УДК 621.314

I. V. VOLKOV, Member of NASU, chief of the department, IED NASU;
S. V. PODOLNYI, phD, scientist, IED NASU.

CASE STUDY OF INCORRECTLY USED CURRENT HARMONICS MITIGATION SYSTEM

The paper describe a real case of a failed power transformer due to incorrectly applied active mitigation systems for VFD drives. The mitigation system injected high frequency current spectrum into the power system what led to overheating in the system components mainly due to skin effect.

Introduction. Nowadays variable frequency drivers (VFD) become among most common loads in modern industrial power networks. To mitigate the converters input current spectrum both passive and active filters are used [1]. Though notably more expensive, active filters in general guarantee better mitigation level and more compact physical size, what for some applications determines final decision [2]. However, in some cases, the choice can lead to unpleasant results. This paper describes one of them, which happened recently on a Middle East electrical installation.

During the active phase of Middle East region development the electric installation procedures was somewhat chaotic and defined mostly by contractors companies what in several cases was the reason of serious failures. The situation led to gradual adoption of international power quality standards, such as IEEE 519. However even now costly installation errors occur due to lack of the power quality issues awareness.

From the other hand majority of the measuring devices concentrated on the spectrum below 50th harmonic, what is the IEEE 519 limit. For example, the standard states that for the voltage range from 120 V to 69 kV the following conditions have to be meet:

IEEE STD 519-2014

Current distortion limits for systems rated 120 V through 69 kV

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order (odd harmonics)^{a,b}						
I_{SC} / I_L	$3 \le h \le 11$	$11 \le h \le 17$	$17 \le h \le 23$	$23 \le h \le 35$	$35 \le h \le 50$	TDD
< 20^c	4.0	2.0	1.5	0.6	0.3	5.0
20 < 50	7.0	3.5	2.5	1.0	0.5	8.0
50 < 100	10.0	4.5	4.0	1.5	0.7	12.0
100 < 1000	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0

Tab. 1 – IEE519 (2014) limitations

Other voltage levels are also limited up to 50th harmonic. Higher frequencies are usually considered EMI–interferences and applied in different cases, however in this case they are complement and extend the general spectrum.

The case. The measurements on the object were carried out by an advanced cycle–by–cycle measuring complex Elspec G4500 with the following features: voltages (L–L, L–N), currents, power, harmonics (up to the 511th), subharmonics and interharmonics, waveforms, frequency. What allowed to analyze all power quality problems in depth. The measurements were carried out and provided to the authors by Ian C. Evans (Sentinel Power Quality FZE, http://www.harmonicsolutions–oilandgas.com) to whom we express our sincere gratitude.

The main factor of the test was aroused from the 2 MVA transformer failure and in order to prevent future system malfunctions. During the transformer preliminary examination it had notable overheating traces.

The electrical system has several switchboards. To the first one two VFDs with active filters are connected. Fig. 1 demonstrates the switchboard THDi & THDu patterns when the active filters (AF) work or switched off. As can be observed during the short AFs switch off period the system THDu drops, whence THDi rises.

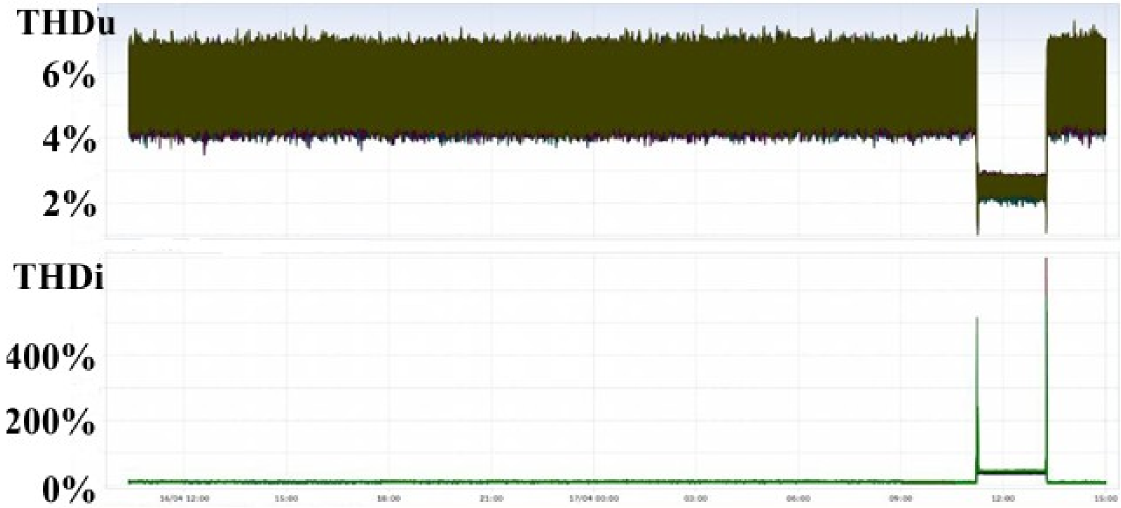

Fig. 1 – THDi (≈5%) & THDu (≈7%) on the first switchboard during the measuring period

