

Hybrid Active Filters For Harmonic Filtering

Two types of hybrid active filters for harmonic filtering of nonlinear loads were proposed in 1988 and in 1990 respectively. Figs. 7 and 8 show the simplified circuit configurations of the hybrid active filters. The proposal of the two hybrid filters has encouraged power electronics researchers/engineers to do further research on various hybrid active filters, concentrating on their practical use.

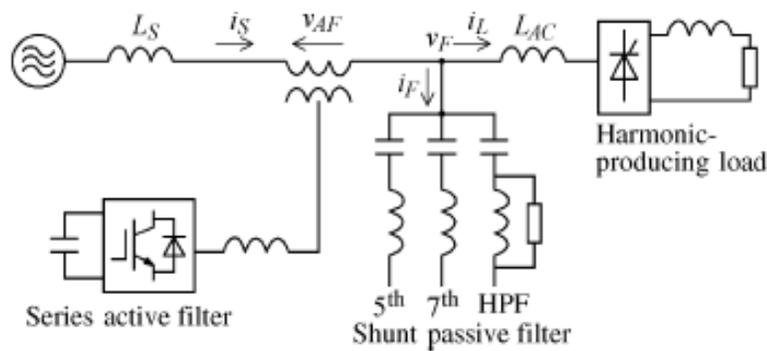


Fig.7 Combination of a series active filter and a shunt passive filter

The two hybrid filters are based on combinations of an active filter, a three-phase transformer (or three single-phase transformers), and a passive filter consisting of two single-tuned filters to the fifth- and seventh-harmonic frequencies and a second-order high-pass filter tuned around the 11th-harmonic frequency. Although these hybrid filters are slightly different in circuit configuration, they are almost the same in operating principle and filtering performance.

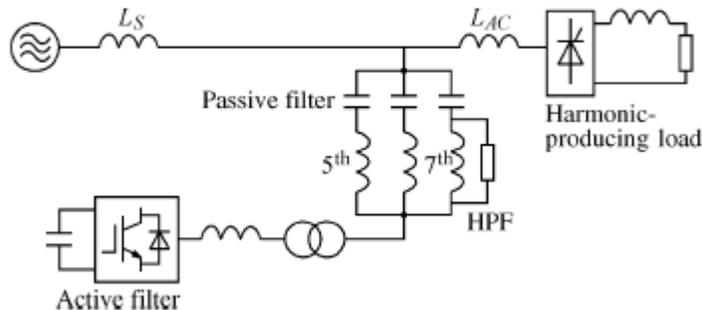


Fig. 8. Series connection of an active filter and a passive filter

Such a combination with the passive filter makes it possible to significantly reduce the rating of the active filter. The task of the active filter is not to compensate for harmonic currents produced by the thyristor rectifier, but to achieve harmonic isolation between the supply and the load. As a result, no harmonic resonance occurs, and no harmonic current flows in the supply.

Standards

The philosophy of developing harmonic limits in recommended practice is to limit the harmonic injection in the network from individual customers so that they will not cause unacceptable voltage distortion levels for normal system characteristics and to limit overall harmonic distortion of the system voltage supplied by the utility.

The harmonics standardization process can be considered as quite complete since this problem is relatively old. The same cannot be said about the interharmonics standardization process, which is in its infancy, with knowledge and measured data still being accumulated.

Standards prescriptions define the limits on voltage supply, measurement method and instruments, mitigation process, etc. The main IEC standards dealing with harmonics and interharmonics are presented in Table 7.13. Essential standards regarding the harmonics are EN 50160, IEEE 519-1992 and IEEE 1159-1995. Table 7.14 shows the voltage distortion limit.

Table 7.13 Main IEC harmonic standards

Subject	Standard
General	IEC 61000-1-4
Emission (description)	IEC 61000-2-2, 61000-2-3, 61000-2-4, 61000-2-6, 61000-2-12
Limits	IEC 61000-3-2, 61000-3-4, 61000-3-9, 61000-3-6, 61000-3-10, 61000-3-12
Testing and measurement techniques	IEC 61000-4-7, 61000-4-13, 61000-4-30, 61000-4-31

Table 7.14 Values of individual harmonic voltages at the supply terminals for orders up to 25

Odd harmonics				Even harmonics	
Not multiples of 3		Multiples of 3			
Order h	Relative voltage (%)	Order h	Relative voltage (%)	Order h	Relative voltage (%)
5	6	3	5	2	2
7	5	9	1.5	4	1
11	3.5	15	0.5	6–24	0.5
13	3	21	0.5		
17	2				
19	1.5				
23	1.5				
25	1.5				

Table 7.15 shows the limits according to IEEE 519-1992. Currently defined distortion limits assume that there will be some diversity between the harmonic currents injected by different customers. This diversity can be in the form of different harmonic components being injected, differences in the phase angles of the individual harmonic currents, or differences in the harmonic injection versus time profiles. In recognition of this diversity, the current limits are developed so that the maximum individual frequency harmonic voltage caused by a single customer will not exceed the limits in Table 7.16 for systems that can be characterized by a short-circuit impedance.

Table 7.15 Voltage distortion limits

Bus voltage at PCC	Individual voltage distortion (%)	Total voltage distortion THD (%)
69 kV and below	3.0	5.0
69.001 kV through 161 kV	1.5	2.5
161.001 kV and above	1.0	1.5

Table 7.16 Basis for harmonic current limits

SCR at PCC	Maximum individual frequency voltage harmonic (%)	Related Assumption
10	2.5–3.0	Dedicated system
20	2.0–2.5	1–2 large customers
50	1.0–1.5	A few relatively large customers
100	0.5–1.0	5–20 medium-size customers
1000	0.05–0.10	Many small customers

Table 7.17 Classification of equipment

Class of equipment	Type of equipment	Note
A	Balanced three-phase equipment Household appliances (not those in Class D) Tools (not portable) Light dimmers Audio equipment Everything else not covered by B, C or D	
B	Portable tools Arc welding equipment (non-professional)	
C	Lighting equipment	
D	Personal computers and monitors TV sets	Power \leq 600 W

If individual customers meet the current distortion limits, and there is not enough diversity between individual customer harmonic injections, then it may be necessary to implement some form of filtering on the utility system to limit voltage distortion levels. However, it is more likely that voltage distortion problems would be caused by system frequency response characteristics that result in the magnification of harmonic current at a particular harmonic frequency. This changing of the system impedances versus frequency characteristic is a result of the system's physical configuration. This situation has to be solved on the utility system either by changing capacitor locations or sizes, or by designing a harmonic filter.

Standard IEC 61000-3-2 deals with the harmonic current emission limits of individual equipment connected to public networks. This standard imposes limits on the current harmonics drawn from the mains supply. The standard requires that electrical appliances be type tested to ensure that they meet the requirements of the standard. The standard defines four classes of waveform according to the different types of equipment (Table 7.17). For example, one of the classes (Class B) applies to portable tools, whereas Class D refers to PCs and TV sets. Each class has different harmonic limits up to the 40th, which must not be exceeded. Some classes have dynamic limits which are set according to the power drawn by the device.