HARMONIC PROTECTION FILTERS

1. Introduction

Presence of harmonics in electrical networks can produce very high overcurrents in power capacitors as well as several problems in many other components of the installation. If a resonance point is achieved, the result can be even dangerous for the whole installation.

Harmonic protection filters are used in supply networks having a high level of harmonic distortion. A guide for selecting when it is necessary to use them is given in TS 03-013. The purpose of protection filters is to avoid that harmonic currents overload the capacitors by diverting them to the mains.

A protection filter is made by connecting capacitors in series with reactors, tuned to a frequency in which there are no harmonic generations.

Keeping in mind that, in three phase systems the first harmonic that usually appears is the 5th, we can tune the filter between the fundamental frequency and the 5th harmonic.

In 50 Hz supply networks it is very common to use filters tuned at 189 Hz. These filters are called 7% filters because in them the power of the reactor is 7% the power of the capacitor.
We can compare the impedances of a capacitor bank and a protection filter on figure1.

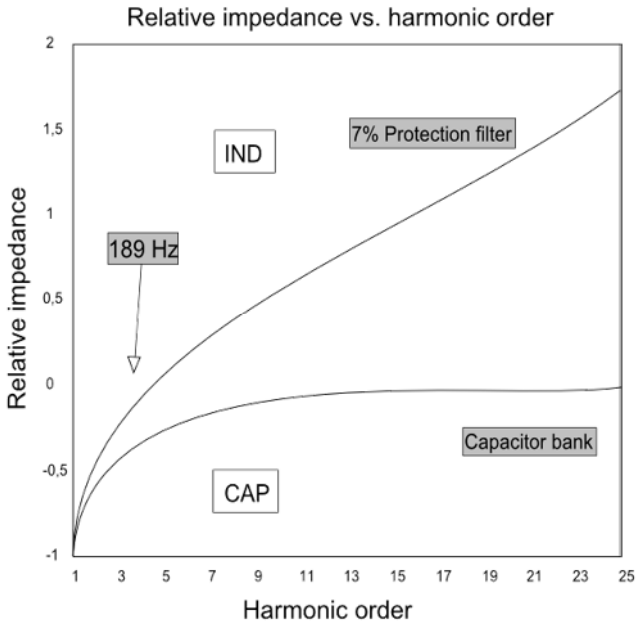


Figure 1

The relationship between the power percent and the resonance frequency is

$$F_{reson} = \frac{10}{\sqrt{X}} * f_n$$

Where:

f_{reson} = *Frequency of resonance (Hz)*

$$x = \frac{Power\ of\ reactor\ (kvar)}{Power\ of\ capacitor\ (kvar)} * 100$$

f_n = *Fundamental frequency (Hz)*

FMLF series and **POLB_HD** of capacitors is specially designed to work with reactors in order to make protection filters tuned at 189 Hz in supply networks of 400 V 50 Hz (On request we can make capacitors and reactors for other tuning frequencies and rated voltages).

As capacitors connected into a filter (reactor) work at a voltage higher than network voltage, FMLF and POLB_HD capacitors have to be selected with higher rated volatge than network voltage. For example, for 400 V networks, FMLF and POLB_HD capacitors must be rated at 460 V.

The rating plates of the **INA** and **INR** reactors show the code of the FMLF or POLB_HD capacitor to be used in order to make the right protection filter.

2. Example of application

The need for using a protection filter can be seen from the following case. On the installation of figure 2, it was planned to install a 250 kvar 400 V capacitor bank for power factor compensation.

Let us see what will be the effects of the introduction of this capacitor bank. Calculations are made taking into account the 800 kVA transformer and also the 10 MVA transformer from the Electrical Supply Company in order to calculate also the distortion level in the Point of Common Coupling (PCC, see Fig. 2)

The fundamental current of the harmonic sources (converters) is 550 A, and has the following harmonic distribution:

I_5	=	20% I_1	=	110 A	
I_7	=	14% I_1	=	77 A	
I_{11}	=	9% I_1	=	50 A	
I_{13}	=	8% I_1	=	44 A	Which is a typical distribution for six pulse rectifiers.

