KAPITEL 2 / *CHAPTER 2* [2]
ENHANCING POWER QUALITY WITHIN THE CONTEXT OF INDUSTRIAL ENTERPRISES: STRATEGIES FOR IMPROVEMENT

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Introduction

Wide experience has been accumulated by now in the field of research concerning power quality effect on the operation of cage-rotor asynchronous motors. For instance, while studying the problems, connected with qualitative estimation of damage by the abovementioned electromechanical converters operating under the conditions of supply voltage asymmetry, authors of paper [1] have concluded that at k_{2U}=3.5% value, motor winding temperature increases by 25%. Paper [2] has determined that operation life of an asynchronous motor halves, if voltage unbalance ratio increases by 4% in terms of negative k_{2U} sequence.

Paper [3] points out that operation of an asynchronous motor (AM) under the conditions of supply voltage anharmonicity involves such negative factors as decrease in the power coefficient and in the torque on the electric machine shaft. It has been defined that each 2.5% of voltage increment factors into 3-3.9% loss in the asynchronous motor as well as in almost 5% increase of the consumed reactive power which influences negatively its power efficiency [3].

It is also known [4] that if noisy supply voltage takes place, attention should be paid to electrical drive systems since the abovementioned results in their decreased reliability and efficiency with the following significant decrease in technical-and-economic indices of numerous production operations. Increase in the capacity loss within asynchronous motors with their excessive heat happens when power quality deteriorates. In turn, that favours intensive insulation deprecation and its fault.

Spontaneous failure of electric motor, being in a production line, may also factor into sizeable economic damage. Moreover, higher harmonics and asymmetrical modes stipulate underutilization of reactive power compensation means (i.e. capacitor banks

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and synchronous compensators) resulting in the decreased power factor of the whole enterprise. In addition, electricity bills grow even in terms of the current rates; the payments dominate in the total cost of capital expenditure and operating expenditure of the majority of electrical facilities used in industries [3].

Specifically, during a year, low- and average-power transverter consumes the amount of electric power that exceeds the cost of the motor by 3-5 times [5]. At the same time, up to 75% of the production power is consumed by AM of the capacity (i.e. up to 75 kW). Thus, even 1% decrease in the motor efficiency due to noisy electricity is substantial economic damage for any enterprise.

On the whole, three basic components of economic damage source are considered: technological, power-producing (electromagnetic), and the one connected with the electric drive life loss. When electric drives consume noisy power, the component one is calculated relying upon the installed equipment cost, probabilistic failure characteristics, and other parameters [3]. The factor, determining the considered technological component, is the reliability degradation of electric drive system caused by the accelerated insulation ageing due to its excessive heat as well as the elevated vibration of the mechanisms and related failure of mechanical engineering assemblies. The listed results in AM fault; moreover, if the motor is a component of technological equipment, quality deterioration of the output product or its quantity decreases.

Taken as a whole, technological component of the damage is expressed by the performance degradation and quality deterioration of the output product, and is determined completely by specific character of the production. Taking into consideration the fact that the most popular malfunctions of drives of pump systems, compressor systems, and ventilation systems result usually in insignificant values of the first damage component, only the latter is of great interest.

Therefore, it is understood that power engineers of enterprises face the necessity to implement measures reducing negative effect of noisy electricity on the energy efficiency of an enterprise. Use of “individual” LC-filters [6] to protect extra important electric drives; use of “group” devices to compensate negative effect of noisy electricity at a workshop level (power active rectifiers are meant with their potential integration into the available converters for the controlled electric drives); and to inhibit voltage distortions within the areas of their origination (i.e. the mains protection against the root cause) are possible means to solve the problems.

The latter is determined by the specific nature of the considered facilities. Moreover, it may involve modernization of a power part of electric drive as well as systems of the automated control; proper selection of the electric drive parameters etc.

The refusal to implement certain measures can also be permissible if they are not expedient economically. Indeed, each of the alternations is characterized by its specific measures: implementation cost and economic efficiency. Nevertheless, despite the problem topicality, Ukraine has not the unified methods to make economically sound decisions to reduce negative effect of noisy electricity on the energy efficiency of an enterprise.

Consider the basic available methods to improve power quality within the mains of enterprises or their workshops [6]. They are classified in terms of quality indices which improvement is supposed: asymmetry, harmonicity distortion etc. The current tendencies involve the most promising developments in the area: active filtration of supply voltage and use of passive resonant filters.

The purpose of this chapter is to substantiate the most effective means of protecting an AM from the negative impact of low-quality electricity in electrical networks of industrial enterprises.

2.1. Optimizing Power Quality in Industrial Environments: Key Improvement Strategies

Essentially, active filters [7] for three-phase consumers are autonomous converters with a condenser installed in the direct current link. Action of the device is as follows: voltage is redistributed between phases at the expense of energy accumulated within its capacitor element. To do that, control system of converter keys is added by sinusoidal reference signal in each phase and a feedback signal on the current within phases of the supply mains.

Fig. 1 demonstrates the simplified circuit schematic of the device.

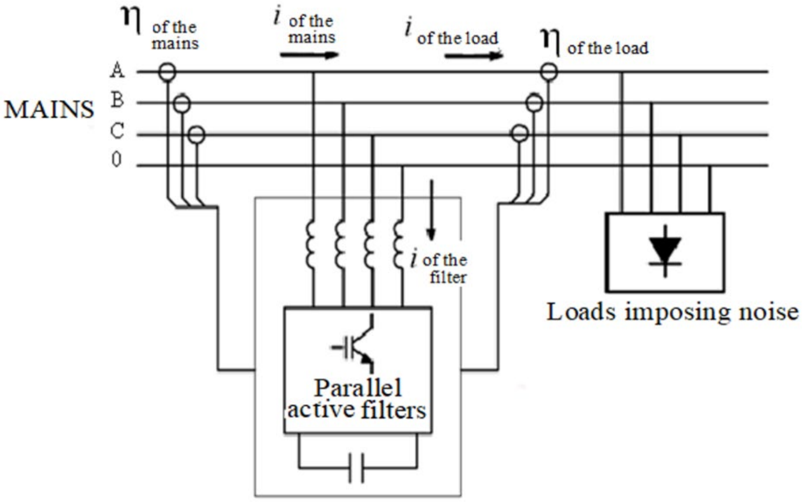


Figure 1 – Simplified circuit schematic of a power active filter

The following can be considered as absolute advantages of the active filters:

– possibility to be adapted to the current forms of phase voltage curves;

– independence of performance capability of the active filter on the consumer load level;

– compensation of anharmonicity as well as asymmetry of phase voltage;

– capability of the active filter use to compensate distortions of supply voltage by several consumers; and

– correction of consumer power coefficient.

Maybe, high cost is the only disadvantage of the active filters. If it is required to compensate reactive power components (for instance, during start-up), power keys should be selected based on the voltage of the same order as the consumer voltage. The abovementioned makes cost of such a device comparable with frequency converter cost.

Meanwhile, modern frequency converter solves the problems of noisy supply voltage relative to AM; moreover, it offers numerous additional advantages which cannot be provided by an active filter.

They are: smooth start with the controlled current and torque; control of production mechanism speed; implementation of feed-back and protection in terms of operational parameters etc.

Hence, rather often active filters turn out to be a reasonless engineering solution. Integration of active filter functions in the powerful frequency converters is a promising tendency. In such a way it is possible to control simultaneously speed of one of themechanisms and perform “group” correction of the supply voltage.

Passive filters [6] are series and parallel LC-chains, adjusted usually to resonance modes. Fig. 2 shows a connection diagram of individual passive LC-filters for asynchronous motor protection. Low cost is their key advantage.

