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DETERMINATION OF THE BASIC PARAMETERS OF A PERFORMING FILTER FOR COMPENSATION OF THE DEFORMING REGIME

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Abstract: In this paper were elaborated the sizing procedures for the main power components of the parallel active filter. The procedures are a set of automated tools that allow an optimal and quick choice of components. First of all, the filter load is established, starting from the parameters of the non-linear consumer to be compensated (nominal current, harmonic content), the proposed compensation level and the compensation strategy to be applied. Then the criteria for sizing inductiveness from the output of the active filter are established.

Particular attention is paid to the passive filter for the switching waving. Different ways of location and their implications are reviewed, different filter topologies are identified, the advantages and constraints of each are examined.

Key words: *Harmonics, filters, adjustable electric drives*.

1. INTRODUCTION

In modern energy systems, nonlinears have an increasing share; the widespread use of adjustable AC drives, having rectifiers with diodes as the first floor of conversion, of DC drives based on rectifiers with thyristors, of cycconverters has as a consequence the increase of the harmonic content of the current absorbed by consumers.

The disadvantages of these current harmonics are well known [1], [6]:

- increased power dissipation in cables, transformers, electric machines, and capacitors.
- in three-phase systems with null, the multiple harmonics of three gather in the null conductor so that the current in this conductor reaches unacceptable values.
- the current harmonics cause the distortion of the supply voltage of all consumers, so linear consumers are also affected, which does not generate

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current harmonics.
- harmonics accelerate the processes of aging of insulation and reduce the life of installations.

The limitation methods can be divided into three groups:
- passive filters,
- harmonic isolation and reduction transformers,
- active filters

Active filters are static power converters that can perform various functions. The current filtration schemes allow the synthesizer of any form of current with harmonic components of relatively high frequencies, sufficient for most practical cases and at increasing power levels [2], [5].

2. FILTER OUTPUT INDUCTANCE

The procedure for sizing the inductance at the filter output is based on the following criteria:
- A *lower limit* of the inductance of **LF(min)** is set so as to limit the flow of current due to the components with the switching frequency and its multiplies (e.g. to 5...15% of the injected current).
- An *upper limit* of the inductance of **LF(max)** is set so that the minimum rate of variation of the current generated by the filter is higher than the maximum speed of variation of the consumer's current; only in this way is an adequate compensation of the harmonics possible.

Following the performance of some simulations, the variation of the ratio between the apparent power of the filter and the apparent power of the nonlinear consumer can be determined in case both the reactive power and the current harmonics are compensated (fig.1), [3], [4]. Similarly, the variation of the ratio between the apparent power of the filter and the apparent power of the nonlinear consumer can be determined if only the current harmonics are compensated (fig.2.)

Lower limit of inductance LF(min)

A relationship of general character is obtained by relating the waving to the maximum value of the current of the $\hat{I}_F$ filter, as in the relation (1); for $\hat{I}_F$, the maximum value of the consumer current can be adopted, i.e. I_d (direct current at the rectifier output)

$$\frac{\hat{I}_{F,ripple}}{\hat{I}_F} = \frac{V_{dc}}{12 \cdot L_F \cdot f_{sw} \cdot I_d} \cdot 100 \quad [\%] \qquad (1)$$

Upper limit of inductance LF(max)

$$\frac{di_F}{dt} = \frac{\frac{2}{3}V_{dc} - \sqrt{\frac{2}{3}}V_{LL}}{L_F} \qquad (2)$$

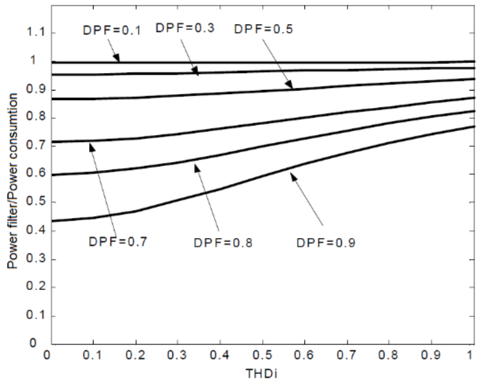

Fig.1. Variation of the ratio between the apparent power of the filter and the apparent power of the nonlinear consumer in case the reactive power and the current harmonics are compensated

