CHOKES IN THE HIGHER HARMONICS FILTERS SYSTEMS

Mirosław Łukiewski[1]

[1] ELHAND TRANSFORMATORY, e-mail: m.lukiewski@elhand.com.pl

The significant level of the higher harmonics in industrial and municipal power networks is caused by the vast growth in the number of converters and non-linear receivers exploitation. The voltage sinusoid deformation leads to increase in losses and, in extreme situations, even to the disturbance in the machines and devices operation. In order to limit the unfavourable impact of the non-linear receivers and converters on electric and power networks, the higher harmonics falters systems are used on the machines supplied from them and batteries of the capacitors connected with the network.

THE OBJECTIVES OF THE HIGHER HARMONICS FILTERS IN POWER NETWORKS

In the most common three-phase bridge converter systems (six-pulse systems), the current run on the transformer primary side – assuming the supply voltages symmetry, commutation impendence and delay angles of thyristors switching off – apart from the basic component, will include at least the following harmonics: 5,7,11,13, whose numbers are defined by the general equation (1).

$$n = kp \pm 1, \qquad (1)$$

where: n – harmonic number, k – natural number, p – rectified voltage pulse number

The values of the harmonics component amplitudes may be determined by using the equation (2).

$$A_n = \frac{1}{n} A_1, \qquad (2)$$

where: A_1 – voltage basic harmonic amplitude, A_n – n^{th} harmonic amplitude.

Too high a number of the supply current higher harmonics may cause a considerable increase in power losses in devices and machines operating with the converter as a result of the current flow with increased frequency, or it may cause disturbances in the operation of the device by deforming the supply voltage. This particularly refers to capacitors batteries, operating in parallel with the converting system. Decreasing the capacitor’s impedances, combined with frequency growth, may cause defects in the battery as a result of overload with the currents in the higher harmonics frequencies.

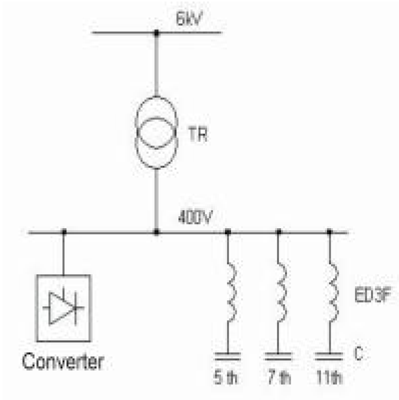
Additionally, the parallel resonance in the system is also a dangerous phenomenon. The harmonics produced by non-degree power transmission systems may be enforced as many as 10-15 times in the parallel resonance circuits, formed by capacitive reactance of the capacitors batteries and network induction. This phenomenon may result in damaging both the capacitors batteries and converters.

In unfavourable conditions, the component harmonics may pose a threat to the mechanical structures of electrical machines. The harmonic pairs, e.g. 5 and 7, may produce mechanical vibrations in the generator or motor at the frequency of 6^{th} harmonic.

These vibrations arise as a result of the turning moment fluctuations by deforming the supply voltage curve. When the frequency of these vibrations converges with the mechanical resonance frequency, the machine’s mechanical structure will be susceptible to considerable overloads.

The strenuous effect of the noisy operation of the electrical machines, resulting from the phenomenon of magnetostriction, is additionally reinforced due to the relatively high frequencies of the component harmonics. The currents, deformed by the higher harmonics content, also cause significant and more intense heating of the power ducts and cables as a result of the skin effect phenomenon or vicinity effect.

The function of LC filters that comprise the 3EDF chokes is to limit the negative impact of the current higher harmonics on the power network and all the devices connected to it.
Drawing 1 shows a typical system for compensating reactive power and harmonics filtration. There are three filtering branches here, adjusted to 5,7,11th harmonic. The number of filtering branches installed depends on the reactive power required and necessary for the compensation and on measurements as well as the precise analysis of the respective harmonics content in the network.