Moreover, passive filters are durable; in practice, they need not any adjustment, service, and repair.

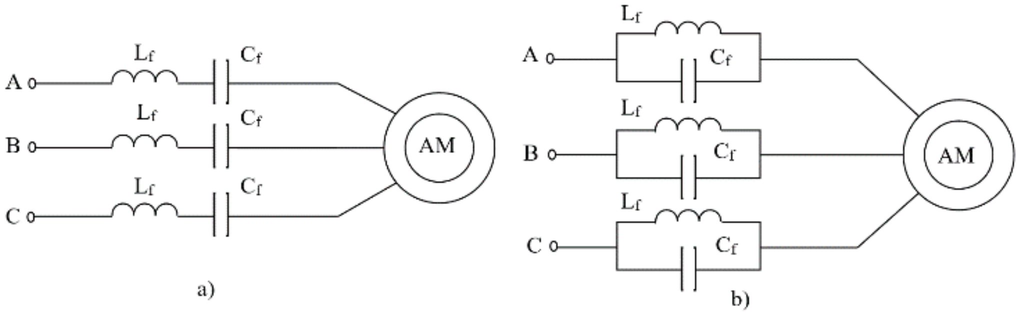


Figure 2 – Connection diagrams for series (a) and parallel (b) passive LC-filters

The following can be considered as disadvantages of passive filters: impossibility to correct supply voltage asymmetry; and instability of resonance modes for certain filter types due to field-assisted motion of the consumer parameters.

As a whole, efficient use of individual passive filters should involve solution of the problems: selection of a filter type to correct AM input voltage in the best way; determination of the filter parameters (i.e. inductance and capacitance) in terms of which the ideal AM performance is provided; and reaching a compromise between specifications (inductance, capacitance, and component power) and cost of the engineering solution; i.e. make cost-benefit analysis.

Consider the basic methods to improve power quality under the conditions of an enterprise or its workshop [6]. The methods are classified in terms of the quality indices providing by them: asymmetry, distortion of harmonicity etc.

Voltage asymmetry, stipulated by nonuniform distribution between phases of consumers, can be limited down to the rated values with the help of circuitry or by using specific balancer set [8]. The latter helps compensate equivalent current of reverse sequence of asymmetrical load as well as voltage stipulated by it. Individual, sectional, centralized, and combined symmetrization methods are recognized.

Individual balancer sets are installed directly at a consumer. In the context of sectional symmetrization, several considered devices are installed within different points of the mains. Each of the devices is responsible for certain mains area with a group of asymmetrical consumers, connected to it. In the context of the centralized symmetrization, one of such devices is installed within the distribution mains. The combined method is the combination of two or three balancer sets.

Individual method makes it possible to neutralize asymmetry right in the consumer; however, in this context the capacity of power elements of such protective devices is used irrationally. The centralized method needs less capacity of balancer set elements. However, current asymmetry continues within the mains where loads are distributed irregularly. Sectional method combines pluses and minuses of both individual method and the centralized one.

Mainly, symmetrization method selection depends upon the mains parameters and load conditions. Balancing sets can be either uncontrolled or controlled depending on the generation schedule features. There are many circuits of such devices having electric and electromagnetic element connections. Consider some of them. Fig. 3 demonstrates the simplified circuits of balancing sets [3].

Compensating devices are also used [9]. They are higher harmonic filters assembled on the basis of Capacitor Battery (CB) of a balancing set; asymmetrical filters. Fig. 4 demonstrates a simplified circuit schematic of the filter compensating device. Its operating principle is to provide voltage resonance on the frequencies of higher harmonics. In such a way, series LC-chains are short circuits for the latter.

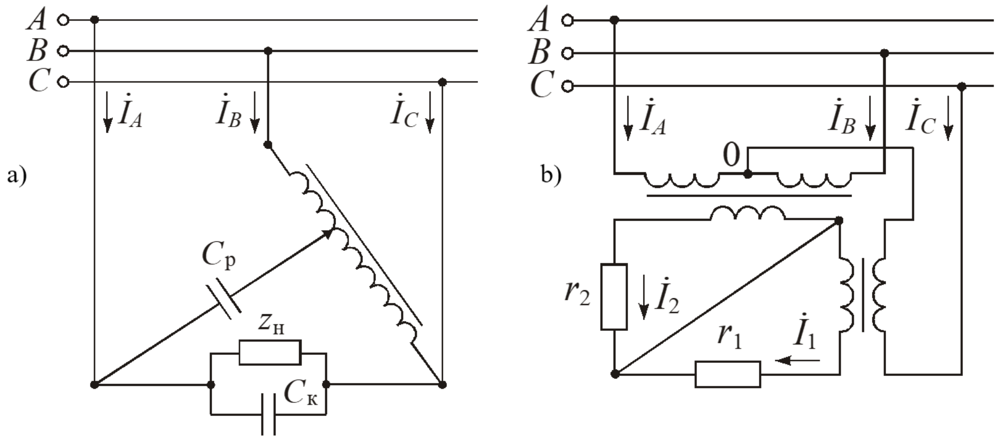


Figure 3 – Simplified circuits of autotransformer (a) and transformer (b) types

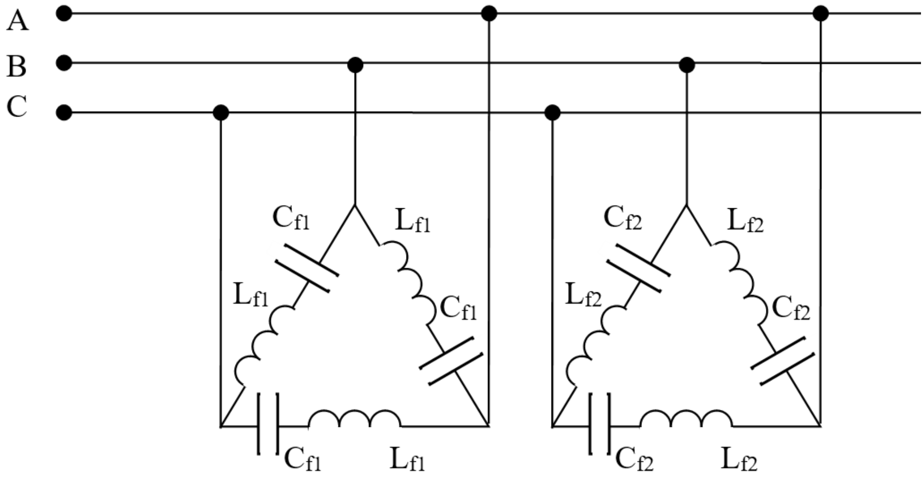


Figure 4 – Simplified circuit schematic of the filter compensating device

Lowered level of higher harmonics within electric mains is a part of the general problem to minimize the effect of nonlinear loads on supply mains and to improve power quality within the electrical power systems of enterprises. Complex solution of the problem, based upon the use of multifunction devices, turns out to be more expedient economically to compare with, say, measures to improve a shape of line converter current. Resonance filters, called filter compensating devices, are the examples of such multifunction devices. They generate reactive power for supply mains while decreasing the levels of higher harmonics.

In terms of parallel connection of LC circuits, adjusted to frequencies of single harmonics, a chain filter compensating device originates. In such a case, reactive-power shortage on the substation busbars may be compensated with the help of capacitor banks; moreover, 80–90% of the rated condenser power is applied. Hence, filter compensating devices are the simplest and the most economical filters; that has popularized them so much.

2.2. Evaluation of the effectiveness of employing existing methods to enhance the energy efficiency of asynchronous motors.