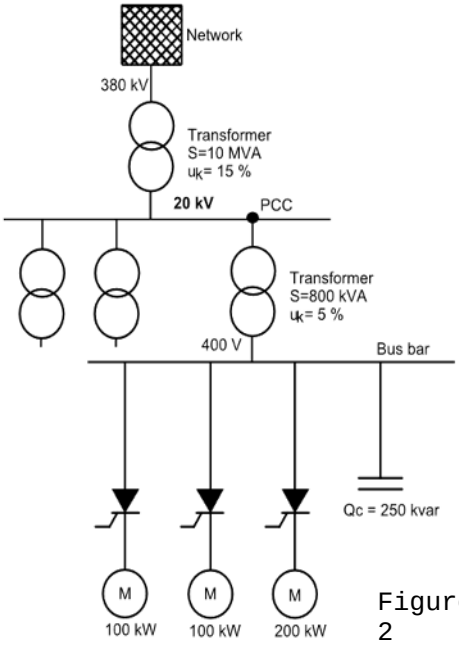


Figure 2

Order	I_{har} (A)	I_{har} (%)	U_{busbar} (V)	U_{busbar}(%)	I_c (A)	U_c (V)
1	550	100	400.0	100.0	360.7	**430.1**
5	110	20	7.4	1.9	41.3	**9.8**
7	77	14	8.5	2.1	20.6	**3.5**
11	50	9	9.1	2.3	11.2	**1.2**
13	44	8	9.6	2.4	9.7	**0.9**

THD (U_{PCC}) = 5.3 %
THD (U_{busbar}) = 26.6 %
U_{busbar} = 415 V
U_c max = 544 V
I_c = 783 A
I_c / I_n = 2.17

The harmonic distortion level of voltage (THDU) in the Point of Common Coupling (PCC) is higher than 5 %. This value is normally considered as the maximum distortion allowed at that point by different Electricity Authorities and standards.

The harmonic distortion level of voltage in the busbar is 26.6 %. This can cause important problems in a wide range of electrical equipments like electronics systems, PLC´s, computers, etc.

The maximum voltage on the capacitors, calculated according to IEC 831 standard, is 544 V. This voltage is much higher than rated voltage of the capacitor (400 V) and also is very far from the maximum overvoltage level stated by IEC (440 V), and will produce premature dielectric degradation.

It can also be seen that a big amount of 7th harmonic current (679 A) is flowing through the capacitor bank due to the resonance at 350 Hz between the bank and the transformer. The total rms current on the capacitor is 2.17 times the rated current. This level of overcurrent will destroy the capacitor.

Let us see what happens if a 7% harmonic protection filter is installed.

We can make a 250 kvar 400 V protection filter by adding FMLF/POLB_HD capacitors(*) and the appropriated reactors (a 7% filter means a tuning frequency of 189 Hz).

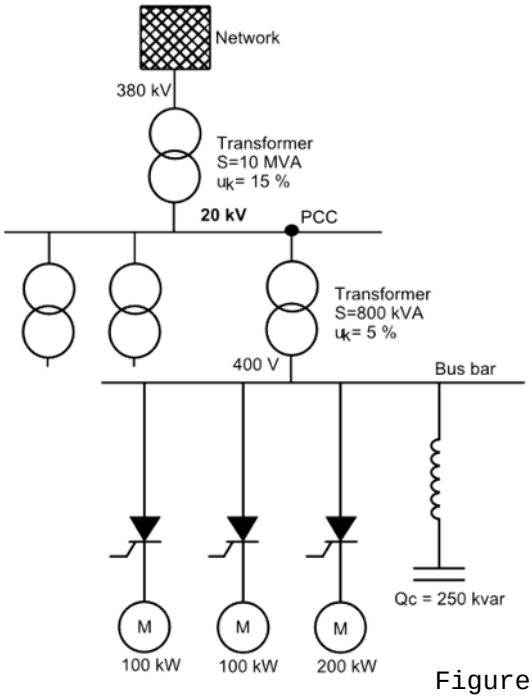


Figure 3

Order	I_{har} (A)	I_{har} (%)	U_{busbar} (V)	U_{busbar}(%)	I_c (A)	U_c (V)
1	550	100	400.0	100.0	360.7	**430.1**
5	110	20	7.4	1.9	41.3	**9.8**
7	77	14	8.5	2.1	20.6	**3.5**
11	50	9	9.1	2.3	11.2	**1.2**
13	44	8	9.6	2.4	9.7	**0.9**

THD (U_{PCC}) = 0.8 %
THD (U_{busbar}) = 4.4 %
U_{busbar} = 400 V
U_c = 430 V
U_c max = 445 V
I_c = 364 A
I_c / I_n = 1.01
THD (U_c) = 2.5 %

The THD in the Point of Common Coupling is in this case well below 5%.

