components. Hoping that this work can be followed and supplemented by a similar study on output voltages ripples (residuals) and the EMC compliance.

PRESENTATION OF THE FIRST PROTOTYPE
This is a resonance prototype made according to the schematic diagram of figure 1.

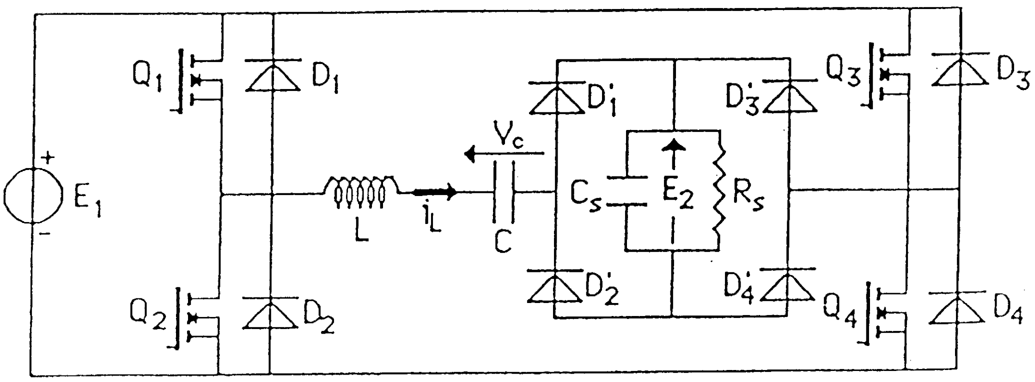

Figure 1: Schematic diagram of the resonant converter

The basis of our comparative study is an indirect converter with series resonance. The input voltage is 48V DC converted into AC by four bidirectional current switches. This AC signal is then reconverted by a Diodes Bridge into DC signal: 12V/20A. The level of the output voltage is adjustable by the control frequency of the switches of the inverter. Indeed, the setting of this frequency will allow to move away from the resonant frequency for which we have a maximum power transmitted at the load: hence the setting of the power transmitted to the load and the output voltage. The adjusting of this voltage will then be done by the frequency; and that's precisely the inconvenience we are trying to avoid by use of classical switching power supplies that works at fixed frequency (the voltage adjust is done by acting on the duty cycle).

As regards the inverter, we chose switches constituted of transistors and diodes in anti-parallel to be able to make experimental tests below and above the resonant frequency (capacitive or inductive behavior).

The soft-switching of the switches used in the resonant converters is the highlight of the latter. This switching is indeed very beneficial effects on the energy efficiency, the heating of components and the quality of voltages and currents even at high frequencies.

PRESENTATION OF THE SECOND PROTOTYPE

As previously announced, the second prototype is designed to challenge the resonant prototype at very high frequencies (2,6MHz). So, this is a DC/DC power converter with classical switching (Figure2) having the same characteristics as the resonant converter presented before: input 48V DC and output 12V/20A DC.

The greatest care has been given to the choice of the converter structure, the magnetic components and the electronic components. At high frequencies, these components are the main limit of classical switching converters. It was therefore necessary to make several simulations and preliminary tests before making the appropriate choices. It is the same for the control circuit of the electronic switch which also is of great importance.