Section II of this chapter considered the available means providing power quality; and mentioned advantages and disadvantages of each of them. It has been pointed out that asymmetry compensation of supply voltage is generally performed by means of symmetrical devices (i.e. "sectional" methods). Parameter calculation and substantiation of the latter is among design problems of electric power supply systems. It is rather difficult task to compensate locally the changes in the supply mains frequency. However, a distortion of sinusoidal voltage form, being typical for workshops of domestic enterprises and determined with the help of their power load nature, needs the use of individual equipment to protect AM.

In the context of the abovementioned, consider specific features of electric drive operation integrated into the devices improving power quality, i.e. individual passive filters. Calculation results will be applied to develop a technique determining both type and parameters of the required individual and sectional filters to provide the necessary improvement of AM power indices.

2.2.1. Active filters and filter-compensating devices

Section II of this chapter considered pluses and minuses of active filters. Below you can find the illustrated features of operation of the devices under the conditions of noisy power.

Papers [10] describe series-parallel active filters making it possible to compensate partly asymmetry of supply voltage, and high frequency distortions to a greater degree. Fig. 5 demonstrates voltage oscillograms within a workshop main before active filter connection and after it.

Authors of [10] mention that the devices, analyzed by them, are efficient to suppress high-frequency interference (7th, 11th harmonics and higher), and compensate some asymmetry degree. That depends upon the limited power amount accumulated with the active filter capacity. As it is seen in Fig. 5, low-order harmonics are still represented in the curves of phase voltage. Moreover, active filters are complex devices which cost is comparable with the converter cost.

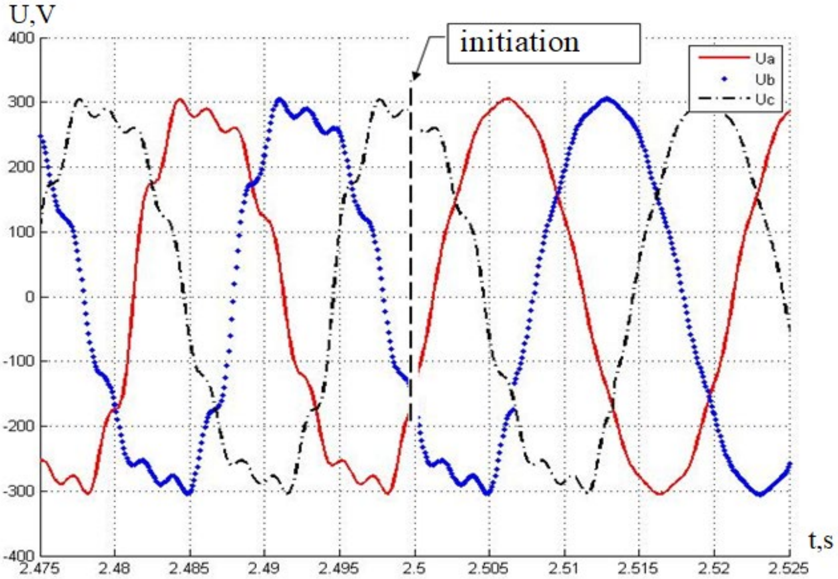


Figure 5 – Graphs of voltage mains before and after the initiation of an active filter

Filter-compensating devices (FCD) suppress harmonics selectively, and correct asymmetry of supply voltage to a certain degree as it is shown in Fig. 6.

It is impossible to suppress the whole range of spurious harmonics with the help of FCD since each of them needs individual resonance short circuit. Usually, FCDs are adjusted to the harmonics generating the greatest negative impact.

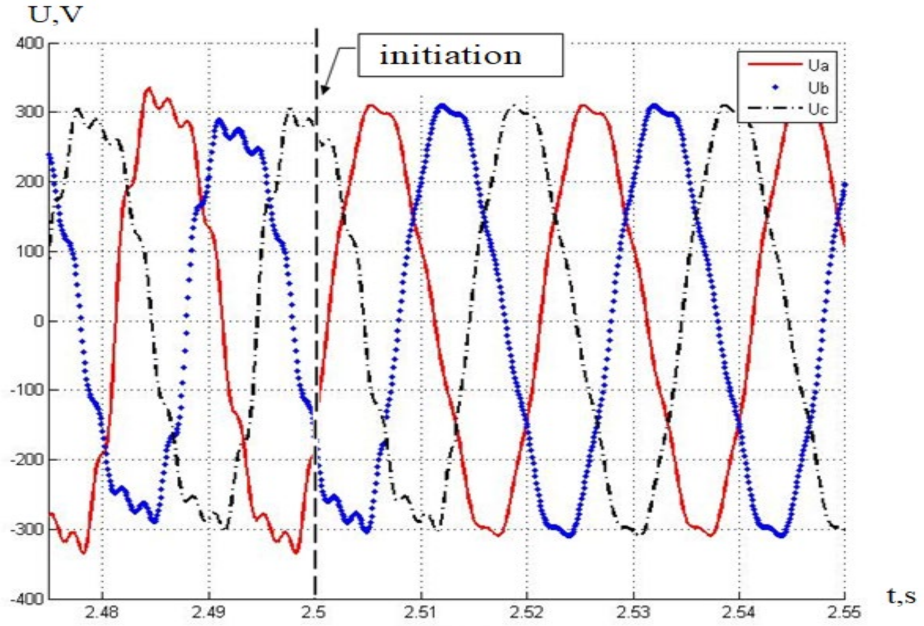


Figure 6 – Graphs of voltage mains before and after the initiation of an active filter-compensating device

2.2.2. Series filters

Increase in the total circuit inductance (i.e. series reactance connection to AM supply voltage) is expedient for higher-order harmonic filtration. However, the process should take into consideration the fact that inductive filter resistance takes place in parallel with a voltage drop value, impacting negatively loading capacity of the motor. At the same time, connection of series LC circuits may help generate resonance voltage and, consequently, minimal resistance for the specified frequency current. Fig. 2a demonstrates such a connection circuit.

Nevertheless, operation of the asynchronous motor integrated into the circuit is not always stable. Resonance mode entry causes the decreased resulting resistance of a filter thus decreasing their voltage drop. Voltage increase within the asynchronous motor terminals factors into the increased stator current and, consequently, into the increased torque factoring into changes in sliding motion. As a result, resulting complex resistance of each phase varies and resonance conditions turn out to be broken. Fig. 7 illustrates the generated unstable operation mode of an asynchronous motor involving series resonance LC filter adjusted to 100 Hz frequency.

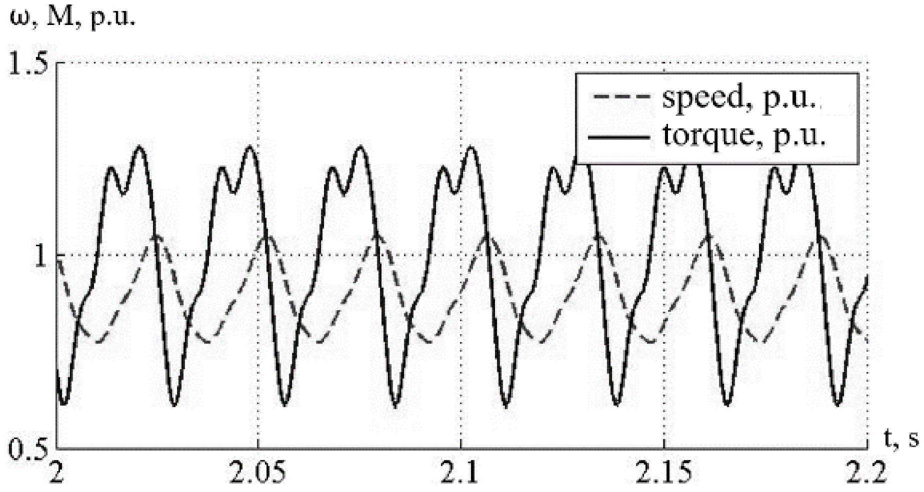


Figure 7 – Changes in torque and speed of an asynchronous motor with the use of series LC filter

Besides, the mode is dangerous due to potential excess voltage within the AM stator. Hence, the use of series LC filters in terms of the circuit, represented in Fig. 2a, is impractical technically due to the resonance mode instability.