The harmonic distortion level in the busbar is also below 5%.

The big overcurrent through the capacitor bank is not present anymore. Now capacitor current is only 1.01 times the rated current.

The amplification of the 7th harmonic current due to the resonance with the transformer is now missed.

The capacitor voltage at 50 Hz is 430 V. The maximum voltage, including harmonics, is 445 V. These operating values give a considerably safety margin from the 460 V rated voltage of FMLF and POLB_HD capacitors.

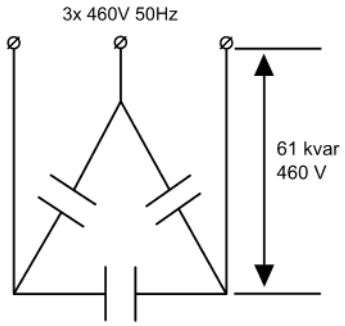
* Note that capacitors work at higher voltage than network voltage: standard capacitors cannot be used to build up filters.

3. FMLF and POLB_HD capacitors: Rated power and voltage

Parameters of FMLF or POLB_HD capacitors like rated voltage, capacitance and rated power and their tolerances are calculated and designed considering their principal function as filter capacitors in harmonic protection filters.

For example, to build up a 50 kvar 400 V 50 Hz 7% filter, according to our catalogue, we have to use a INA40507 reactor and a FMLF4661 prismatic capacitor or, alternatively, with two units of POLB46300HD cylindrical capacitor.

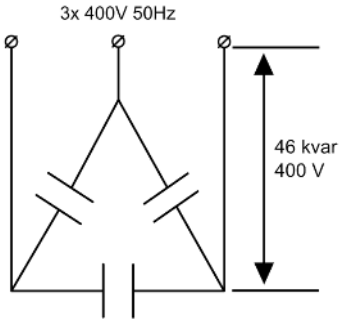
This FMLF capacitor will have different power outputs depending on its connection as shown in the following examples:



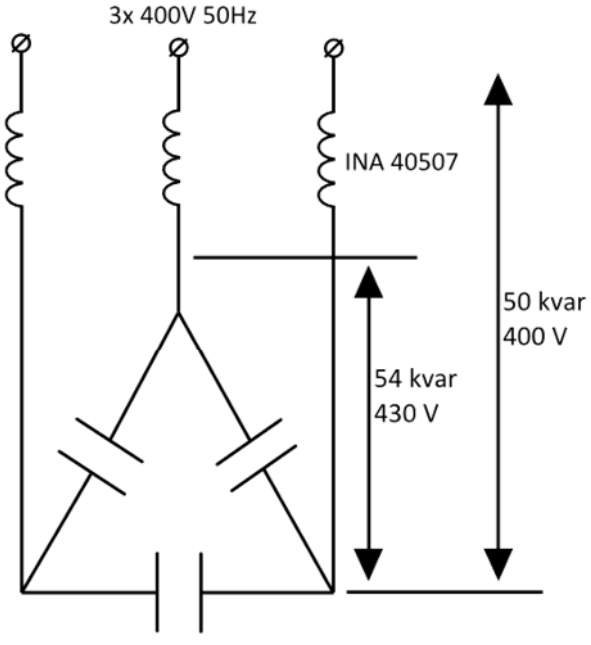
FMLF4661
2xPOLB46300HD

FMLF4661 capacitor has a rated voltage of 460 V. It is possible then to connect it to a network having this voltage. In this case it will give 61 kvar.

If FMLF4661 capacitor is connected to a 400 V 50 Hz network, its power output will be only 46 kvar.



FMLF4661
2xPOLB46300HD



FMLF4661
2xPOLB46300HD

When the FMLF4661 capacitor is connected to the INA reactor to form the protection filter, the working voltage of the capacitor within the filter will be 430 V (50 Hz) and its power, within the filter, will be 54 kvar.

The total reactive power of the filter will be 50 kvar at 400 V network voltage.