International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 9 (2017) pp. 2027-2030

Electric Power Quality Distortions Influencing Oil Processing Plant Parameters and Characteristics

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Abstract
Studies have been conducted in connection with electric power quality under conditions of actual equipment at the electro-technical complex of LLC "Kirishinefteorgsintez" oil processing plant. Disclosed are the values for distortion coefficient of the voltage sinusoidality curve in the mains in connection with higher harmonics spectrum of 6k±1 (5,7,11,13,17) that demonstrated that the sources thereof are the 6-pulse frequency convertors of adjustable drives. Unfavorable effect has been proved for the current and voltage higher harmonics to influence electric current receivers causing additional losses in electric machines, transformers and networks, insulation aging, degradation of capacitors, relay protection and automation tools, decreasing the reliability of electricity receivers operation at the oil processing plant.
Steps for normalizing the electromagnetic conditions and lowering non-sinusoidality of voltage include: scheme measures, using filtering devices, using dedicated equipment with lower higher-harmonic disturbances generation.

Keywords: electric power supplies quality, voltage higher harmonics, electro-technical complex, oil-processing plant.

INTRODUCTION

Distinctive features of national oil processing plants at the modern stage of development include:

1. Large power consumption, with total power consumption of electricity receivers exceeding 100MW.
2. Joint work of different technological process equipment, with different design and construction time, different approaches to design.
3. Ever-going implementation of new and upgrading the existing equipment, aimed to deep oil processing (approaching 64%) under the conditions of mass employment of frequency-regulated drive.

In connection therewith, and also because power component of the prime cost of oil processing is 15% and tends to increase, developing electro-technical complex of an enterprise faces challenges in connection with electromagnetic compatibility issues. The electromagnetic compatibility level is an important metric characterizing the electromagnetic conditions that guarantees normal operation of and interaction between all technical devices that may interfere or be interfered.

At production enterprises, the most common are power transformers with nominal power of 1000 kVA with voltage 6/0.4 kV (more than 60% of all power transformers). Therewith, the power to be consumed by frequency transformers, as part of electro-technical complexes at such enterprises, achieves 10% of the total production enterprises power. A rectifier that feeds the frequency convertor invertor is designed in accordance with three-phase bridge scheme. That results in higher harmonics curve of the 6k±1 order in the current consumed. There is a trend for increasing the number of such drives and the total power thereof.

RESULTS OF STUDIES

The terms of technological process suggest the transformer load at power substations at oil processing plants approaches 40% per bus section, i.e. 0.4. relative units (r.u.) of power transformer 6/0.4 kV (as the basis, the nominal power of the most common power transformer type, 1000kVA, U_{base} = 6kV, is taken). Power supply system inductive impedance, with feeding power system taken into account: Xs $=3.33.10^{-4}$-$6.66.10^{-4}$ r.u.

Electromagnetic compatibility characterizes not only the interaction between electric devices, equipment units and electromagnetic environment, but also the interaction of those technical tools in between. [1]

The quality of electric power, being the component of electromagnetic compatibility, as defined by electric power indicators (EPI), as set forth by GOST R 13109-97 (GOST R 32144-2013) characterizes electromagnetic environment, where electric receivers operate. [2], [3]

EPI is noticeably influenced by electric power lines parameters, while electric receivers and devices may be connected thereto in different points along the line. A good example may be the values of voltage at electricity receiver (ER) terminals, depending on the electrical circuit length and circuitry. In turn, ER, too affects the indicators of electric power supply quality, introducing voltage distortions.

Because oil processing technological process includes multiple oil transportation operations with specific temperature to be kept, electro-technical complexes are characterized with multiple adjustable drives, which, in accordance with the studies undertaken at LLC "Kirishinefteorgsintez", are the sources of higher harmonics of current and voltage, as those drives use asynchronous engines and frequency convertors. Such electricity receivers consume electric current the shape of which is different from the sine one, therefore, creating voltage drops in electric power mains elements to be defined by harmonic composition of the current curve, being in fact the cause for distortion of voltage/current sine shape in one or another point in the network. [7]

Allowed distortion coefficient values for voltage curve sine shape, in accordance with regulation norms in the Russian Federation, at the points of shared access to electric power mains with different nominal voltages (U_{nom}) are presented with the table 1.