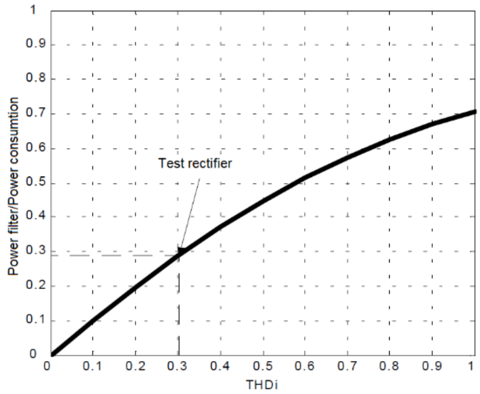

Fig.2. Variation of the ratio between the apparent power of the filter and the apparent power of the nonlinear consumer in case only the current harmonics are compensated

In fig. 3 is represented the relation (1) for f_{sw} = 10 kHz, having as parameter V_{dc} and in fig. 4 is represented the relation (2), having as parameter Vdc.

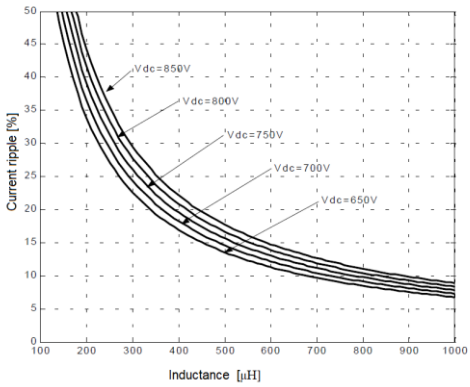

Fig.3. Curves $i_{F,\ ripple}=f(L_F)$ for determination the minimum inductance of the L_F inductance (min)

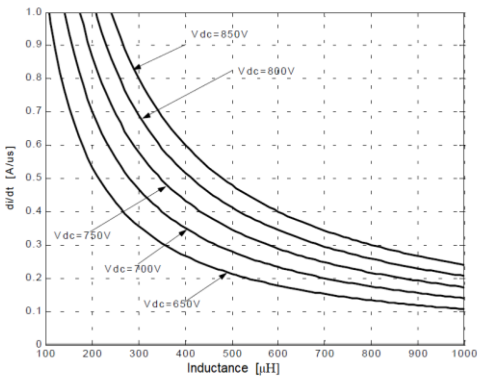

Fig.4. Curves $di_F/dt = f\ (L_F)$ for the determination maximum inductance limit

3. FILTER CAPACITOR

The procedure for sizing the filter capacitor is based on the balance of powers. The calculation assumptions are as follows:

- The active power dissipated in the converter is negligible.
- The energy stored in the output inductiveness is negligible.

- The continuous voltage is kept constant with the help of the specially designed adjustment loop, so the undulating component of the continuous voltage $v_{dc,\sim}(t)$ is much lower than the mean value V_{dc}

$$v_{dc}(t) = V_{dc} + v_{dc,\sim}(t) \cong V_{dc} \quad (3)$$

- Since the chosen switching frequency - f_{sw} (10kHz) is much higher than the frequency of the network, f_s the undulating component at the switching frequency and its multiplies of the current absorbed by the capacitor $i_{C,sw}$ is negligible in relation to the low frequency undulating component of the current absorbed by the capacitor $i_{C,\sim}$ (multiples of the network frequency)

$$i_c(t) = I_c + i_{c,\sim}(t) + i_{c,sw}(t) \cong i_{c,\sim}(t) \quad (4)$$

In relation (4) the mean component I_C is null as a consequence of the fact that the losses are neglected in the converter – the first calculation hypothesis.

- Only the current harmonics are compensated, the reactive power is not compensated.

It is useful to express the curling component Δv_{dc} relative to the mean value V_{dc}

$$\frac{\Delta v_{dc}}{V_{dc}} = \frac{THD_I}{\sqrt{1+THD_I^2}} \cdot \frac{S_L}{C_d \cdot V_{dc}^2 \cdot \omega_S} \quad (5)$$

