26. Брындин Е.Г. Управление непрерывной обработкой программ на виртуальной памяти // Суперкомпьютеры. – № 3. – 2014. – С. 50-52.
27. Евгений Брындин. Управление роботом с подражательным мышлением. Germany: LAP LAMBERT Academic Publishing. 2015. – 77 с.

DESIGNING OF OPTIMUM DETECTING FILTER FOR SYNCHRONOUS GENERATOR DIAGNOSTIC SYSTEM

Yu. Z. Vassilyeva
Tomsk Polytechnic University

The necessity of developing digital band-pass filter at creation of synchronous generator diagnostic system of turn-to-turn short circuit rotor winding based on the harmonic component separation from the signal obtained in the output of the magnetic field sensor [1]. A problem complexity is the low value of the intelligence signal - 1.5 ... 3% of the fundamental harmonic, and it is also a large number of noises (pulse noises, higher harmonic components, etc.) [2].

Statement of objectives: to develop the minimal order digital band-pass filter capable of suppressing constant and higher harmonic components and passing a signal with frequency equal to the rotor frequency.

There was a problem of dedicating the signal which is proportional to the value of sinusoidal half-wave asymmetry during the diagnostic system development.

For example, Figure 1 shows a perfect EMF signal from the sensor output. The signal asymmetry is manifested in the decreasing one of the *2p* half-wave amplitude (Δe) (Figure 1, $p = 1$), where p is machine pole pairs number.

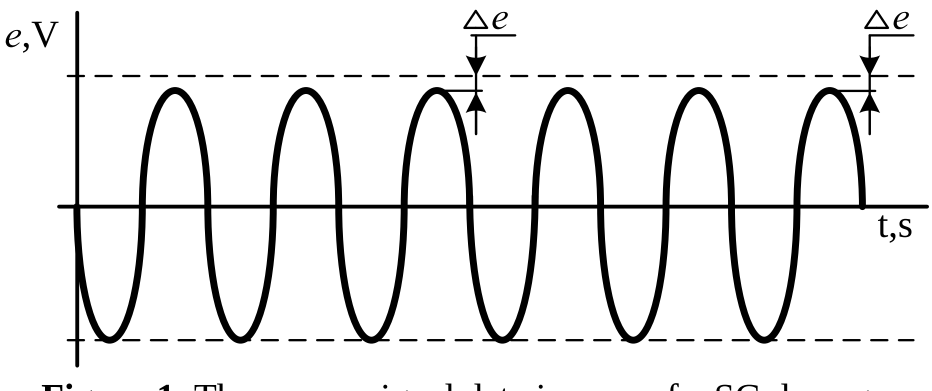

Figure 1. The sensor signal data in case of a SG damage

The problem was solved by converting the EMF into a unipolar signal, followed by the band-pass dedicating of the subharmonic frequency $f_1=f_s/p$, where f_s is a network frequency. The digital band-pass filter (BPF) consists of the high pass filter (HPF) and low pass filter (LPF).

The level of the BPF useful signal increases with increasing LPF order, the filter response time also increases. It has a negative impact on the device operating speed.

Special requirements to the HPF order were not made in the development. The smallest filter order N was the criterion for the required level of noise suppression. The required level is determined by the ratio of useful signal level to general signal level:

$$R_S = 20\log\frac{A(2f_s)}{A(f_1)}.$$

The calculation showed that the required attenuation level was equal 60 dB at the minimum level of the selected signal was being 1.5% of the total.

The Chebyshev filter, Butterworth and elliptic filters were selected as the basis LP-filter. The each selected filter order was calculated according to formulas (1), (2), (3) at the suppression level R_S = 60 dB [3,4].

The Butterworth filter order:

$$N_b = \frac{\log\left(\frac{\sqrt{10^{0,1R_P}-1}}{\sqrt{10^{0,1R_S}-1}}\right)}{\log\left(\frac{\omega_1}{\omega_0}\right)}, \quad (1)$$

The Chebyshev filter order:

$$N_{ch} = \frac{\operatorname{arch}\left(\frac{\sqrt{10^{0,1R_P}-1}}{\sqrt{10^{0,1R_S}-1}}\right)}{\operatorname{arch}\left(\frac{\omega_1}{\omega_0}\right)}, \quad (2)$$

The Cauer filter order:

$$N_k = \frac{K'\left(\frac{\sqrt{10^{0,1R_P}-1}}{\sqrt{10^{0,1R_S}-1}}\right)K\left(\frac{\omega_0}{\omega_1}\right)}{K\left(\frac{\sqrt{10^{0,1R_P}-1}}{\sqrt{10^{0,1R_S}-1}}\right)K'\left(\frac{\omega_0}{\omega_1}\right)}, \quad (3)$$

where, N_b, N_{ch}, N_k – are Chebyshev, Butterworth and elliptic filters orders, R_P – is a signal distortion level in the pass-band, R_S –is a noise suppression level, ω_0– is a passband, ω_1 – is a rejection frequency, K – is a complete elliptic integral, K'– is a complementary elliptic integral.

The dependence of the filters order from the useful signal level Δe at the given suppression level is shown in Figure 2.