Table 1

Normally allowed value under U_{nom}, kV				**Maximum allowed value under U_{nom}, kV**			
0.38	6-20	35	110-330	0.38	6-20	35	110-330
8.0	5.0	4.0	2.0	12.0	8.0	6.0	3.0

During the studies at distributing substations, the 0.4 kV busses of which were connected to frequency convertors ACS-600 (ABB), oscilloscope charts for voltage were obtained. To register harmonics spectrum, a system was used, the system comprised a digital oscilloscope DSO 2100. While measuring harmonics, the corresponding frequencies were compared to the basic one to be isolated from the remaining part of spectrum with an internal digital filter. The oscilloscope was used to record the voltage curves in spectrum analyzer mode. Current and voltage curves, as well as current/voltage harmonics spectra, were duplicated with spectrum analyzers Fluke 41 B and 43 B. Aperture error of the measuring complex did not exceed 1.5%. [9]

The oscilloscope chart from the figure 1 for voltage demonstrates the voltage curve shape at 0.4 kV busses is different from the sine one.

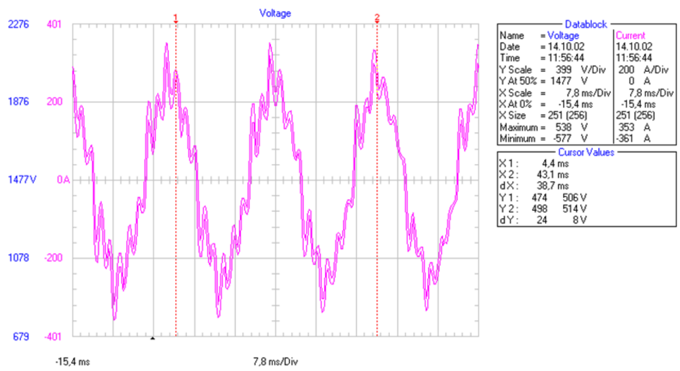

Figure 1: Figure 1. The oscilloscope chart for voltage at 0.4 kV busses.

As result, for analysis of harmonic composition of the voltage (fig.2), for nominal equipment operation mode, the following peaks of the higher harmonics in the spectrum 6k±1 (5,7,11,13,17) showing that the source thereof was the 6-pulse frequency convertor.

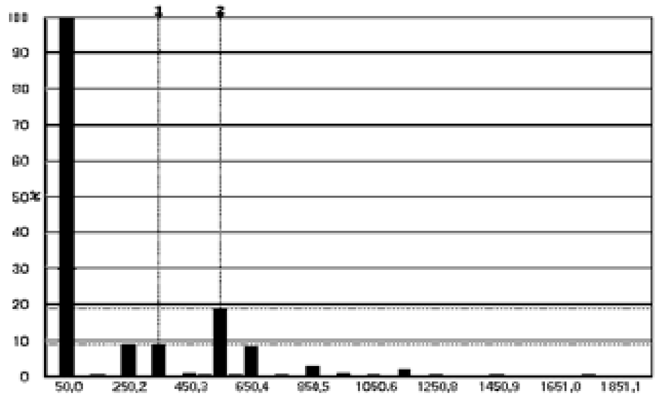

Figure 2: Harmonic composition of voltage at the oil processing substation busses.