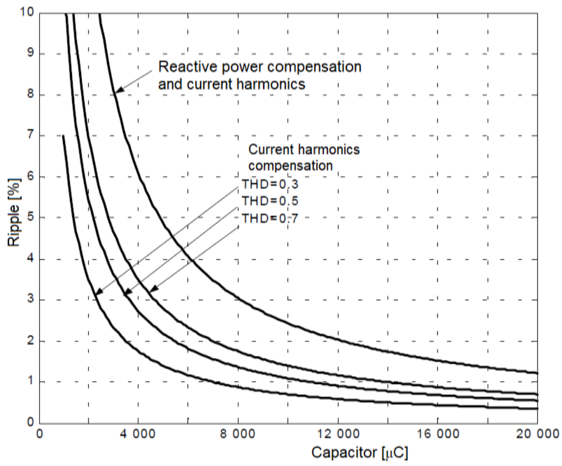

Fig.5. Condenser value curves filtering

A useful form of materialization of the sizing procedure is the representation of the relationship (5) as in Fig. 5.
The dependence of the relative ripple on the value of the filtering capacity is highlighted. It is observed that if it is desired to compensate the reactive power, the required value of the filtering capacity is much higher at the same ripple percentage, [4], [5], [6].

4. PASSIVE FILTER FOR SWITCHING RIPPLE

In the absence of measures to limit the switching wave of the current absorbed by the active filter, these harmonics enter the non-line consumer to compensate and the supply network, which may result in the deformation of the supply voltage in the CCP.

Simple active filter structures use the output inductances of the L_F filter as the only interface between the converter and the network [7].

But in order to have a good dynamic of the active filter, a maximum limit is imposed for the value of the L_F inductance; thus, a very high switching frequency is required to maintains the switching ripple of the absorbed current within acceptable limits, only with a low output L_F inductance. In order to achieve good dynamic performance and eliminate current ripple at a lower switching frequency, a passive filter, located between phases, is required [4], [8].

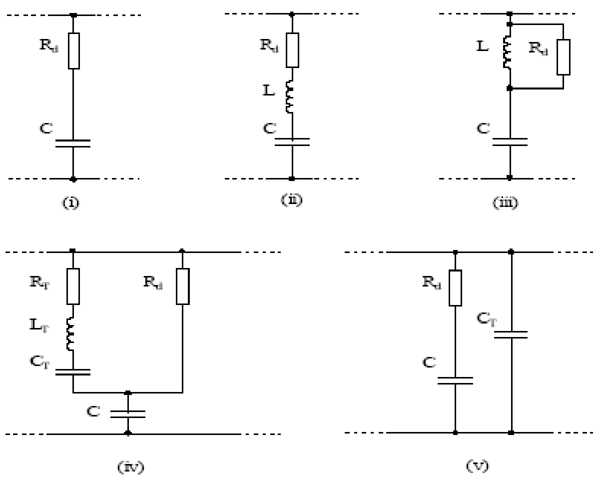

Fig.6. Passive filter topologies for switching waving

The objective of this filter is to remove the current harmonics with the switching frequency and its multiples, produced by the converter. If properly designed, the passive filter for the switching ripple can also attenuate the upper harmonics in the current absorbed by the nonlinear consumer, located above the frequency band of the active filter regulator, [6].

Some of the more widespread typologies for passive filters are shown in Fig. 6.

The approach in Fig. 6, consists in creating two separate paths: one path LT, C_T, C on the switching frequency of the converter (fig. 7a) and another of broadband R_d, C (fig. 7b). The resistor R_d shall be sized to ensure the damping of any resonance possibility with the network or consumers, at frequencies above the active filter band.

Therefore, it is not necessary to increase the frequency band of the converter, in order to achieve active damping of the resonances.

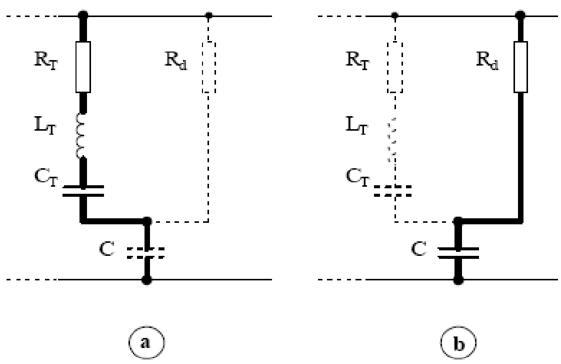

Fig.7. Topology in Fig. 6,
(a) The path for the switching frequency.
(b) Broadband path.

The value of the network frequency current is determined by the capacitor C. At the network frequency the impedance of the capacitor C is much higher than the resistance R_d and, as a result, the fundamental voltage is found on the capacitor C, and on the circuit granted to L_T, C_T the amplitude of the fundamental component of the network voltage is very low (fig. 8).