2.2.3. Parallel filters

As it has been demonstrated, 2nd harmonic of supply voltage, which filtration is the priority task, generates the most negative impact on the power indices of AM [10]. Parallel LC filters are the most adequate solution for the problem (Fig. 2b), if they are adjusted to current resonance on 100 Hz frequency. In this context, filter resistance for 2nd harmonic approaches infinity thus opening circuit for it. That is why such filters are often called “traps”.

In practice, selection of filter parameters should involve simultaneously several factors. Technologic implementation of the required inductance and capacity values; and value and nature of resistance introduced by the filters on the basic frequency are the key factors. The parameters also depend upon selection of a harmonic which should be suppressed by the filters. To provide current resonance, the inductance and capacity should be selected relying upon ratio:

$$\omega_r^2 LC = 1, \qquad (1)$$

where $\omega_r = 2\pi f_r$ is the resonance angular frequency.

Any inductance-capacity combination, satisfying the equation, will provide the required resonance. However, it is necessary to involve the resulting complex filter resistance first, since efficiency of filter traps will vary depending upon different L-C combinations. Cost of components (i.e. inductance and capacity), providing resonance effects, is also important.

Fig. 8 demonstrates changes in a complex resistance of the resonance trap filter adjusted to 100 Hz frequency, if capacity varies within 1 μF-10 mF (technically implementable capacity values). The graphs are represented logarithmically. In terms of 2nd harmonic (100 Hz), resistance of ideal filter traps is equal to infinity; thus, the Figure does not show it.

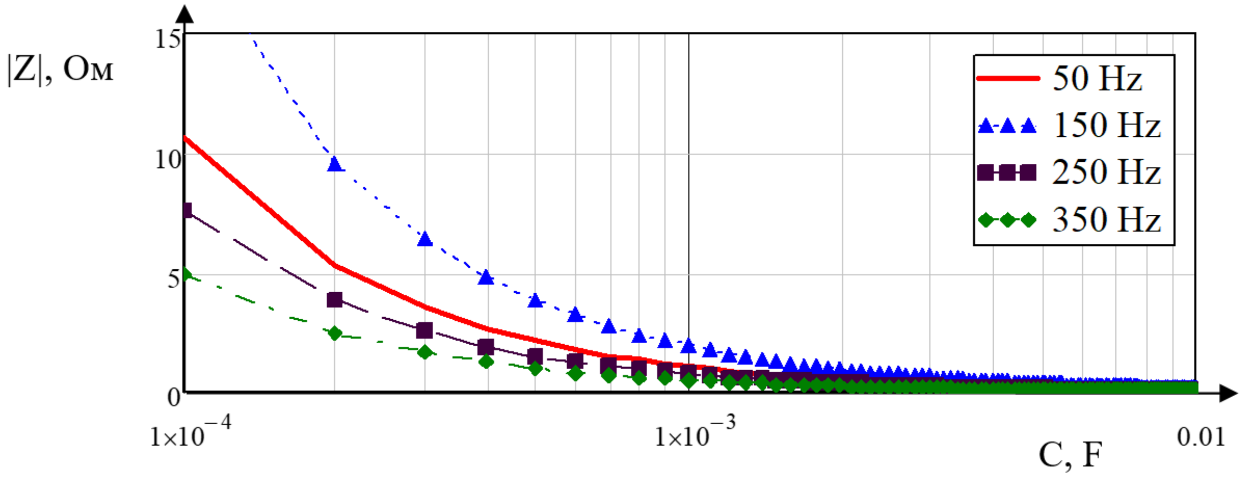


Figure 8 – Dependences of resulting resistances of the resonant filter trap upon the capacity value for different higher harmonics

Analysis of graphs in Fig. 8 explains that capacity increase results in rapid decrease in the trap filter for the basic frequency. It is understood that use of the filters which input resistance is dozens of Ohm on the basic frequency is inadmissible due to significant voltage decrease.

Thus, almost 100 μF (10^{-4} F) value should be a lower capacity boundary restricting input resistant value at the level of Ohm units. Upper capacity boundary is identified with the help of the filter efficiency in terms of integral power criterion and economic criterion.

To provide current resonance inside 2nd harmonic, 25-0.5 mH inductance should be selected in terms of capacity changes within a certain small range to identify the value. In this context, resulting filter resistance will be 10-0.1 Ohm.

Modeling [11, 12] has helped verify efficiency of the filter traps which parameters were selected as mentioned above. Fig. 9 demonstrates voltage graphs without the filter and with it; values are L=25 mH and C=100 μF if 2nd harmonic prevails in the supply voltage.

As it is seen, a curve shape of the phase voltage “evens out” in this context at the expense of 2nd harmonic suppression. Fig. 10 shows AM stator current with the filter and without it.

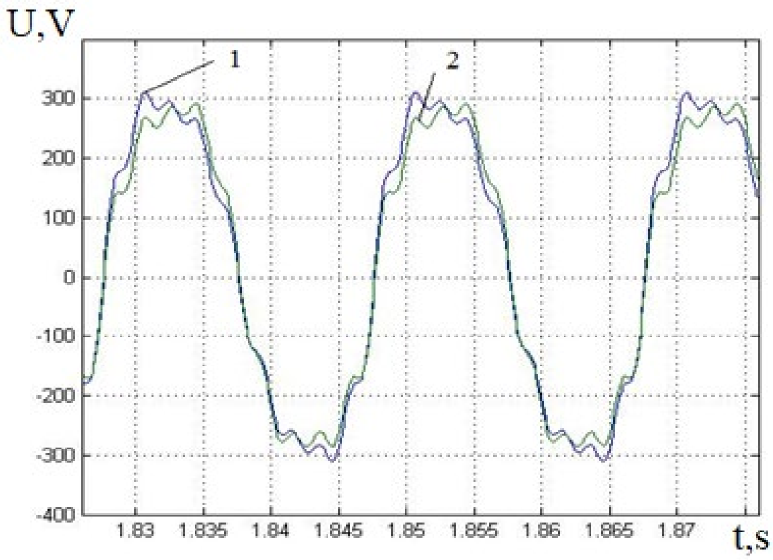


Figure 9 – AM phase supply 7.5 kW power without a parallel trap filter (1) and with it (2)

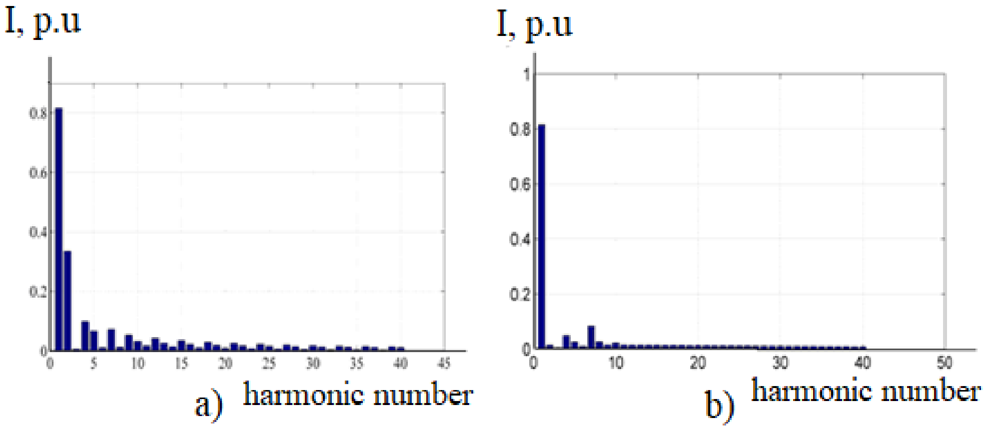


Figure 10 – Range of stator current in the process of AM supply without a filter (a) and with a trap filter (b) adjusted to 100 Hz resonance

Thus, the filter traps may be applied as the independent means to improve power quality during the operation of asynchronous motors.