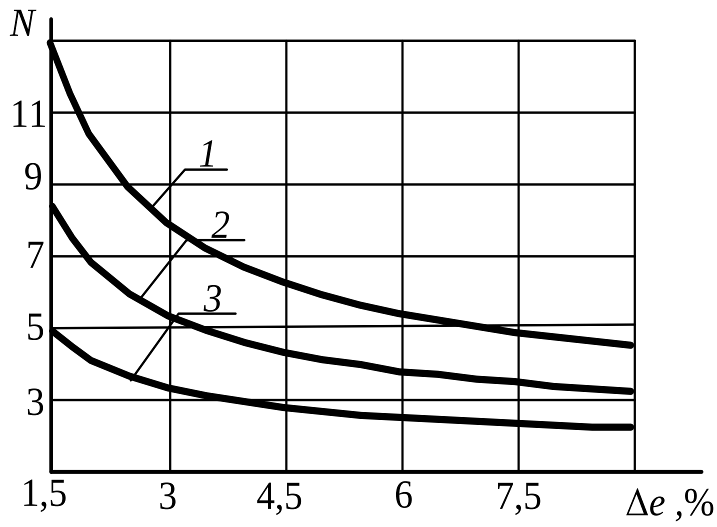

Figure 2. The dependence of the filters order from the useful signal level Δe at R_S = 60 dB
(1 - by Butterworth 2 - by Chebyshev, 3 - by Cauer)

As it can be seen from figure 2, the minimum order value N_k of elliptic filter equals 5 in case of R_S=60 dB and Δe =1,5 % . The BPF was implemented on basis of the elliptic filter. A useful signal distortion in the passband was amounte
0.5 dB.

The BPF consists of the high-pass and low-pass filter component, which can be represented as the following transfer function:

$$H(s) = \frac{a_5 s^5 + a_4 s^4 + a_3 s^3 + a_2 s^2 + a_1 s^1 + a_0 s^0}{b_5 s^5 + b_4 s^4 + b_3 s^3 + b_2 s^2 + b_1 s^1 + b_0 s^0},$$

where $H(s)$ is a transfer function, s is a complex variable, a_i, b_i are transfer function coefficients. The BPF transfer function coefficients values for the above-mentioned example are shown in Table 1.

Table 1. The BPF coefficients

LPF	a_0	a_1	a_2	a_3	a_4	a_5
	$7{,}994\cdot10^{11}$	0	$3{,}168\cdot10^{6}$	0	2,62	0
	b_0	b_1	b_2	b_3	b_4	b_5
	$7{,}988\cdot10^{11}$	$9{,}204\cdot10^{9}$	$4{,}652\cdot10^{7}$	$2{,}08\cdot10^{5}$	376,5	1
HPF	a_0	a_1	a_2	a_3	a_4	a_5
	0	$3{,}101\cdot10^{8}$	0	$3{,}852\cdot10^{4}$	0	1
	b_0	b_1	b_2	b_3	b_4	b_5
	$1{,}168\cdot10^{13}$	$4{,}457\cdot10^{10}$	$2{,}497\cdot10^{8}$	$5{,}66\cdot10^{4}$	$1{,}136\cdot10^{3}$	1

The BPF experimental test was carried out on synchronous generator GAB-4-T/230 at the laboratory. Filter characteristics coincided with the calculated values. It reliably allows revealing at least 2% of short circuits in generator various operating modes.

Conclusion

1. The designed filter fully meets the requirements of the synchronous generator diagnostic system;
2. The band-pass filter designing method is justified for synchronous generator diagnostic system;
3. The efficiency of operationally designed filter is experimentally confirmed.

REFERENCES

1. Gutnikov, V. S. Filtraciya izmeritelnyh signalov [Filtration of measuring signals]. – L.: Energoatomizdat, 1992. – 192 p.
2. Polishchuk, V. I., Novozhilov, A. N. Ustrojstvo zashchity sinhronnoj elektricheskoj mashiny ot vitkovyh i dvojnyh na zemlyu zamykanij v obmotke rotora [Protection device of synchronous electric machine against turn-to-turn and double earth fault in the rotor winding] // Patent № 22450 (KZ). Official bulletin. Prom. Property. – 2010. – №. 4.
3. Polishchuk, V. I. Postroenie zashchity ot vitkovogo zamykaniya v obmotke rotora sinkhronnogo generatora na osnove induktsion-nogo datchika magnitnogo polya rasseyaniya [Construction of protection interturn fault in the winding of synchronous generator rotor based on inductive sensor magnetic stray field] // Bulletin of the Tomsk Polytechnic University. – 2012. – Vol. 321. № 4. – PP. 57-61.
4. Rhodes, J. D. Teoriya elektricheskih filtrov [Theory of Electrical Filters]. – M.: Sov. radio, 1980. – 240 p.

ИСПОЛЬЗОВАНИЕ СОВРЕМЕННЫХ ТЕХНОЛОГИЙ ОБУЧЕНИЯ В ВУЗЕ

А. В. Вельш, О. И. Качалова, Н. С. Суслов

Томский политехнический университет

Российская академия народного хозяйства и государственной службы при Президенте Российской Федерации

Одной из особенностей современного мирового сообщества является все большее углубление процессов глобальной информатизации во всех сферах общественной жизни. От уровня и темпов развития информационных технологий во многом зависят состояние экономики, качество жизни общества, национальная безопасность и роль государства среди мировых