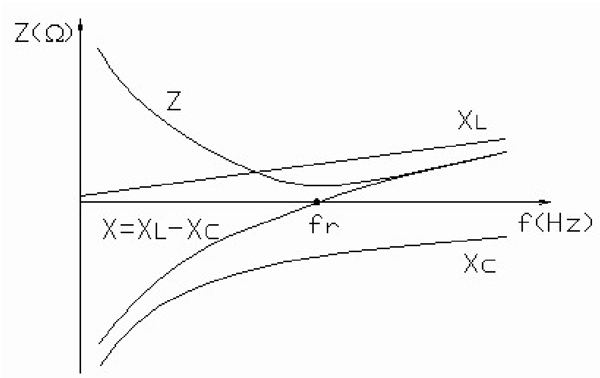
Drawing 1 Simplified diagram for the reactive power compensation circuit and harmonics filtration [on the basis of literature].

Filters are LC resonance systems in series, switched in parallel into the converter supply circuit, the aim of which is twofold: to compensate the reactive power consumed through the power transmission system and to prevent the higher harmonic permeation to the power network. Depending on the harmonic number, the filter reactance is as follows (3).

$$X_{nf} = nwL_f - \frac{1}{nwC_f}, \qquad (3)$$

where: L_f ,C_f – L_f, C_f – induction and circuit branch capacity, being a filter; n – harmonic number, - pulsation [5,6]

When the induction values and capacities are properly selected for the basic harmonic and for the harmonics with numbers lower than n_r (resonance frequency), the filter will create capacitive load and for all the harmonics with higher numbers, it creates the induction load. For the resonance frequency, LC branch will have rather small impendence, in practice equal to the choke winding resistance. The current with the resonance frequency will close between the converter and filter, not permeating to the supply network. For the basic harmonic, the filter branches are always capacitive in their character, which – in practice – means the execution of the reactive power compensation (drawing 2) [2].



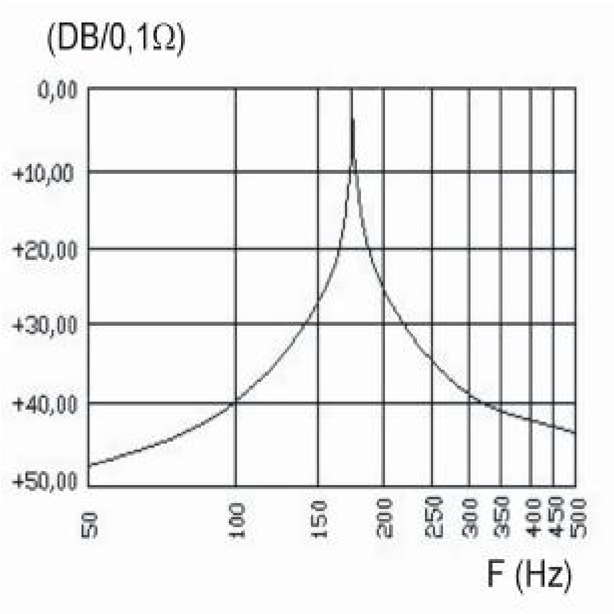
Drawing 2. LC filter impendence characteristics [1].

The suppression chokes used for protecting capacitors batteries are a variation of the ED3F chokes. The application properties of these chokes are determined by the suppression ratio p (5). The suppression ratio value may be determined on the basis of the following equation (4).

$$p(\%) = 100 \cdot \frac{U_L}{U_C} = 100 \cdot \left(\frac{f}{f_r} \right)^2 \qquad (4)$$

where: U_L,U_C –voltage on induction and LC branch capacity,
f – network frequency, f_r – resonance frequency.

