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Power systems with improved energy performance

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This article focuses on reduction of the power factor. It presents the research of power supply with improved energy performance taking a reverse thyristor converter as an example.

Definition of active and reactive power has an obvious physical meaning for circuits with a sinusoidal voltage and current. Active power P characterizes fraction of the instantaneous power (s = ui) which can be converted into other forms of energy (thermal, mechanical, chemical, electromagnetic and others). Reactive power Q characterizes the exchange energy between the source and the load, which loads the circuit (it creates interference) but it can't be used useful. Vector sum of active and reactive components of the current (voltage) in a circuit leads to a geometric addition of active power P and reactive power Q in the resulting power called the apparent (full) power: $S = \sqrt{P^2 + Q^2}$.

Full power is a calculated value that characterizes the resource costs of device implementation. In other words, full power characterizes the total cost (in a scale) resources (copper, steel, insulation and so forth) for the implementation of this device.

Determination of the total power is significantly complicated when energy processes of a circuit are non-sinusoidal. Nonsinusoidal processes arise due to the presence of non-linear elements in the load. This leads to appearance of higher harmonics in the current and voltage waveforms.

It is known, that useful work in a load can be performed only by the power which is carried by the first harmonic. All harmonics transfer power, which, as well as reactive power Q, characterize the energy exchange between the source and the load. This energy can't perform useful work in load, but its physical nature completely differs from the physical nature of reactive power Q.

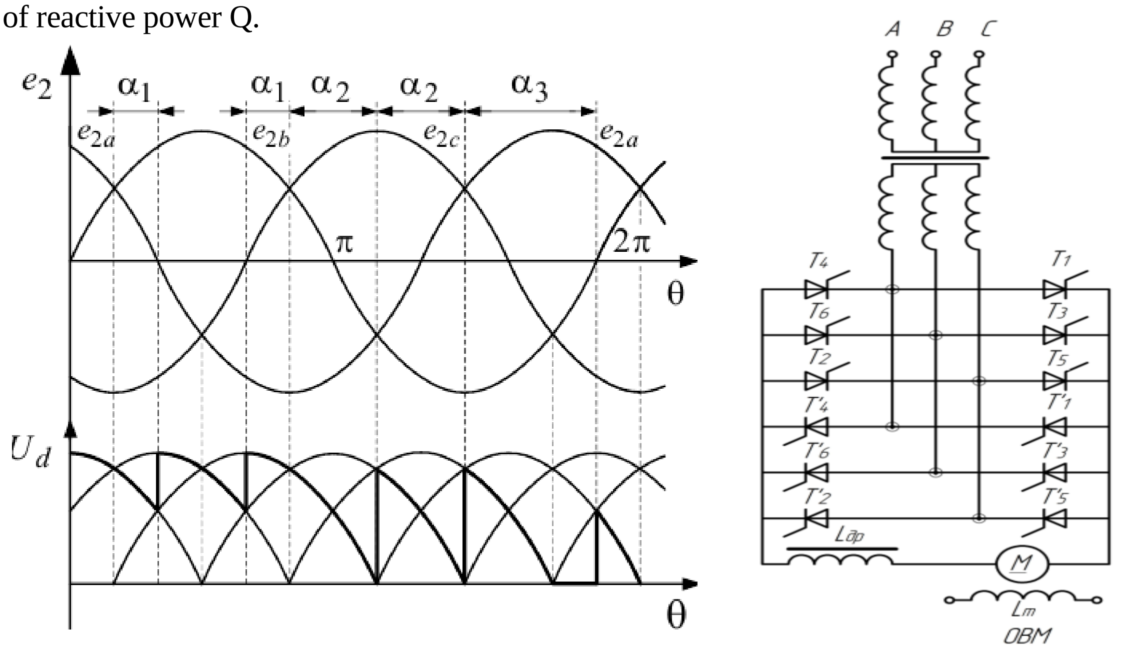


Figure 1 – Three-phase bridge anti-parallel circuit and a diagram explaining the operation of the scheme.

Voltage unbalance in three-phase circuits with non-uniform loading phases provides a similar impact on the mains supply. It leads to a considerable complication of determining the total power and estimation of the influence of electrical installations in networks.

