Electric power quality control in electro-technical complexes of oil processing plant

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Abstract. The paper deals with electric power quality research, in the load buses of the electrical networks of oil processing plant (“Production Association “Kirishinefteorgsintez”, LLC). Measurements were carried out under conditions of operating equipment at the distribution substations of the enterprise and at the division boundary of inventory responsibility with the power-supply system at the points of power transmission from the power-supply system to the industrial consumer. Assessment of the allowed contribution to the deterioration of electric power quality showed that at the increase in the rated capacity of drives based on frequency converters over 12% of the total installed capacity of electricity receivers of oil processing plant, the maximum allowed voltage waveform distortion coefficient values at the points of power transmission will be exceeded. To implement normalizing the electromagnetic environment and lowering non-sinusoidality of voltage, proposed is a system of measures, that allows controlling electric power quality indicators within the limits, stipulated by regulatory documents, resulting to reducing the risk of penalties by the power-supply authority and large scale undersupply of products under conditions of continuous technological cycle.

1. Introduction

Electric power quality is closely related to the security of supply, since the normal mode of power supply to consumers is deemed to be a mode, wherein the consumers are provided with uninterruptible power supply of standardized quality, in amounts agreed in advance with the power supply authority.

According to the present-day state of energy sector of Russia, with energy performance of power complexes at industrial enterprises being one of the promising directions for the development, electric power quality is one of its main components.

Priority directions for the development of oil processing plants involve measures to improve oil processing and energy saving during petroleum products production.

The total capacity of electricity receivers used during the technological process at modern oil processing plants exceeds 100 MW. The most commonly used in the power supply system of oil processing plants are power transformers with rated capacity of 1000 kVA and voltage of 6 (10)/0.4 kV (more than 60% of the total number of power transformers).

Herewith, the installed capacity of electric drives with frequency converters, included in the electro-technical complexes of such enterprises, reaches 10% of the installed capacity of the oil processing plant. The rectifier, that feeds the inverter of the frequency converter, is designed according to a three-phase bridge circuit. There is a tendency towards increasing the number and installed capacity of such drives.
According to the conditions of the technological process, the converting load on the power substations of the oil processing plant reaches, per bus section, more than 40% of the feeding transformer capacity of 6(10)/0.4 kV.

In connection therewith, as well as owing to the fact, that the energy component in the prime cost of oil processing is 15% and has a tendency towards continuously increase, the studies to determine electric power quality of the electro-technical complex of "Kirishinefteorgsintez" oil processing plant have been carried out.

2. Results of studies
Measurements of electric power quality indicators have been carried out under conditions of operating equipment at distribution substations of the oil processing plant at the division boundary with the power-supply system. Voltage waveform distortion coefficient values in the mains in connection with higher harmonics spectrum of 6k ± 1 (5, 7, 11, 13, 17), showing that the sources thereof are 6-pulse frequency converters of a controlled drive, were revealed.

Based on data on equipment repair and insulation measurement protocols, negative influence by high harmonics in current on electricity receivers, causing additional losses in electric machines, transformers and networks, insulation depreciation, deterioration of the operating conditions of shunt capacitive compensation devices (SCCD), relay protection and automation tools, decreasing reliability of electricity receivers operation at the oil processing plant, has been proved [1, 2].

Under conditions of oil processing plants, capacitor banks contribute to creating conditions close to the resonance of currents at a frequency of any of the harmonics, which results to dangerous overloading by current [3, 4, 5, 6].

To determine the influence of capacitor batteries on the level of conductive electromagnetic interference in the electric mains of the enterprise, under conditions of varying the operating mode parameters of SCCD, studies of the operating modes of electrical equipment, connected to the bus sections of the studied power sub-stations, have been conducted. When changing the operating mode of SCCD within the range of 0 ÷ 100% at a pitch of 25%, an increase in voltage non-sinusoidality ratio by 7 times and more was revealed. This phenomenon and the presence in the current, consumed by SCCD, 19% of the current component of the 11th harmonic confirms the presence of a resonance of higher harmonic currents in the electric mains. In this case, the currents at the terminals of the capacitors exceed their rated value by 1.54 times.