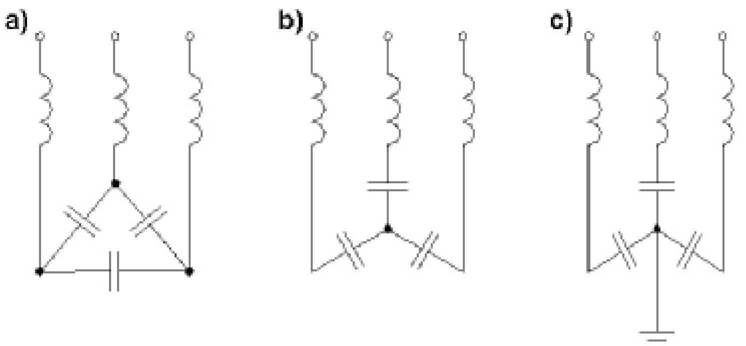
In most cases, it is the chokes with the suppression ratios p=7% and p=5%, which are compliant with the resonance frequencies - f_r=189Hz and f_r=223Hz, respectively (drawing 3). The chokes with such suppression ratios are widely used in compensation systems, where the fifth and seventh harmonic reach dangerously high levels. In the systems with a considerable content of the third harmonic, the chokes with the suppression ratio p=14% are used, i.e. with the resonance frequency f_r=133Hz.



Drawing 3. Suppression characteristics for LC system with a protective choke with the ratio p=7%. [on the basis of literature].

SELECTED EXECUTIONS OF LC PASSIVE FILTERS

There are many technical solutions in industrial applications. However, the LC passive filters are most common (drawing 4).



Drawing 4. Selected LC passive filters systems [on the basis of literature]

While operating, the branches of LC filter, shown in Drawing 4, are under the network forward voltage. In connection therewith, the capacitors batteries and chokes will be considerably more expensive than in the systems, especially in the scope of medium voltages (Drawing 4b,c). For this reason, the filter configuration (Drawing 4a), is commonly used in the low-voltage systems. The drawback of this solution is the lack of the possibility to filter triple harmonics. This is possible only in the star system with an earthed zero point.

In the system from Drawing 4b, the distribution of voltages at the respective filter phases is dependant on the capacity and induction of each branch. Due to the necessity to ensure proper working voltage in all the three phases, a precise symmetry of capacity and induction is required. The systems (Drawing 4a,b) may be used in any three-phase network system. However, the system (Drawing 4c) may not be applied in the network with an insulated zero point or a zero point earthed by an arc-suppression coil. In such a system, the filter branches operate practically under equal voltages ($U_p / \sqrt{3}$). In case of short circuit with the earth in one phase, the inter-conductor voltage U_p appears. This voltage is $\sqrt{3}$ times higher than in the state of normal operation. The capacitors battery in this situation should be switched off as soon as possible ($t \leq 1$min.). However, in the networks with an insulated zero point, usually only earth faults are signalled and last longer, which poses a serious threat to the filters systems [1,2].

The parameters of the chokes assigned to operate in the harmonics filtration systems fit into the ranges from decimal parts to a few millihenries and from a few to a few hundred amperes respectively. These parameters are dependant on the filter system and the power and capacity of the capacitors battery, with which the choke is to operate. The choke core is made of electric and technical silicon sheet, of a thickness ranging between 0,25 and 0.5 mm. The windings are coiled with round winding wire and rolled formed wire. When formed in the right manner and rolled on frames, they are then placed at the core columns. When the core is closed, the whole product undergoes vacuous impregnation, which effectively protects it against environmental impact. Once the choke is equipped with branches and cable tips and mechanical instrumentation, the completed devices are tested at the electrical testing station in order to detect possible defects in the product that may not have been noticed during the manufacturing process.

All the activities, from material procurement through the production process to the shipment of the completed product, are carried out on the basis of the procedure for quality assurance, compliant with norm ISO 9002, guaranteeing the highest quality of the machines and devices produced.

BIBLIOGRAPHY

[1] Hanzelka Z., Klempka R. *Pasywne filtry wyższych harmonicznych* Napędy i Sterowanie nr 9,10 2000r.
[2] Nartowski Z. *Baterie kondensatorów do kompensacji mocy biernej.* WNT W-wa 1967r.
[3] Barlik R., Nowak M. *Technika tyrystorowa* WNT W-wa 1994r.
[4] Nowak M., Barlik R. *Poradnik inżyniera energoelektronika* WNT W-wa 1998r.
[5] Kuczewski Z. *Energoelektronika* WNT W-wa 1980r.
[6] CIRCUTOR – *Filtering reactors* katalog 2000r.