At present, the evaluation of the negative impact of these factors in the supply mains is carried out by using the full power factor. It is the ratio of active power PA and apparent power S: $\chi = P_a / S$.

Full capacities consider not only the active P and reactive power Q, but also distortion power T, which is carried by higher harmonics, and unbalance power N, which is carried by the reverse sequence and zero sequence of currents: $S = \sqrt{P^2 + Q^2 + T^2 + N^2}$.

Today the problem of harmful effects reduction at electrical installations in supply networks is an important task in the global electrical engineering because it is a very important economic problem.

The power section of conversion device is a reverse thyristor rectifier which is made by a three-phase bridge circuit. Also it includes a power (matching) transformer, control system and protection system of the drive. Rectifiers connect antiparallel, power kits are separately controlled (Figure 1).

Anti-parallel circuit with close-coupled thyristor groups is the most promising circuit with separate management. This design significantly reduces the size reversible converter.

Influence of electric power systems to the thyristor converter is shown by the distortion of current and voltage of synchronous generators, increase of additional losses in generators, induction motors, transformers, trouble with the automatic and computing machinery, network loads by additional reactive power and distortion power, reduction of the power factor.

Network impact on the thyristor converter increases the harmonics of the rectified voltage, reduces stiffness characteristics of the external transducer malfunction, control systems of a thyristor converter.

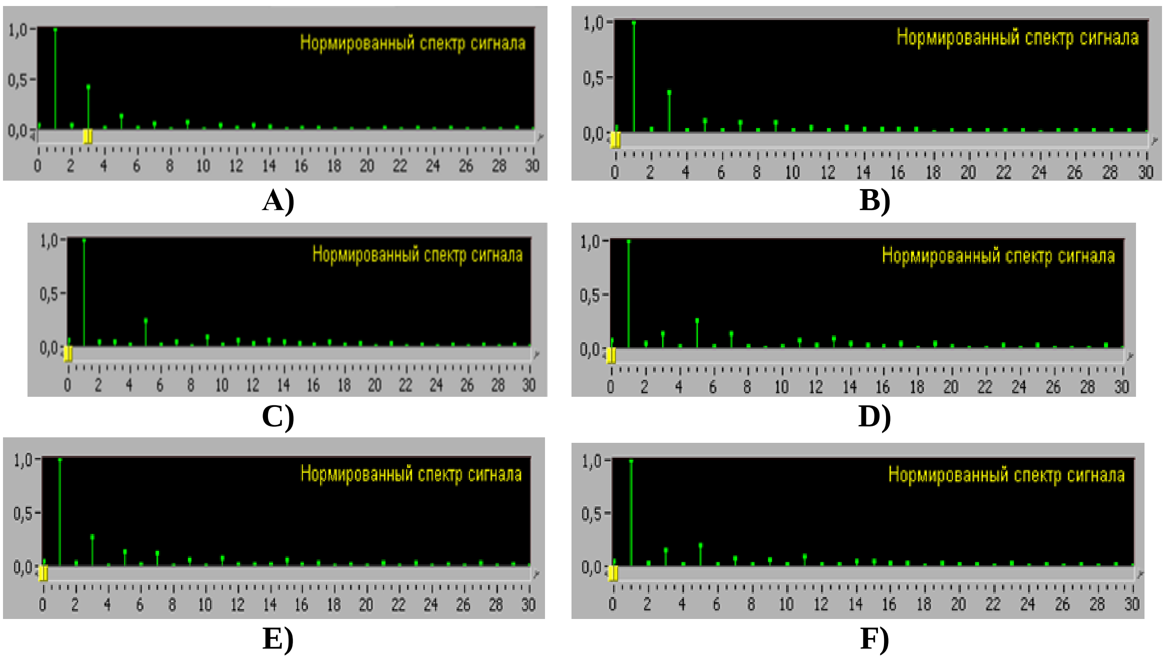


Figure 2 – The amplitude spectrum of input control current harmonics for angles A) α=10°, B) α=20°, C) α=30°, D) α=40°, E) α=50°, F) α=60°.