The power systems engineers used filters produced by DANFOSS, the THDu reduced from around 6.6% to 2.8% when the filters were switched off. Fig. 2 shows that the AF compensating current works normal in the near spectrum, 5^{th} / 7^{th} / 11^{th} / 19^{th} harmonics are mitigated considerably, however in comparison to other AF models like Comsys ADF or Schneider AccuSine the result is poor. Somewhat similar behaviour was observed on other panels, where this type of filters was employed.

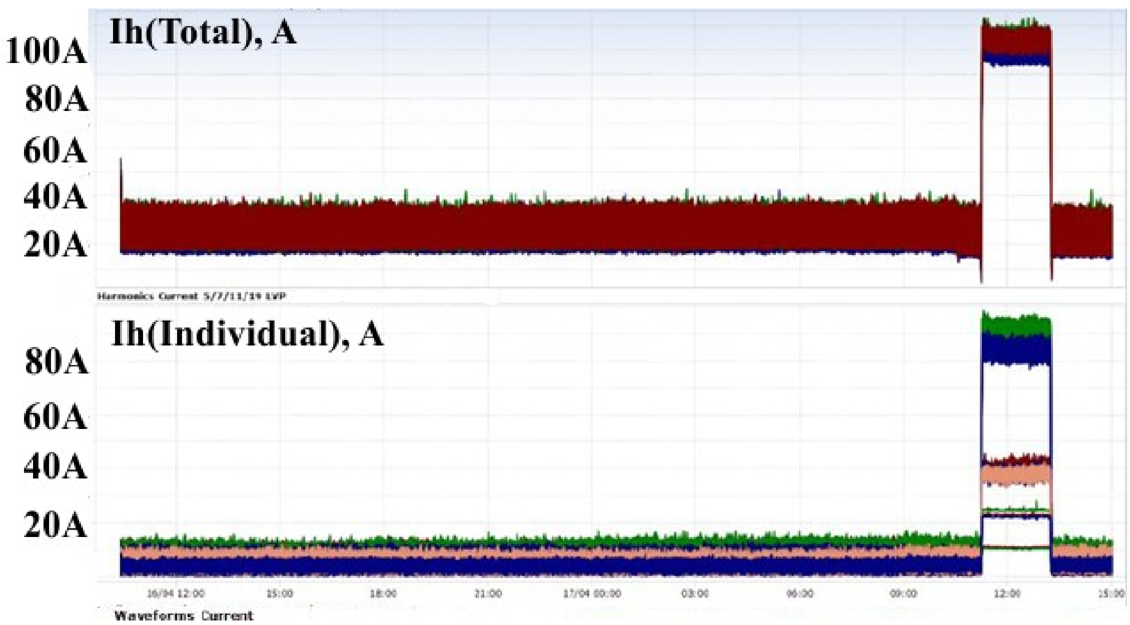

Fig. 2 – 5^{th} / 7^{th} / 11^{th} / 19^{th} harmonics mitigation (magnitudes below)

The 5^{th} harmonic is reduced from 98A to around 15 A, 7^{th} – from 45 A to 9 A, and 11^{th} – from 25 A to 5 A.

Fig. 3 shows the switchboard waveforms during period of maximum THDu 7.38%. On the voltage waveform high frequency components created by the AFs switching algorithms are clearly observed.