2.2.4. Combined filters

It goes without saying that filter efficiency may be improved by means of combination of circuits matching up various approaches to suppress supply voltage harmonics. The circuit, represented in Fig. 11, is one of them being applied currently to filter output voltage of frequency converters [13]-[15].

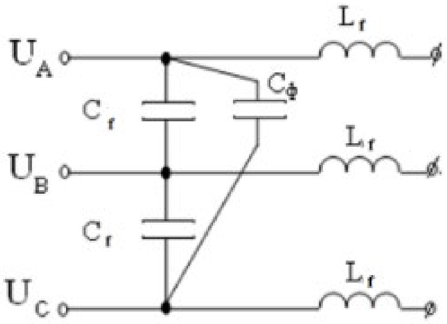


Figure 11 – LC filter applied in output of frequency converters

Capacities, being a part of such filters, are low resistant for impulse fronts of output stages. As a result, supervoltage levels decrease within a system with a long cable; intensity of electromagnetic interference, generated by a converter, drops etc. At the same time, the series connected on-load inductances are the restricting resistance for high-frequency current. We believe that nonavailability of resonance is the circuit disadvantage.

Consider possible circuits of the combined resonance filters, and evaluate their efficiency. Below you can find only their components, corresponding to one phase. The procedure will simplify the circuit implementation. A circuit, shown in Fig. 12, may be applied as the simplest resonance filter.

To compare with the traditional circuit of filter compensating devices, in this case inductance is connected in parallel with load. In such a way, higher harmonics are limited.

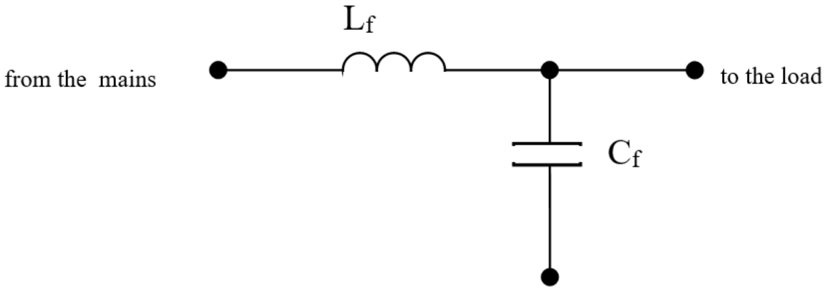


Figure 12 – L-shaped resonance first-order LC filter

Taking into consideration the fact that here we can find resonance short circuit for one of the higher harmonics from the mains, the filter helps suppress that of them, corresponding to resonance frequency, and to restrict other significantly.

Papers [16, 17] represent second-order series-parallel filter which circuit is shown in Fig. 13. Two resonance circuits are implemented in it.

The researchers tried to identify such combination of the filter parameters in terms of which the circuit is of maximum resistance on the frequency of spurious harmonics, and of minimum one on the basic frequency.

The activities are performed simultaneously with the consideration of all parameters – L_f inductance, and C_{f1} and C_{f2} capacities. Active resistance plays a role of a trimming element. Unfortunately, implementation of the filter is complicated due to conflicting requirements for the total voltage drop on it, and parameters of the components.

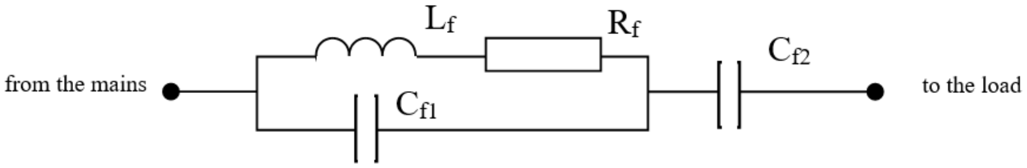


Figure 13 – Second-order series-parallel filter

2.3. Studies concerning parameter selection and efficiency of the proposed means to improve AM energy performance

It is more expedient to use circuits shown in Fig. 14. The filter, implemented in such a manner, is a combination of a rejecting device connected in series with load to provide current resonance on the frequency of one of higher harmonics, and a secondary member (capacity of inductance) to provide short circuit for another harmonic.

The two possible filter structures differ in the type of a member, connected to load in parallel. Selection of one or another structure depends upon selection of resonance frequencies for the blocking filter component f_1 providing current resonance to "trap" one of the harmonics, and f_2 component for a "phase-zero point" circuit providing voltage resonance and, hence, short circuit for another harmonic.

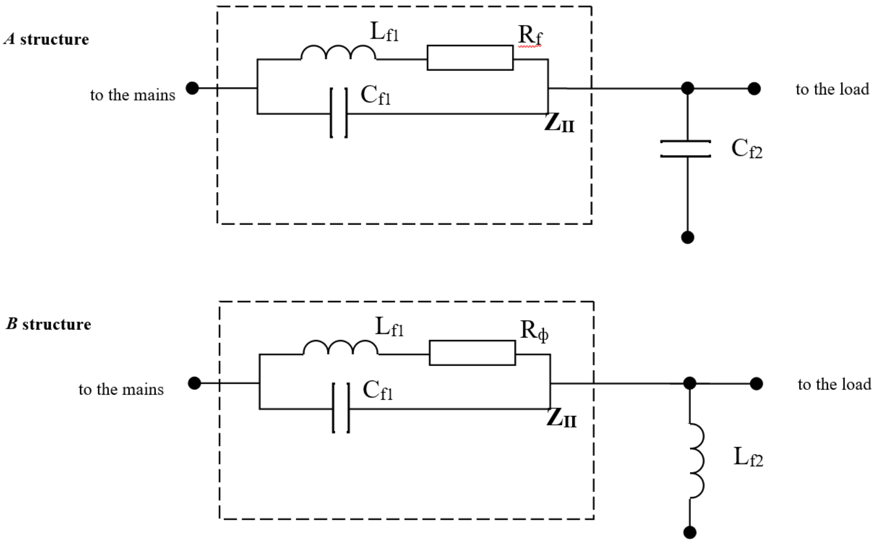


Figure 14 – Proposed alternations to implement the combined second-order L-shaped LC filter

All the filter parameters (i.e. resonance frequencies; branch resistances on different frequencies; and complex resistance on the basic frequency) are interconnected. They are determined using its inductance-capacity combination. Suppose the filter part series-connected with a load as a "filter trap"; when a "mains-zero point" current flow circuit (i.e. current flow through the whole filter) is meant, then resistance of the combined filter is discussed.

Hence, formulate optimization problem relying upon simultaneous fulfillment of the conditions:

- current resonance on the undesirable spurious harmonic within a circuit, series on load (trap filter);
- voltage resonance of the combined filter on the frequency of one of spurious harmonics; selection and substantiation of the voltage resonance frequency;
- trap filter resistance should be minimal one on 50 Hz frequency;
- inductive nature of the trap filter resistance should be provided;
- voltage frequency of the combined filter on the required frequency of one of the spurious harmonics;
- to compensate reactive power within the mains, nature of the combined filter should be capacitive one; and
- technical operability of the filter parameters.