Therefore, despite the fact that the capacitor unit allows to increase power factor (cos ϕ) from 0.81 to 0.98, its inclusion on the bus section on the side of 0.4 kV seems to be inexpedient without taking measures to improve power quality in the load bus of the electric mains.

To check the possibility of higher harmonics penetration to a level of 6(10) kV, the levels of higher harmonics on 6(10) kV buses of the power supply centers of oil processing plant have been measured. It was revealed that attenuation of current/voltage higher harmonics by several times, during the penetration of electromagnetic interference, propagating in 0.4 kV networks to the 6(10) kV side, owing to the presence of only magnetic coupling of the windings of power transformers, is favorable to the arrangement of SCCD on the 6 (10) kV side.

Based upon the current regulatory documentation and existing techniques for measuring, controlling and analyzing electric power quality, an assessment of the allowed contribution to the deterioration of the electric power quality by oil processing plant electricity receivers at the division boundary with the power-supply system was made [7, 8].

The assessment of the allowed contribution to the deterioration of electric power quality was carried out by the level of non-sinusoidality of voltage.

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The measurement of the nth harmonic voltage component $K_{U(n)}$ was carried out for linear voltages [9, 10, 11].

The value of the nth harmonic voltage component $K_{U(n)}$ in percentage form as a result of averaging N observations $K_{U(n)}$ within the time interval $T_{vs}$ equal to 3 sec:
The consumer's requirements concerning the allowed level of harmonic emission in the power-supply system at the point of common coupling are determined by the expression:

\[ K_{U(n)} = \left( \sum_{i=1}^{N} (K_{U(i)})^2 / N \right)^{1/2} \]

The normal permissible value of the nth harmonic voltage component coefficient is calculated using the formula:

\[ K_{U(n)\text{pred}} = 1.5 K_{U(n)\text{ind}} \]

where \( K_{U(n)\text{ind}} \) is the normally allowed value of the nth harmonic voltage component coefficient, according to Table 1.

As a result of processing the data of industrial experiments, it was established that with a change in the power of the transverse capacitive compensation installations from 0 to 120 kvar, the non-sinusoidality coefficient in voltage and current increased and amounted to about 3% in voltage and 17.5% in current. The presence in the current consumed by the installation of a high value of the component of the current of the 7th (350 Hz) harmonic indicates the presence of a resonance of higher harmonic currents in the network. The non-sinusoidal current level with the transverse capacitive
compensation unit turned on is presented in Figure 1.

![Figure 1](image)

**Figure 1.** The higher harmonics spectrum in the site of the electrical network of the enterprise when connecting installations of transverse capacitive compensation of 120 kvar. The value of the non-sinusoidal current coefficient is 17.5%.

Research results shows, that the widespread introduction of frequency-controlled drives, which are the main source of voltage waveform distortion, results to an increase in the allowed contribution to the deterioration of electric power quality by electricity receivers of the oil processing plant at the division boundary with the power-supply system.

Thus, with an increase in the installed capacity of drives based on frequency converters over 12% of the total installed capacity of electricity receivers of the oil processing plant, the maximum allowed voltage waveform distortion coefficient values at the division boundary with the power-supply system will be exceeded.

3. **Conclusion**
Consequently, in combination with the widespread introduction of controlled drives, as the most cost-efficient steps, while producing petroleum products, under conditions of oil processing plant, scheme measures, the use of filtering devices, the use of special equipment, characterized by low level of higher harmonics emission in the mains, can be proposed for normalizing the electromagnetic environment and lowering non-sinusoidality of voltage.

The results of studies and the measures developed in connection therewith are examined by the energy services of “Production Association “Kirishinefteorgsintez”, LLC with the aim of implementation.

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