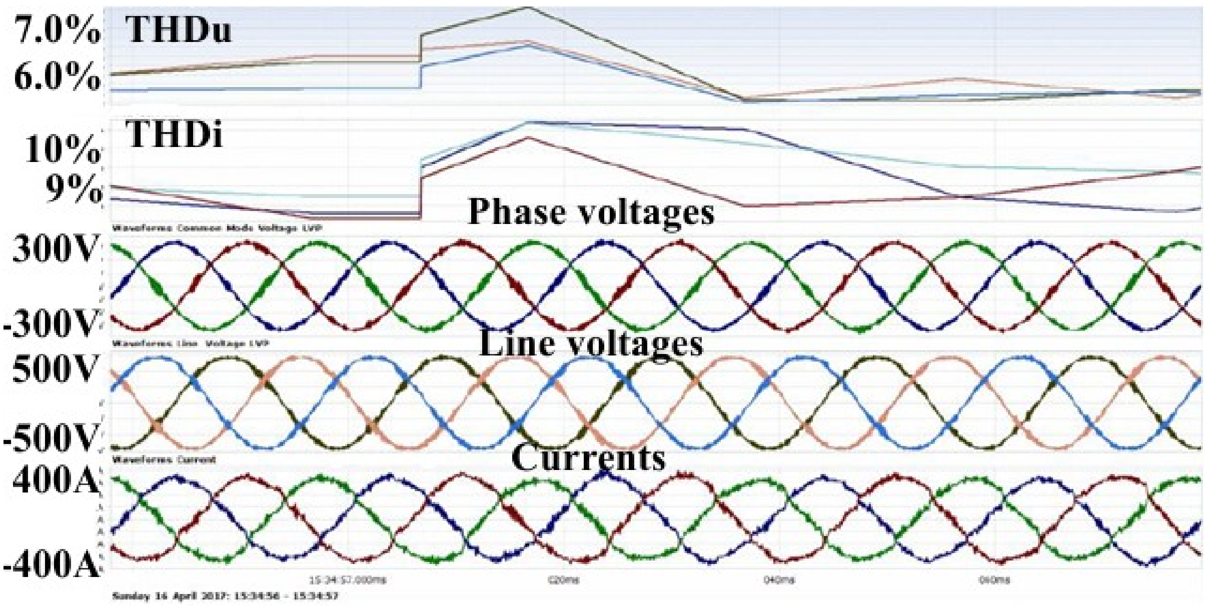

Fig. 3 – THDi / THDu and common mode voltage, line voltage and current waveshapes during period of maximum THDu (7.38%)

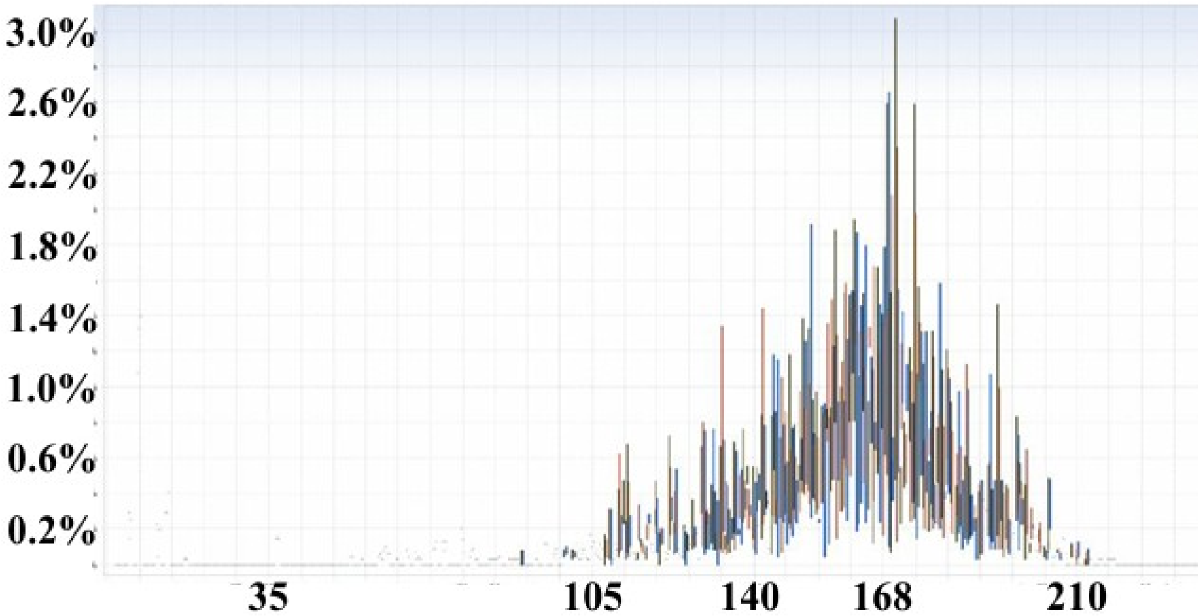

Fig. 4 – Line voltages THDu spectra during period of maximum THDu (7.38%)

The spectrum starts from 89th order (4.45kHz) to 10.9kHz injected by IGBT power devices in the Danfoss filters. Fig. 5 illustrates the corresponding currents spectrums during this period. The harmonic orders below the 50th, which are relatively static and within the limits set by IEEE 519.