Non-sinusoidality of voltage affects all kinds of electricity receivers. This results from the additional heating by electric insulation die to the current higher harmonics. The higher harmonics form direct sequence components (1, 4, 7, etc.), reversed sequence components (2, 5, 8, etc.) and those of the zero one (harmonics that can be divided by three). In particular, zero sequence currents additionally magnetize the steel in electric devices, making their characteristics worse and additionally heating the cores (asynchronous engine stators, voltage transformers). [4]

Current and voltage higher harmonics influence power coefficient values, engine torque values. Studies revealed that the level of additional active losses due to higher harmonics in oil processing enterprise power mains may approach as much as 10-15%. [11]

At oil processing plants, capacitor banks facilitate creating conditions that are close to those that form currents resonance at a frequency of one of harmonics, and that results in dangerously overloading them by current. The studies revealed the specific harmonic meeting those requirements is the 11-th one (figure 2).

Capacitor banks, where losses are proportional to frequency, have higher harmonics as the cause for additional heating of capacitor causing permanent damage thereof.

$$\Delta P = U^2 \omega C tg\delta \qquad (1)$$

Restrictions of capacitor bank additional heating correlate with allowed increase of voltage on terminals up to 10% of the U_{nom} and the actual current value up to 30% of the I_{nom}. Besides, increasing the non-sinusoidality coefficient results in insulation premature aging, the quality of which is characterized with tgδ. Operating the capacitor bank (CB) with non-sinusoidality coefficient K_u=5% results in tgδ increasing twice. [6]

$$\Delta P_{CB} = C\omega tg\delta \sum_{n=2}^{40} U_n^2 n, \qquad (2)$$

where Un is the actual value of voltage of the n-th harmonic. [12]

Studying influence by voltage non-sinusoidality on oil processing plant electricity receivers verified the dependences evaluating the additional power losses for various electric equipment pieces resulting from the current higher harmonics. [4]

Asynchronous engines (AE):

$$\Delta P_{AE} = \Delta P_{м1ном} I_n^2 \sum_{n=3}^{40} \frac{\sqrt{n} + \sqrt{n \pm 1}}{n^2}, \qquad (3)$$

where $\Delta P_{м1ном}$ - are the losses in stator copper with nominal main frequency current; I_n - is the starting current multiplicity factor under nominal voltage of the main frequency;

$\sqrt{n+1}$ - are the harmonics creating rotation fields that are opposite to the main frequency field. $\sqrt{n-1}$ - are the harmonics that create rotation fields with the same direction as the main frequency field.

Power transformers (PT):

$$\Delta P_{PT} = \Delta P_{xx} K_U + 0{,}607 \frac{\Delta P_{кз}}{U_к} \sum_{n=2}^{40} \frac{1 + 0{,}05n^2}{n\sqrt{n}} K_{U(n)}^2, \qquad (4)$$

where $K_{u(n)} = \frac{U_n}{U_{nom}}$ is the relative voltage of the n-th harmonic.

The same relates to cable that are similarly vulnerable to higher harmonics, where the insulation quality is characterized with fault current. With K_u=6.85%, operating the cable for 2.5 year results in increasing the fault current for 36%, the same for 3.5 years is 43%.

CONCLUSION

The studies undertaken on real equipment revealed power losses by major types of electricity receivers at oil processing plant due to current/voltage higher harmonics. The total power loss may be as high as 4.31%.

Steps for normalizing the electromagnetic conditions and lowering non-sinusoidality of voltage at oil processing plants may include:

1. Scheme measures to reveal non-linear volt/ampere electricity receivers to be connected to the dedicated bus system.
2. Using filtering devices. [8], [10]
3. Using dedicated equipment with lower higher-harmonic disturbances generation. (Using multiphase convertors, "unsaturable" transformers).

The results of studies and the recommendations in connection therewith are now studied by relevant services of LLC "Kirishinefteorgsintez" oil processing plant for the possibility of implementation.

The presented results were obtained as a part of scientific researches according to the contract № 13.3746.2017 within the scope of the State task "The designing on the base of systematic and logic probability evaluations of rational and economically proved structure of centralized, autonomous and combined power supply systems with high reliability and stability level with usage of alternative and renewable power sources for uninterrupted power supply of enterprises with continuous technological cycle".

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