Experiment

It is necessary to determine the harmonic composition of the rectified voltage and current of a three-phase bridge, which is controlled by a rectifier, that works with an active-inductive load (Figures 3,4).

Amplitude spectrum of harmonics current consumption for different angles control α was defined. Results are presented in Figure 2.

Odd harmonics (3, 5 and 7) have most powerful influence on the operation of the converter. The third harmonic can be significantly reduced by the schematic. If the primary windings are connected in a triangle, then all the harmonics in the secondary currents are transformed curve from the secondary windings in the primary. At the same harmonics with a serial number, which are multiples of three, closed inside the triangle of primary windings and do not penetrate into the mains supply.

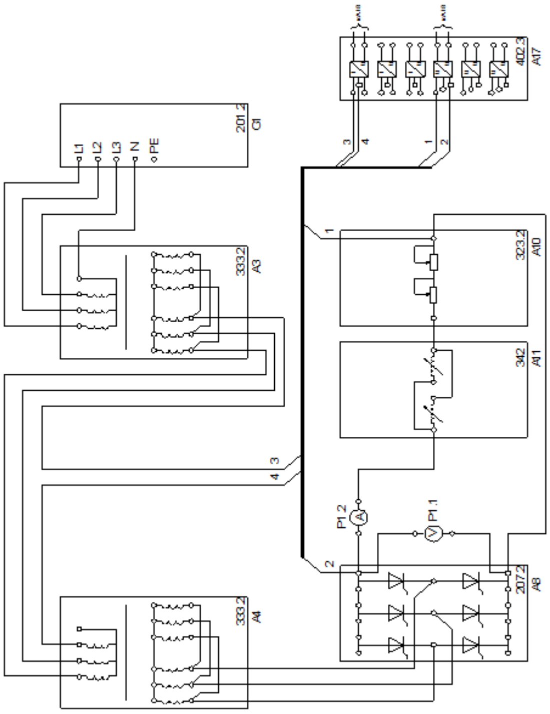


Figure 3- Electrical scheme.

When the primary windings are connected in a triangle, diagram magnetically balanced. Therefore, the primary windings of converter transformers expedient to combine into a triangle (Figure 5).

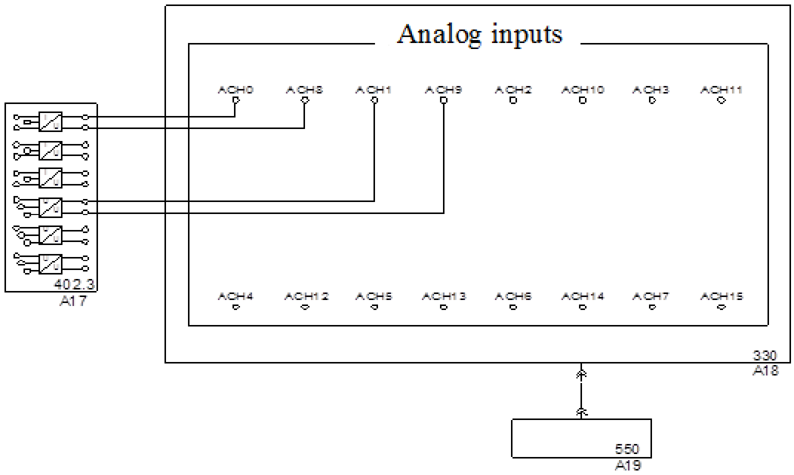


Figure 4 – Electrical scheme.

The fifth harmonic can be greatly reduced by using a parallel LC – filter tuned at 5 harmonics in each phase of the transformer secondary winding.

Resonance occurs in a parallel resonant circuit with the resonance condition current when the current in the inductance and capacitance filter equal in magnitude and opposite in phase. As a result, the resulting harmonic current is zero (Figure 5).

7 harmonic also has a significant impact on the operation of thyristor converter. However, its removal is not economically viable, as it would require the installation of another filter. The installation of the filter will take more money than could have been saved in eliminating harmonic 7. The power factor χ for different control angles was calculated.