Total filter resistance in terms of *A* circuit can be calculated as a resistance of series-connected “trap” and C_{f2} capacitor. In this context, dependence of complex resistance upon frequency is:

$$Z_\Sigma(\omega)=\frac{R_f\omega^2L_{f1}^2}{R_f^2+\left(\omega L_{f1}-\dfrac{1}{\omega C_{f1}^2}\right)^2}+j\left[\frac{\omega L_{f1}R_F^2+\dfrac{L_{f1}}{\omega C_{f1}^2}}{R_F^2+\left(\omega L_\phi-\dfrac{1}{\omega C_{f1}^2}\right)^2}-\frac{1}{\omega C_{f2}}\right], \tag{2}$$

where ω is the angular frequency of supply voltage.

In terms of *B* circuit, the dependence is:

$$Z_\Sigma(\omega)=\frac{R_F\omega^2L_{f1}^2}{R_F^2+\left(\omega L_{f1}-\dfrac{1}{\omega C_{f1}^2}\right)^2}+j\frac{\omega L_{f1}R_F^2+\dfrac{L_{f1}}{\omega C_{f1}^2}+\omega L_{f2}}{R_F^2+\left(\omega L_{f1}-\dfrac{1}{\omega C_{f1}^2}\right)^2}. \tag{3}$$

The total resistance of the combined filter (2) and (3) is a function of several variables. It is of interest to analyze its frequency characteristics, dependence upon frequency to which current resonance of the trap filter is adjusted, and L_f, C_{f1}, C_{f2}

parameters of the filter. It is impossible to represent graphically functions of three variables; hence, analyze the dependence in terms of sections.

Fig. 15 demonstrates dependences of resistances, introduced by the trap filter into the circuit in series, in terms of different frequencies. In this context, different resonance frequencies of a trap filter correspond to different lines. Their analysis means that the higher the frequency is (to which current resonance is adjusted), the less resistance is, introduced into a consumer supply circuit on 50 Hz frequency. Hence, the trap filter adjustment to current resonance on 100 Hz frequency is inexpedient; it is more preferable to use adjustment to higher harmonics (i.e. 5th, 7th, 11th etc.) since in this context filter resistance on the basic frequencies is Ohm units. 2nd harmonic should be suppressed with the help of short circuit.

Voltage drop on the trap filter is determined by means of resulting resistance as well as by means of consumer current. Thus, the higher consumer voltage is, the resonance frequency greater should be, which the trap filter is adjusted to.

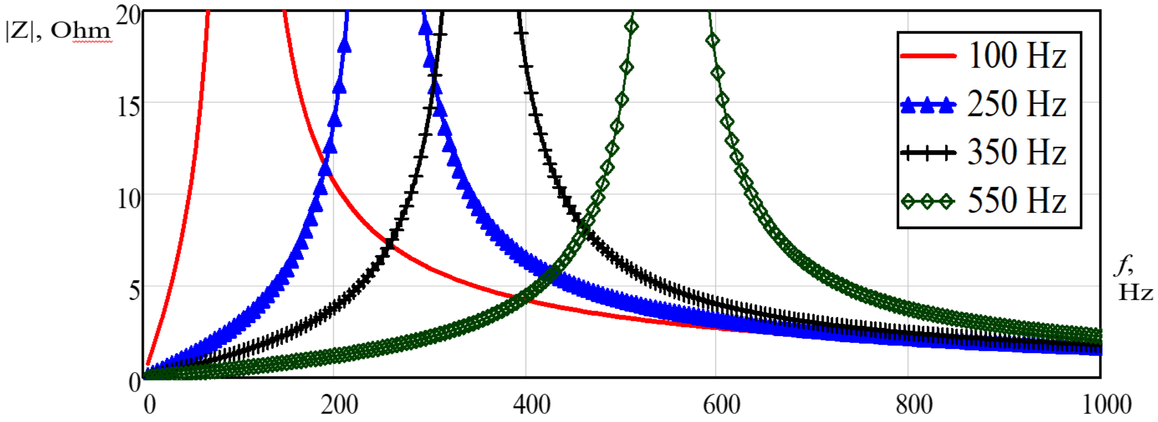


Figure 15 – Dependence of the trap filter resistance at a frequency of 50 Hz on the frequency to which the current resonance is tuned

Determine the best combination of resonance frequencies of the combined filter. Specify a cycle in terms of which consider all possible combinations of f_1-f_2 frequencies. Calculate resistances of the filter members for each combination; simulate the steady conditions to evaluate electric drive efficiency taking into consideration filter availability in terms of a circuit in Fig. 14.

It should b noted that if $f_1 > f_2$, it is required to select *A* structure; otherwise, *B* structure is selected. That is connected with a condition of the specific nature of resulting resistance of the trap filter.

Fig. 16 shows efficiency dependence upon the resonance frequencies f_1 and f_2, being 3D surface (a) and its projection within the frequency plane (b).

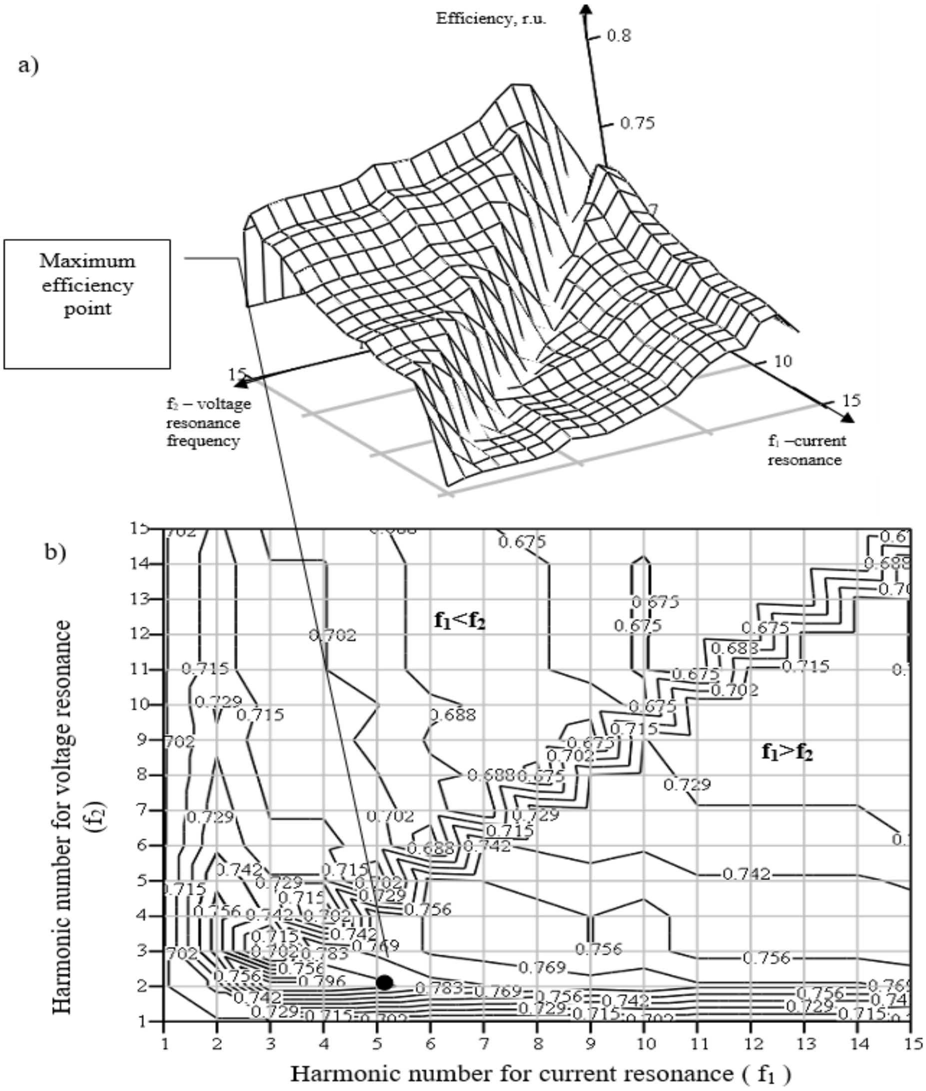


Figure 16 – Dependence of the efficiency of an asynchronous motor with the combined filter upon resonance harmonics (a); its projection (b)

Analysis of the represented surface demonstrates that the resultant efficiency of an electric motor is greater when current resonance is higher to compare with the voltage resonance frequency $f_1 > f_2$.