5. SIZING THE BASICS

5.1 Task specification

The active filter shall compensate the non-linear consumer's current harmonics so that the distortion factor of the total current absorbed is within the limits imposed. The inverter on which the active filter is implemented is a deck with IGBT transistors of 200 A, 1700 V, SKM type 200GB173D1, cooled with an axial fan type SKF16B. A current capability of the inverter of 55 A at 16 kHz has been estimated (fig.9).

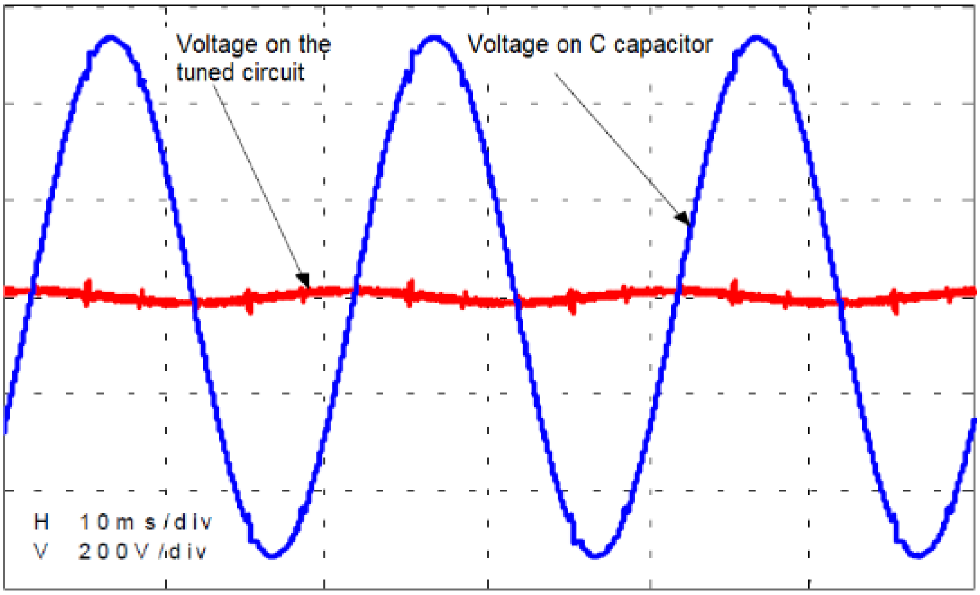

Fig.8. Topology from Fig. 6,
The fundamental voltage is found on the C capacitor

5.2. Passive filter sizing for switching waving

The purpose of the passive filter is to create a way of deflection of the waving current so that it does not penetrate the power supply network, [1], [4]. The efficiency of the passive filter can be assessed by means of the current transfer factor with the output in short circuit $\mathbf{H_{21}}$. The (ideal) efficiency criteria of the passive filter are:

- module | $\mathbf{H_{21}}$| to be unitary throughout the frequency band and null to the frequency f_{SW} and
- the phase shift inserted to be zero throughout the frequency band.

Of course, an achievable physical filter will partially meet these requirements. It is chosen for the passive filter the topology in fig. 6, which has an optimal structure. Let the value of the capacitor C capacity of 60 μF; its impedance at 50 Hz is about 53 Ω and, if you want to reduce the voltage on the circuit granted {L_T, C_T} toabout 10 V, it results in a resistance R_d of about 1.3 Ω. (Table no.1)

Table 1. ***Parameters of the filter***

f_{SW}	10.8	kHz
L_T	32	μH
C_T	50	μF
R	60	mΩ
C	60	μF
R_d	1.5	Ω

Fig.9. IGBT transistor bridge

Choose C_T=6.8μF and result in L_T=32μH. The parameters of the passive filter with the structure in fig. 5.9, are recapitulated in the table above; the resistance R_T is the resistance of the winding of the inductance L_T of about 50...100 mΩ, which leads to a quality factor of 50...100 for the circuit granted L_T, C_T.

6. CONCLUSIONS

All modern electrical and electronic equipment has switching sources or controls the power absorbed in one way or another and thus results in non-linear loads. Linear loads are relatively rare, uncontrolled incandescent lamps and uncontrolled heating systems are the only examples.

This class of equipment causes most of the problems caused by harmonics, encountered in industry and commerce, on the one hand due to the large number installed and on the other hand due to the type of harmonics they produce - with a multiple of three.

Due to the increase in the number of equipment and without the application of strict rules, followed by drastic measures, it is likely that harmonic pollution will increase. It is a risk for companies that have invested, based on good design practice, in the right equipment and in the right maintenance.

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