Series passive, Low Pass Broadband and C filters

Series passive filters :

Unlike a notch filter which is connected in shunt with the power system, a series passive filter is connected in series with the load. The inductance and capacitance are connected in parallel and are tuned to provide a high impedance at a selected harmonic frequency. The high impedance then blocks the flow of harmonic currents at the tuned frequency only. At fundamental frequency, the filter would be designed to yield a low impedance, thereby allowing the fundamental current to follow with only minor additional impedance and losses. Figure 6.16 shows a typical series filter arrangement.

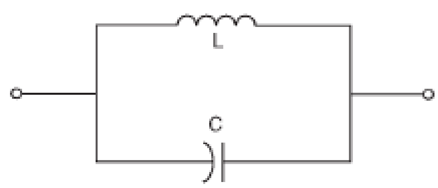

Figure 6.16 A series passive filter.

Series filters are used to block a single harmonic current (such as the third harmonic) and are especially useful in a single-phase circuit where it is not possible to take advantage of zero sequence characteristics. The use of the series filters is limited in blocking multiple harmonic currents. Each harmonic current requires a series filter tuned to that harmonic.

Low-pass broadband filters

Multiple stages of both series and shunt filters are often required in practical applications. For example, in shunt filter applications, a filter for blocking a seventh-harmonic frequency would typically require two stages of shunt filters, the seventh-harmonic filter itself and the lower fifth-harmonic filter. Similarly, in series filter applications, each frequency requires a series filter of its own thus, multiple stages of filters are needed to block multiple frequencies.

In numerous power system conditions, harmonics can appear not only in a single frequency but can spread over a wide range of frequencies. A six-pulse converter generates characteristic harmonics of 5th, 7th, 11th, 13th, etc. Electronic power converters can essentially generate time-varying interharmonics covering a wide range of frequencies. Designing a shunt or series filter to eliminate or reduce these widespread and time-varying harmonics would be very difficult using shunt filters. Therefore, an alternative harmonic filter must be devised.

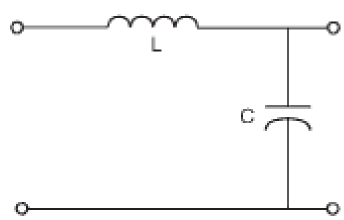

Figure 6.17 A low-pass broadband filter configuration.

A low-pass broadband filter is an ideal application to block multiple or widespread harmonic frequencies. Current with frequency components below the filter cutoff frequency can pass; however, current with frequency components above the cutoff frequency is filtered out. Since this type of low-pass filter is typically designed to achieve a low cutoff frequency, it is then called a low-pass broadband filter. A typical configuration of a low-pass broadband filter is shown in Fig. 6.17.

C filters

C filters are an alternative to low-pass broadband filters in reducing multiple harmonic frequencies simultaneously in industrial and utility systems. They can attenuate a wide range of steady state and time varying harmonic and interharmonic frequencies generated by electronic converters, induction furnaces, cycloconverters, and the like. The configuration of a C filter is nearly identical to that of the second order high-pass filter shown earlier in Fig. 6.12. The main distinction between the two configurations is that the C filter possesses an auxiliary capacitor *Ca* in series with the inductor *Lm*. A typical configuration of a C filter is shown in Fig. 6.21. The auxiliary capacitor *Ca* is sized in such a way that its capacitive reactance cancels out *Lm* at the fundamental frequency, bypassing the damping resistance *R*. For this reason, the losses associated with *R* are practically eliminated, allowing a C filter to be tuned to a low frequency.

The impedance frequency response of a C filter is also essentially identical to that of a second-order high-pass filter. At high-order harmonic frequencies, the reactance of *Ca* is small, while that of *Lm* is large. Therefore, the impedance of the series *Lm* and *Ca* branch is dominated by the reactance of *Lm*. The high-frequency responses of the C filter and second-order high-pass filters are similar (see Fig. 6.21).

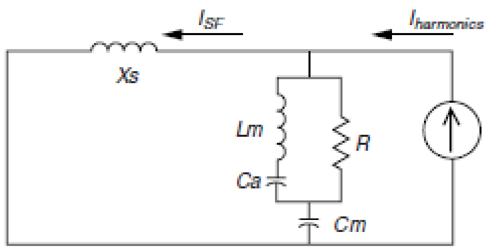

Figure 6.22 Equivalent circuit for deriving C-filter specifications.

Drawbacks of Passive Filters

The drawbacks are as follows:

1. An electric power system with passive filters is a weakly damped *LCR* circuit which, in order to exclude resonance phenomena, requires a careful analysis of the frequency characteristics at the design stage.
2. The effectiveness of the filter strongly depends on the supply network impedance at the point of connection. Normally its exact value is not known and it varies with changes in network configuration. The reduction of the current value (due to the effect of the fifth-harmonic filtering and compensation of the load current reactive component) and the reduction of the fifth-harmonic voltage magnitude are evident.
3. Filters are subject to detuning due to variations in the supply frequency and changes in *LC* component values (e.g. due to the effect of capacitor ageing). The adverse effect of detuning can be mitigated by an appropriate tuning or reducing the filter quality factor. The latter method, however, increases both the active power loss and the unfiltered harmonic content in the supply voltage.
4. The filter current also contains harmonic currents produced by the supply source voltage harmonics.
5. Only selected harmonics of dominant magnitude are filtered. The load non-characteristic harmonics, which may occur in the load supply current, are not filtered.
6. Passive filters are a large and expensive component of compensation systems. The number of single harmonic filters equals the number of filtered harmonics.

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