It depends on the fact that if trap filter is adjusted to certain frequency f_1, this filter share is the inductive resistance for all harmonics, which frequencies are less than

f_1. Consequently, extra decrease in loss, stipulated by supply voltage distortion, takes place.

Hence, the highest efficiency of the system is obtained if voltage resonance is adjusted to the 2nd harmonic frequency (f_2=100 Hz). It is required to select the frequency, to which current resonance is adjusted, relying upon specific nature of quality indices under the conditions of the definite workshop.

It has been identified that in the context of cases, considered in chapter one, 500 Hz frequency is the most expedient one.

Thus, iterative approach may help determine such a ratio of parameters of the combined L-shaped filter, in terms of which high resistance on the frequency of one of spurious higher harmonics is introduced into supply circuit of AM; along with it, interphase short circuit is developed for one of the harmonics (say, on 100 Hz frequency).

The abovementioned should take into consideration actual coat of the filter components depending upon the desired adjustment. Their prices have to be used.

Fig. 17 demonstrates current of earlier asynchronous motor with 7.5 kW capacity, operating under the conditions of noisy power when the combined filter is connected to it.

The parameters have been calculated according to the represented technique. Analysis of the graphs supports the idea that significant decrease in harmonic component level has been achieved.

Efficiency of the proposed technique has also been verified by computations of all-purpose electric motors with 7.5 to 250 kW capacity, operating under the conditions of noisy electricity. Histograms in Figures 18 and 19 represent the basic power indices, involving nonavailability/availability of input combined filter in terms of circuit shown in Fig. 14 (a).

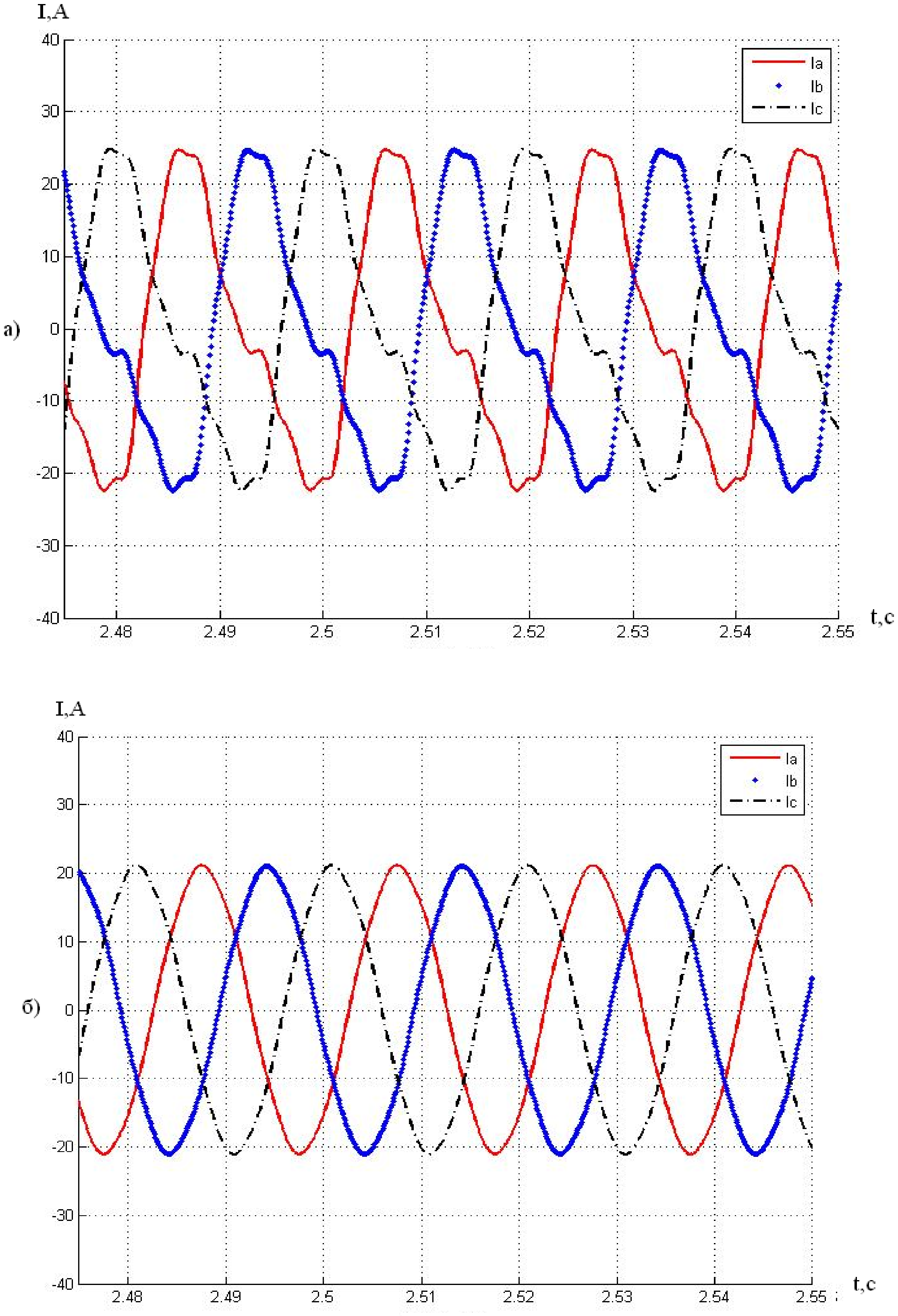
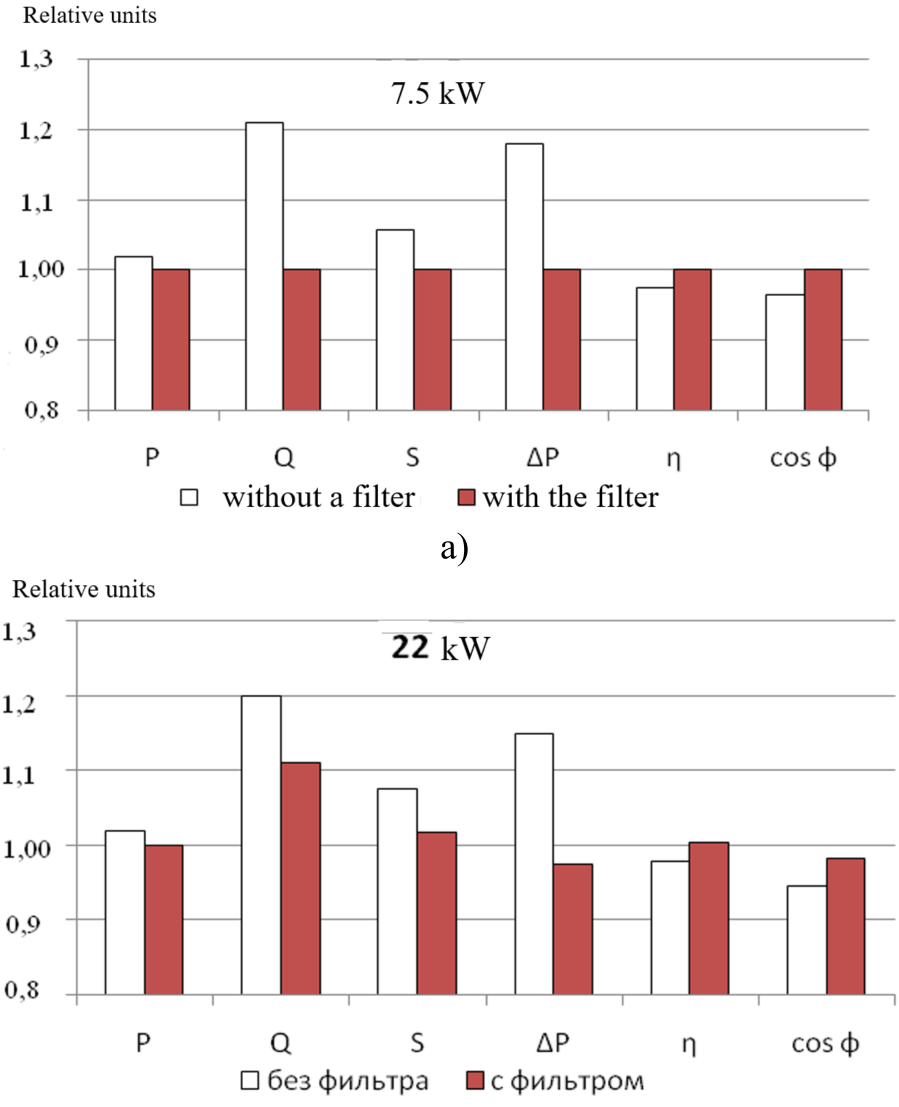