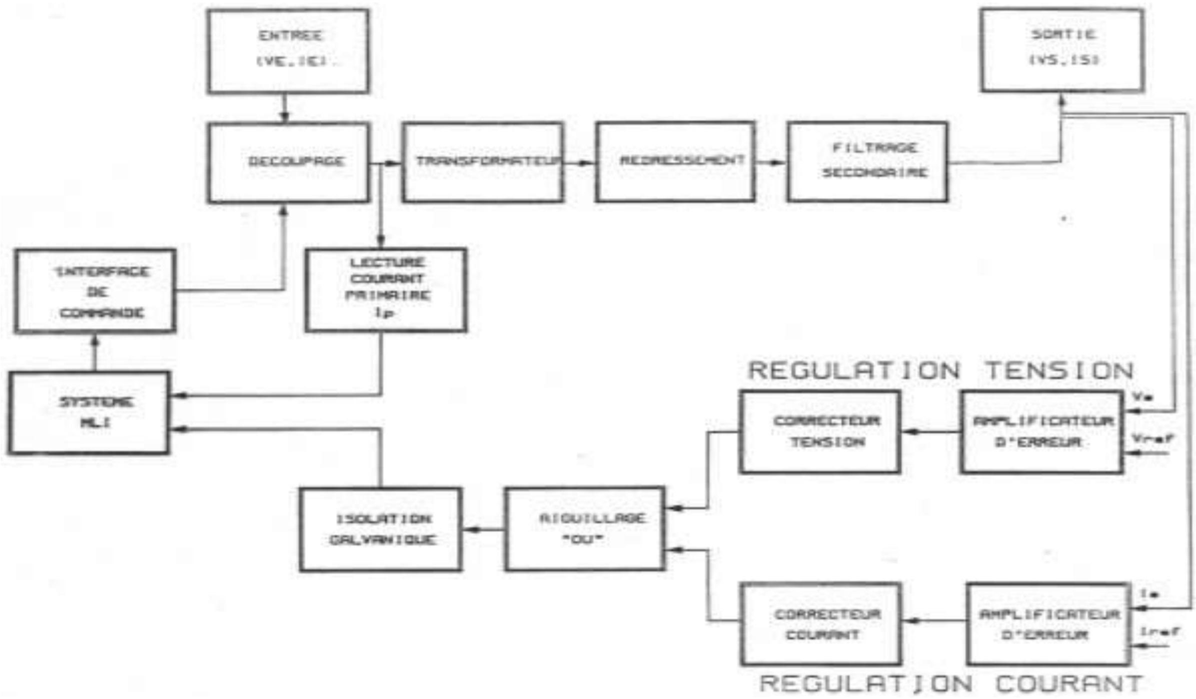

Figure 2: Schematic diagram of classical switching converter

It should be noted here that the solutions chosen for the classical prototype were often more expensive than the resonance prototype and demanded more care and more time in the design phase and the implantation phase.

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COMPARISON OF STATIC BEHAVIOR

We began the confrontation of the 2 prototypes by comparing the static behaviors of the resonant converter and classical switching converter. For this, we measure in control voltage mode, the output voltage Vs of each converter when the input voltage Ve varies. Then we do the same thing when it is the output current Is that varies.

Classical switching converter						Resonant converter					
Ve(V)	30	40	48	52	60	Ve(V)	30	40	48	52	60
Vs(V)	12.00	11,98	12.00	12.01	12.03	Vs(V)	11.70	11,97	12.00	12.02	12.10

Classical switching converter						Resonant converter					
Is(A)	0	2	7	13	16	Is(A)	0	2	7	13	16
Vs(V)	11,88	11,95	11,97	12,00	12,00	Vs(V)	11,17	11,70	11,90	11,98	12,00

From these measurements, we can note that the results are better for the classical switching converter. In effect, the output voltage of the latter is less affected by the variations of the input voltage and the variations of the output current.

COMPARISON OF DYNAMIC BEHAVIOR

The static test was followed by a comparison of the dynamic behavior of the two converters. Indeed we measured the replies to a voltage echelon and the replies to a pulsed current with severe spikes.

In the first test, we pass the input voltage Ve instantaneously, at startup, from 0 to 48V and we measure the output voltage Vs with a slow scrolling memory oscilloscope (figure3a and figure3b).

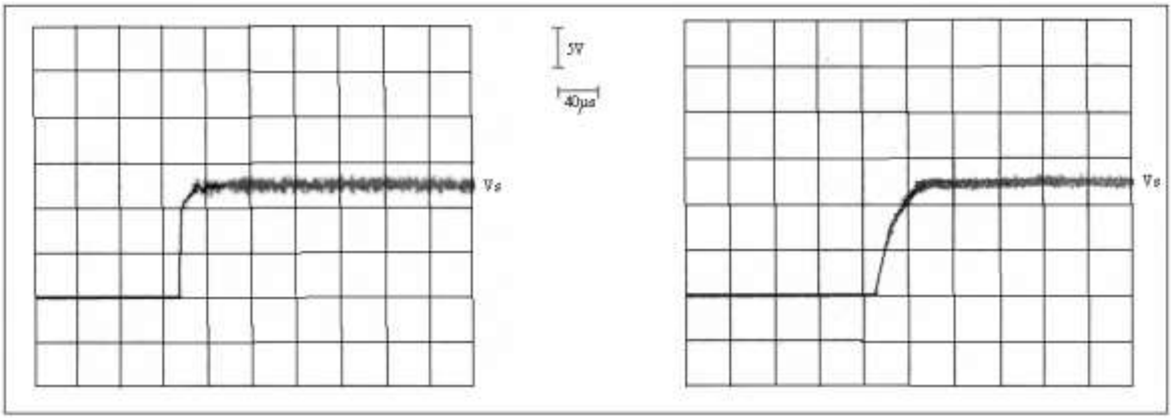

Figure 3a: Classical converter *Figure 3b: Resonant converter*

We can see that the two prototypes are responding very well to a voltage echelon. The exceedances are negligible; with, however, a reaction time smaller and therefore best for the classical switching converter.

In the second test on the dynamic behavior, we put at the output of each converter a transistors load consuming a pulsed current Is with repetitive peaks that reach 20A, at a frequency of 65kHz, then we measure the output voltage Vs (Figure4a and Figure4b).