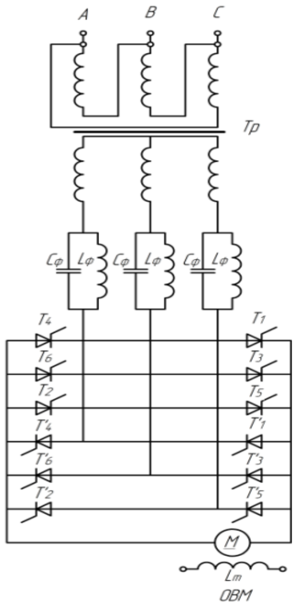
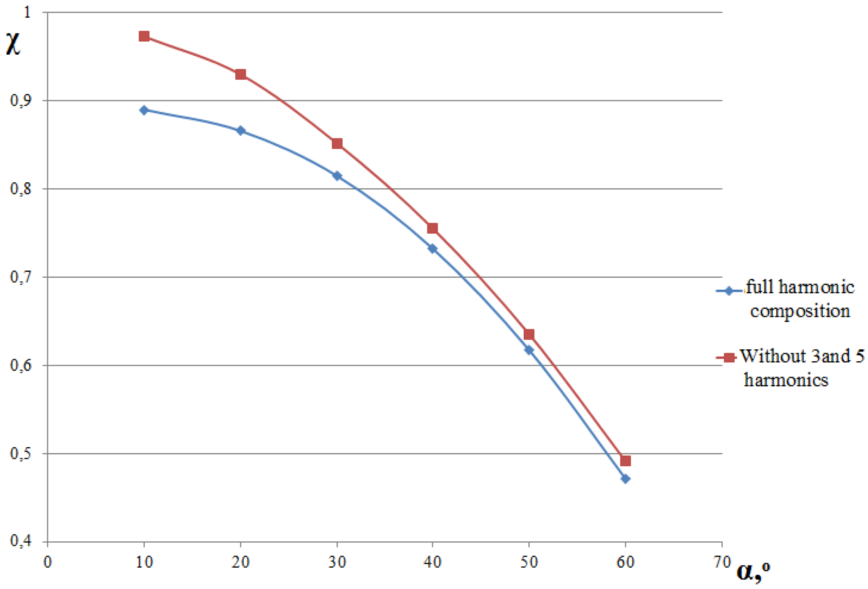


Figure 5– Controlled three-phase bridge rectifier with LC-filter.



According to this graph shows that the power factor is significantly improved, especially for control angles α = 10 ° ÷ 30 °. The obtained results are fully consistent with the theory.

Figure 6 (left) – Dependence χ=f(α).

Verification

An experiment was conducted and 3 harmonics have been removed. Amplitude spectrum of harmonics current consumption for different angles control α was defined. Results are presented in Figure 7.