Figure 17 – Current of an asynchronous motor (7.5 kW), operating under the conditions of noisy electricity: a) without filter; b) after the combined filter connection

Analysis of the modeling results shows the filter efficiency (i.e. relative changes in power parameters are inversely related to the specified capacity of the electric motors). That is connected with less sensitivity of high-capacity motors to the supply voltage distortions.

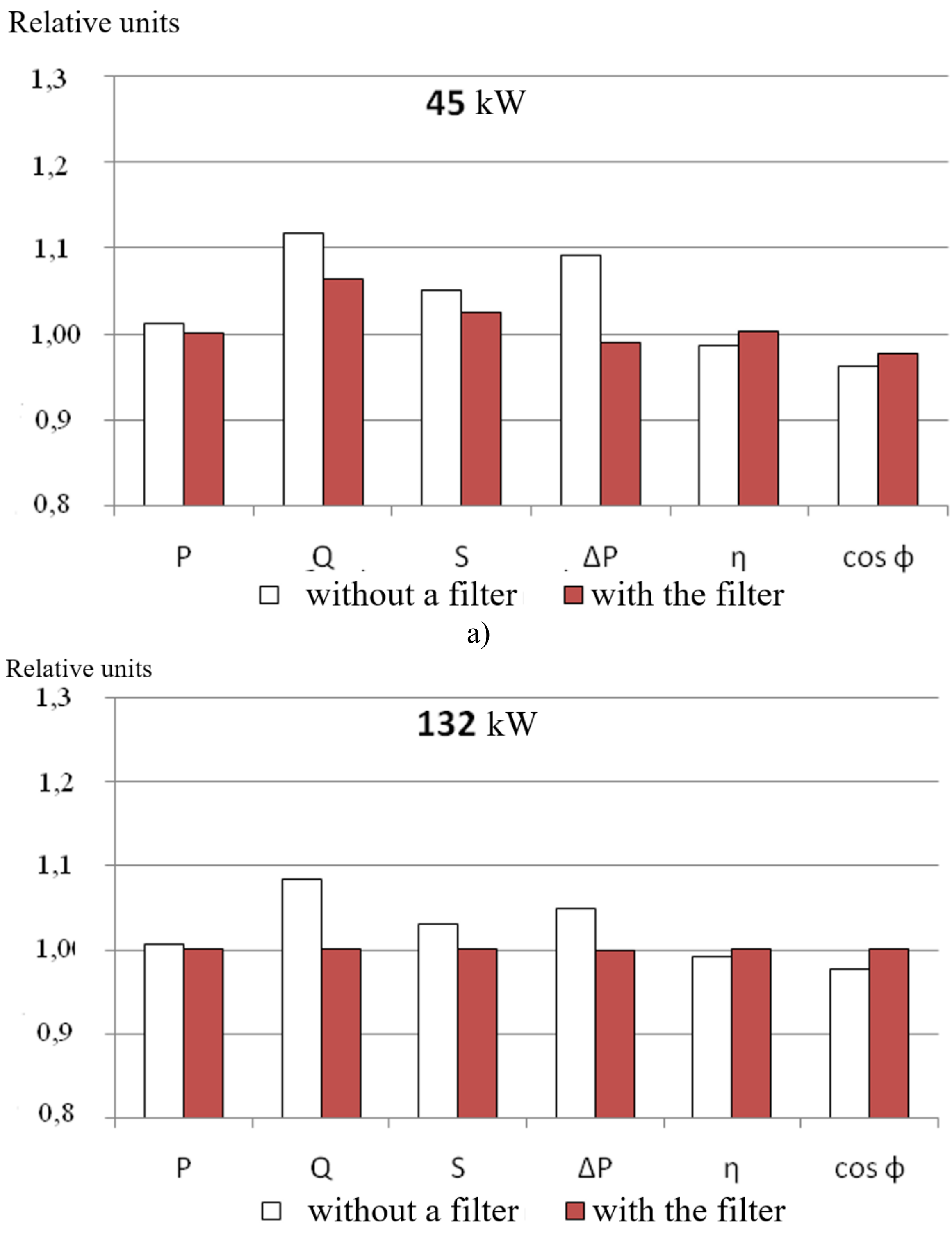


a)

b)

Figure 18 – The basic power indices of motors with 7.5 kW capacity (a), and 22 kW capacity (b) in terms of availability/nonavailability of input combined filter

It should be noted that although the proposed filter options have been studied in relation to the operation of an induction motor with a power of 7.5 kW, there are no fundamental restrictions for their use, for example, for asynchronous motors with a power of 45 kW.



a)

b)

Figure 19 – The basic power indices of motors with 45 kW capacity (a), and 132 kW capacity (b) in terms of availability/nonavailability of input combined filter

In section II of this chapter, it was noted that passive filters, in contrast to active ones, have a low cost compared to the cost of an induction motor. However, the final decision on the use of a particular filter or refusal from it is a difficult task, depending on many technical and economic factors and should be made based on the results of computational studies on a simulation energy-economic model of an induction motor [18-20].

Conclusions

1. To improve efficiency of asynchronous motors, operating within the mains with noisy electricity, it is expedient to apply the combined filter being a series-connected trap (stopper) in each phase, and star-connected capacities.
2. The highest efficiency of electric motor equipped with such a filter, being a series-connected trap (stopper) in each phase, and star-connected capacities, is achieved when the trap is adjusted to current resonance on 100 Hz frequency and 500 Hz voltage resonance.
3. Passive combined filters are the most expedient ones for small- and average-capacity electric motors (up to 45 kW).
4. The developed method, described in the chapter, makes it possible to adjust parameters of AM power efficiency improvement for the specific operation conditions.

The results of the research can be recommended for use in the learning process of students of the next Fields of knowledge: 14: Electrical engineering, specialties: 141 - Electrical power engineering, electrical engineering and electromechanics; 17- Electronics, automation and electronic communications, specialties: 172 - Electronic communications and radio engineering; and specialties: 174 – Automation, computer-integrated technologies and robotics.