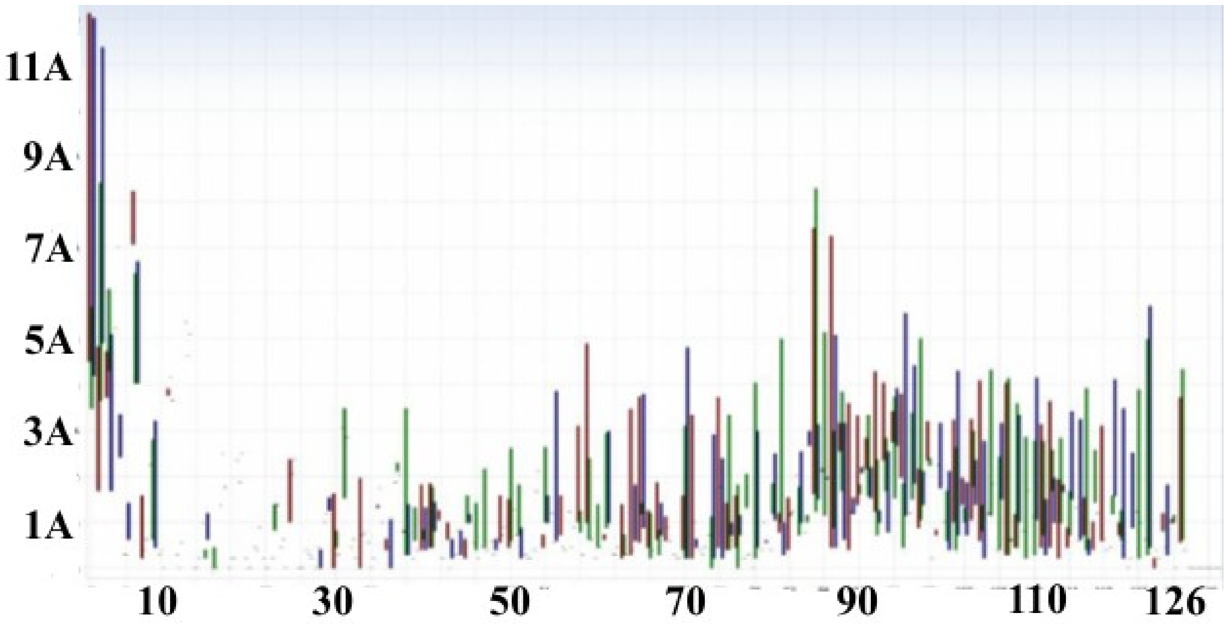

Fig. 5 – Current spectrum during period of maximum THDu (7.38%)

The background voltage distortion was also measured (Danfoss filters switched off).

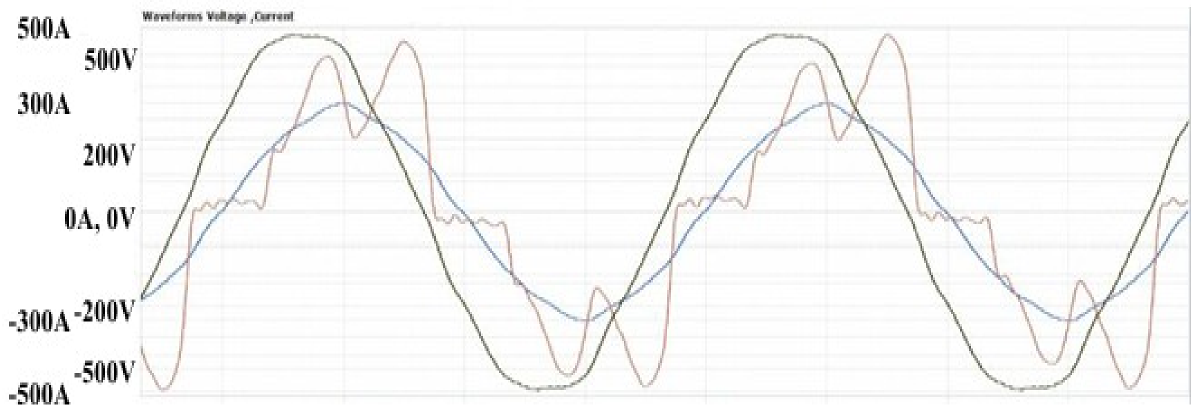

Fig. 6 – Background voltage distortion

During the test THDu for line voltages did not exceeded 2.99%.

Conclusions. The aforementioned case demonstrate real word improper AF commission for VFD–application purposes. Incorrect AF supplier selection, which is not suitable for the task, or mistakes in its grounding system led to emerging of high frequency voltage components in the power system, what can adversely affect motors, transformers and generators due to the effects of increases losses associated with proximity losses, iron and copper losses and skin effect where the outer circumstance of the cable carrying the majority of the current. Excessive common mode voltage (and current) also damage the bearings in VFD fed motors and is very disruptive to sensitive and susceptible electronic equipment. All those features have to taking into account by national electrical designers, which quote active filters from international companies.

List of references: **1.** M.H. Rashid. Power Electronics Handbook. N.Y. Academic Press, 2002. – 895 p. **2.** Harmonic Current Emissions. Guidelines to the standard EN 61000-3-2, 2004-09-06, http://www.epsma.org .

Received 11.06.2017