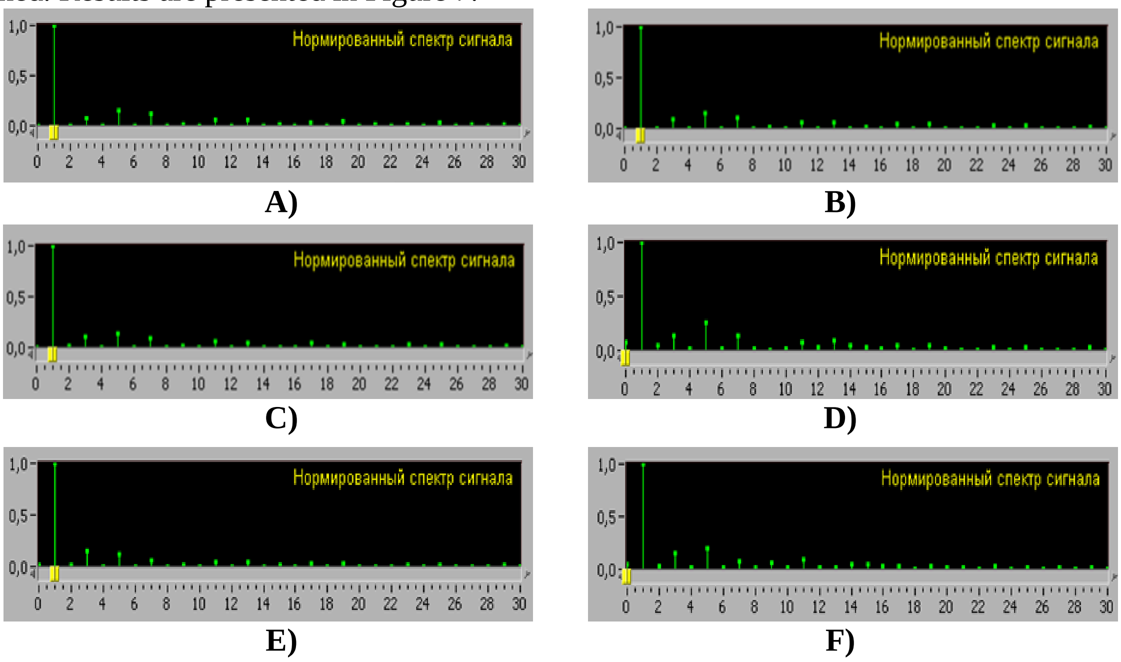
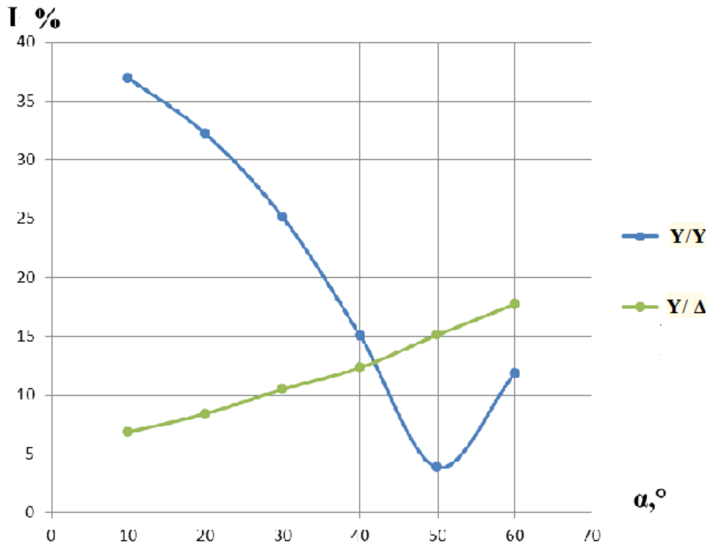


Figure 7 – The amplitude spectrum of input control current harmonics for angles A) α=10°, B) α=20°, C) α=30°, D) α=40°, E) α=50°, F) α=60°.

From the results it can be seen that the dependence of the third harmonic is greatly diminished. Theoretically, the third harmonic should be zero when it connects the transformer primary winding in a triangle, but in practice, due to the switching processes the third harmonic can't completely disappear.

This article describes the measures taken to reduce the impact of higher harmonics of the frequency converters. Thus, the third harmonic is substantially reduced by the schematic, connecting the primary windings of the transformer in the triangle. All data of theoretical calculations were verified experimentally, the amplitude of the third harmonic is really noticeably diminished. Fifth harmonic has been significantly reduced by parallel LC – filter,



which is tuned to the frequency of the 5 harmonic. Problem of energy saving is one of the most important moment in the world. Therefore, improving the power factor can significantly reduce the loss of electricity.

Figure 8 (left) – Dependence of the percentage of the third harmonic on the input current from the control angle α.

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Power apparatus and systems malfunction diagnostic on the basis of its own electromagnetic emission analysis

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With the modern strategies development in order to organize the main electrical substation equipment, power lines maintenance and repair there appears so called "on-condition" [1] repairs concept. In this respect, technical diagnostics becomes extremely important in any industries. The Economic Effect of high voltage equipment diagnosis is associated with its ability to determine the current technical condition and equipment residual life for detecting defects at an early stage of their development and the really required repair works. Nowadays there are a lot of different technical diagnostics methods but the most preferable are the automated methods of controlling the state of the energized equipment [2-4].

One of the perspective diagnosis methods that are able to determine the technical state of the object and track the defects dynamics is to analyze the changes in the electrical equipment electromagnetic radiation.