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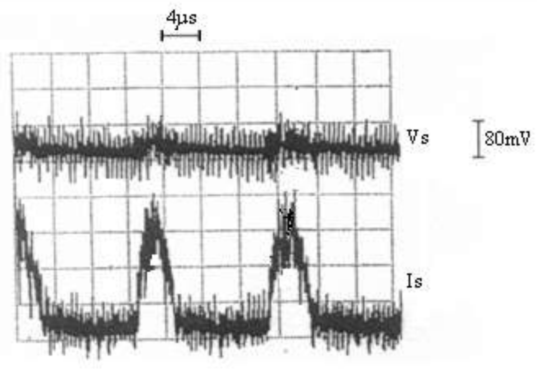

Figure 4a: Classical converter

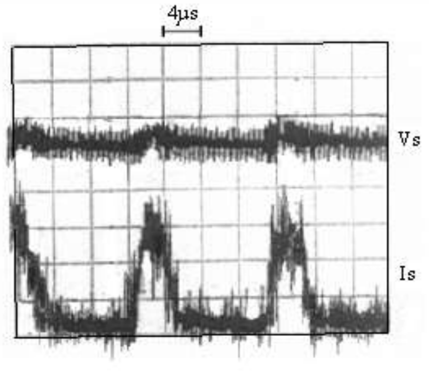

Figure 4b: Resonant converter

We find that the results are very interesting and highly similar for both converters. Indeed, despite the severe current peaks, the output voltage remains almost constant with very little variation for both.

COMPARISON OF THE ENERGY EFFICIENCY

In the fourth test of comparison, we have made an energy balance of the two converters by measuring the efficiency. This allows us, at the same time, to conclude about the power dissipation in the components and the heating of these latter. We make these measurements for different values of output current Is.

Classical converter							Résonant converter						
Efficiency (%)	87	88	88	89	90	91	Efficiency (%)	84	86	87	89	91	92
Is (A)	1	4	7	10	13	16	Is (A)	1	4	7	10	13	16

We can see that the efficiencies are satisfactory and very close for the two prototypes. It's the same thing for the power losses in the components since the heating of these latter can't be excessive when the efficiencies are high.

COMPARISON OF CONDUCTED PERTURBANCES (EMC COMPLIANCE)

To conclude, we measured with a spectrum analyzer the parasites injected to the network (conducted perturbances) by the classical switching converter to see if the CEI1210 standard, limiting the rate of parasites, is respected.

Regarding the resonant converter we know in advance, thanks to the soft switching, that these parasites are very low and meet this standard.

The result of test with the classical converter is shown in figure5.

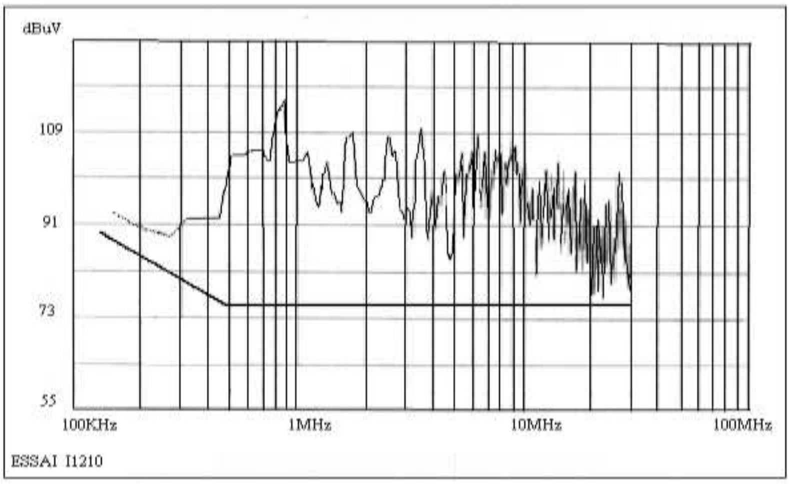

Figure5: The conducted perturbances

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As expected, the CEI1210 standard is not met. Indeed, the parasites returned to the network (conducted perturbances) by the classical converter are well above the limit. Unlike the resonant converter that largely meets this standard.

CONCLUSION

In summary, to comment these test results, we will say that, except for the test on the conducted perturbances (EMC compliance), the results obtained with the classical switching converter are best, or at worst, close to those obtained with the resonant converter. This supports the thesis that we are trying to defend through this work.

In conclusion to this study, we can confirm that the exclusivity dedicated to the resonance at high frequencies is not a matter already ruled. Indeed, these preliminary results should incite us to do more researches in this direction. Because with the progress achieved in the magnetic and electronic components well as the technology progress in the control strategy of the switches, the classical switching converters can resurface and compete with the resonance even at very high frequencies.

Thus, our future goal would be to make a similar comparative study focusing this time on new and interesting aspects of confrontation; namely the quality of the output signal, the output voltage ripples (residuals) and the conducted perturbances by equipping this classical switching converter with deworming filters and by improving the current prototype.

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