

Design of Resonant Inverter Input Filter

Nikolay D. Bankov¹

Abstract - A method for the design of Π -shaped input filter that supplies autonomous resonant inverters is proposed. The choice of relevant filter elements is based upon the following criteria: decreasing the amplitude of the high-frequency input inverter current; limiting the over voltage of the inverter terminals during switch-off. The results obtained are confirmed by means of computer simulation with the OrCAD PSpice.

Keywords – input filter; resonant inverter

I. INTRODUCTION

It is widely known that autonomous resonant inverters are usually supplied by a constant voltage source. This source is in fact a rectifier and an input filter for the inverter. When the control of the power takes place in the inverter, the rectifier can be uncontrollable. When the power is low (up to 5kW) the input filter is most often Π -shaped.

In this article is given a method for designing the input filter regarding the peculiarities of the work of the resonant inverter.

II. DESIGN OF THE INPUT FILTER

The input filter can be considered as consisted of two parts (Fig.1) – low-frequency (C_1) and high-frequency (L и C_2) filter.

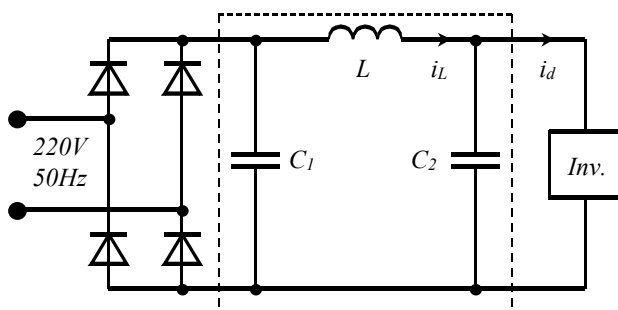


Fig. 1. Scheme of the input filter

The low-frequency filter is in fact the electrolytic capacitor C_1 . In order to dimension the capacitor we suppose that the current through the inductivity L is absolutely leveled and its value is $I_d = P/U_d$. (P – input invariable current power of the inverter; U_d – average value of the erect voltage). In this case $U_d \approx 300V$, because the input rectifier is connected directly to the single-phase network ($U=220V$; $f=50Hz$).

The waveform of the voltage of the terminals of capacitor C_1 is shown at Fig. 2. The charge of the capacitor is carried out by virtue of sinusoidal law and the discharge – by invariable current I_d .

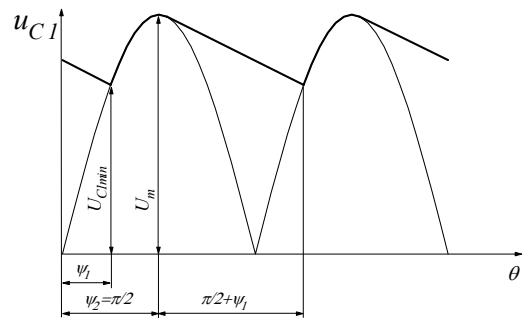


Fig. 2. Voltage of the terminals of the capacitor C_1

The leveling effect of the capacitor in accordance with [1] can be valued using the ratio U_{C1min}/U_m . U_{C1min} and is defined by the expression:

$$U_{C1min} = U_m - \frac{1}{C_1} \int_{\pi/2}^{\pi+\psi_1} I_d dt \quad (1)$$

$$= U_m - \frac{I_d}{2\pi f C_1} (\pi/2 + \psi_1)$$

where ψ_1 is angle of the firing and is equal to:

$$\psi_1 = \arcsin \frac{U_{C1min}}{U_m} \quad (2)$$

From Eqs. (1) and (2) we reach to the following expression of the capacity of the capacitor C_1 :

$$C_1 = \frac{I_d (\pi/2 + \psi_1)}{2\pi f (U_m - U_{C1min})} \quad (3)$$

$$= \frac{I_d \left(\pi/2 + \arcsin \frac{U_{C1min}}{U_m} \right)}{2\pi f U_m \left(1 - \frac{U_{C1min}}{U_m} \right)}$$

In order to set the low-frequency network apart from the high-frequency inverter, a filter, constituted of C_2 and L is used. The choice of elements of the high-frequency filter is based on the following criteria:

¹ Nikolay Dimitrov Bankov, Higher Institute of Food and Flavour Industries, 26 Maritza Blvd., 4002 Plovdiv, Bulgaria, E-mail: nikolay_bankov@yahoo.com

1. Decreasing the amplitude of the high-frequency input inverter current through the inductivity L ;
2. Limiting the over voltage of the inverter terminals when switching it off.

The input current of the inverter i_d has a constant component I_d and a variable component, whose basic frequency is equal to the doubled working frequency of the inverter - $\omega = 2 \cdot (2\pi f_{inv})$. In case that the inverter is implemented according to a single-tact scheme, the basic frequency of the variable component will be $\omega = 2\pi f_{inv}$.

Using the first harmonic approximation, we reach the following conclusion for the scheme shown on Fig.1:

$$\frac{I_{L(1)}}{I_{d(1)}} = \frac{1}{\omega C_2} = \frac{1}{\omega L - \frac{1}{\omega^2 LC_2 - 1}} \quad (4)$$

where $I_{L(1)}$ and $I_{d(1)}$ are the effective values of the first harmonics respectively to i_L and i_d .

Eq. (4) can be used to dimension the elements of the high-frequency filter in accordance with the accepted first criterion. For example if the attenuation of $I_{L(1)}$ has to be 40dB ($I_{L(1)}/I_{d(1)} = 0.01$), we reach the following conclusion:

$$\sqrt{LC_2} = \frac{10,05}{\omega} \quad (5)$$

From Eq. (5) the elements cannot be simply calculated, that's why the second criterion should be used.

The process of switch-off of the autonomous inverter is shown Fig 3. This process can start when stopping the work of the inverter, when the conditions for natural commutation in the inverter are disturbed and when operating a current protection.

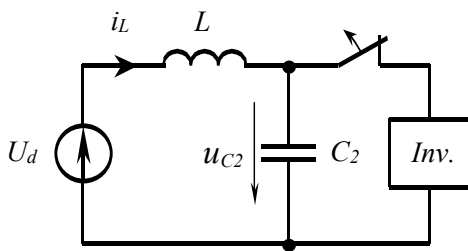


Fig. 3. Switch-off of the inverter

The combination of supply network, uncontrollable rectifier and low-frequency filter is presented as a source of a constant voltage with value U_d . The independent starting conditions of the scheme from Fig. 3 are: $i_L(0) = I_d$ and $u_C(0) = U_d$.

The process after the switch off of the inverter can be presented in the phase plane ($u_{C2}; i_L \sqrt{L/C_2}$). The trajectory of the working point is shown on Fig. 4. It, in accordance with

[2] and [3] is a circumference with center ($U_d; 0$), radius $R = I_d \sqrt{L/C_2}$ and equation:

$$(u_C - U_d)^2 + (i_L \sqrt{L/C_2})^2 = I_d^2 L/C_2 \quad (6)$$

From Fig. 4 you can see that the increase of the voltage of the capacitor C_2 over U_d is:

$$\Delta U = I_d \sqrt{L/C_2} = \kappa U_d \quad (7)$$

It is recommended to choose the coefficient κ within the range $\kappa = 0,1 \div 0,3$. It is necessary for the increase ΔU to be confined in such a way so that it is up to the requirement:

$$U_d + I_d \sqrt{L/C_2} < U_{DSM} \quad (8)$$

where U_{DSM} is the impulse voltage of the MOSFET transistors, used in the inverter.

Eq. (7) is the second criterion, on which the choice of the elements of the high-frequency filter (L и C_2) is based. Their values can be defined by solving the system of Eqs. (5) and (7).

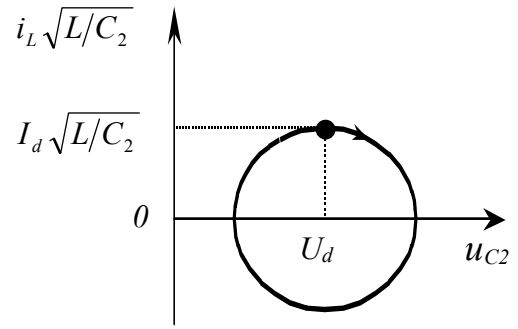


Fig. 4. Trajectory of the working point when switching the inverter off

III. EXAMPLE FOR DESIGN AND COMPUTER SIMULATION

With the help of the above-described method the input filter of ZVS resonant inverter for inductive smelt of Ni-Cr-Co alloys for the needs of dentistry is designed. The inverter's power is $P=3\text{kW}$ and its working frequency is $f = 135\text{kHz}$. We accept a ratio $(U_{C1min}/U_m) = 0,95$ and the capacity according to Eq. (3) is $C_1 = 5781\mu\text{F}$. We choose the values of the fading 40dB ($I_{L(1)}/I_{d(1)} = 0.01$) and coefficient $\kappa = 0,1$. In this case the elements of the high-frequency filter in accordance with Eqs. (5) and (7) are $L = 17,77\mu\text{H}$ and $C_2 = 1,975\mu\text{F}$.

With the help of the program OrCAD PSpice a computer simulation of a transistor resonant inverter is made in accordance with the calculations done. On Fig. 5 are shown the time diagrams of the current through the inductivity L - $I(L1)$ and of the voltage of the terminals of the capacitor C_2 - $V(2)$.

IV. CONCLUSIONS

The method proposed gives us the opportunity to dimension the elements of the input filter and at the same time to decrease the amplitude of the high-frequency inverter current towards the network and to limit the over voltage of the terminals of the inverter when switching it off or in cases of break-down stopping. This method is simple and has a satisfactory accuracy for the practice.

REFERENCES

- [1] N. Nachev, co. Industrial electronics, Sofia, Technika, 1988, (in Bulg.).
- [2] Y. Cheron. "La commutation douce dans la conversion statique de l'energie electrique", Lavoisier, Technique et Documentation, 1989.
- [3] Segulier, G., F. Labrique. Les convertisseurs de l'electronique de puissance. Volum 4 - La conversion continu - alternatif. Technique et Documentation - Lavoisier, 1989.

A very satisfactory coincidence between the results from

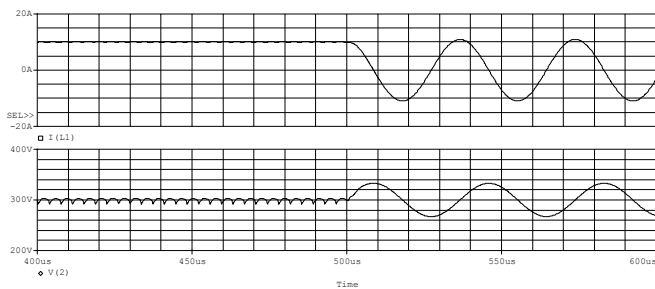


Fig. 5. Results from computer simulation

the calculations and the computer simulation is achieved. We see a considerable decrease in the amplitude of the input high-frequency current of the inverter through the inductivity L and limiting of the increase in the voltage of the capacitor C_2 over 300V up to 33V when switching off the inverter.