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OPTIMIZATION OF ELECTRIC ENERGY USE IN TELECOMMUNICATION OBJECTS UNDER THE CONDITIONS OF NON-LINEAR LOADING

The article deals with an improved method of optimization of the usage of electric energy in the object of telecommunications provided constant and variable non-linear load. The mentioned method deals with contradictions, which stands in the need of increasing fundamental harmonic, which causes problems in the practical implementation and reduction of the current with high harmonics of nonlinear variable load. It was established that a weighty part of telecommunication equipment is a non-linear load, operation of which leads to significant network distortions. The classification of negative factors, associated with the emergence of higher harmonics of currents and voltages and methods of their suppression was given. To optimize the transmission of electricity in the nonlinear load it was proposed to use a special power supply, which further need to be enabled in electrical circuit and then it provides compensation of the higher harmonics of nonlinear current. Scheme solutions of optimizers of transmission of electric energy to the non-linear load with constant and variable parameters were presented. The structure and algorithm of the method of optimization of electricity, which deals with determination of the amplitude and phase of harmonics of non-linear load by the method of fast conversion of Fourier and formation of signal control by the active filter of harmonics, were determined. **Conclusion**. Due to the application of the method of optimization of transmission and usage of electric energy, which takes into account changes in nonlinear load and harmonic current parameters, the quality of electric energy usage is increased and the nominal mode of operation of telecommunication objects is provided.

Keywords: telecommunications, non-linear load, active filter, optimization, harmonious component.

Introduction

Formulation of the problem. Telecommunication systems and network technologies are currently used in any subject matter of the society. The current level of complexity of telecommunication equipment is constantly rising.

For each telecommunication object, the nominal parameters of electric energy (frequency, voltage, current, etc.) are determined, therefore the required quality of electric power must be provided for normal operation [1].

In practice, telecommunication systems and networks must overcome a number of problems associated with fluctuations, failures and power outlets; noises of various origin, including high-frequency, as well as a number of interferences, in particular impulse ones.

In the case of linear loading and harmonic modes of operation, optimization processes of this mode were conditioned by the presence of the reactive power and its compensation with the help of special reactive elements in the electric circuit.

However, the process of optimization is significantly complicated in the case of distortions of the form of voltage, which is related to the harmonic components of current consumed by nonlinear load [2].

Negative impact on the quality of electric energy, in general, is carried out by consumers with a nonlinear characteristic. It is a distortion of the form and, as a consequence, the emergence of higher harmonics, not only on the clamps of consumers, but also throughout the network electricity supply.

Analysis of recent achievements and publications.A significant proportion of telecommunication equipment is a nonlinear load, the exploitation of which leads to significant network distortions [3].

The overall negative effect of nonlinear consumer leads to distortion of voltage, which, in turn, can cause communication network failures, impairs the synchronization of telecommunication devices, and causes high heating of equipment and a number of other unwanted effects [2, 3].

The set of negative factors, in accordance with [4], can be divided into instantaneous and long-term effects.

The immediate problems are caused by the distortion of the form of supply voltage of telecommunication objects, the voltage drop in distribution networks, the effect of higher harmonics, resonant phenomena at the frequencies of these harmonics, and also with leaks in telecommunication networks.

Long-term problems include increased heating of distribution network cables and shortened service life of telecommunication equipment through the intensification of thermal and electrical aging insulation.

The negative factors include the unjustified triggering of the safety equipment due to additional heating internal elements of the devices protection.

In accordance with [512], the following methods of suppressing the higher harmonic components of voltages and currents exist:

a) changing the topology of the network;

b) the usage of passive protective filters in networks;

c) usage of active filters;

d) usage of devices with automatic stabilization of the form of voltage (current).

The first method is not a universal one for reducing the distortion of the form of power parameters, since the frequency characteristic of the system does not depend on the configuration of its network, but also on the change in the nature and magnitude of the nonlinear load.

The usage of passive filters, in addition to its main function - reactive power compensation, can offset one of the harmonious components. It depends on the oscillation circuit settings.

The usage of devices with automatic stabilization of the form of voltage and current is based on the stabilization of the instantaneous values of these parameters. So it is a so-called filter of input voltage, the usage of which from an economic and technical point of view is not always appropriate.

The most promising solution, in terms of technical implementation, performance indicators and cost criteria, is the use of active filters [13].

The purpose of the article is the guidance of an improved method for optimizing the use of electric energy, based on active filters, under non-linear load conditions.

The main part

To estimate the power efficiency of energy transmission of power supply with the alternating current, the power factor cos φ is used.

Optimization of the energy transfer process occurs at the expense of the increase of the power factor, which leads to increase of active power, reduction of losses in transmission lines and generator systems, increase of the efficiency of the transmission system as a whole.

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The degree of distortion is determined by the ratio of the acting value of the higher harmonics to the acting value of the first harmonic ki (sinusoidal distortion coefficient), according to [3, 5], as well as the coefficient of the amplitude ka-relation of the peak value of the current to its current value.

Under the conditions of nonlinear loading, the process of energy transfer in the electric circuit is complicated. At harmonic voltage, the current in the electric circuit is inharmonious; the difference between the total power and the active and reactive is not equal to zero. The relationship between powers in the supply chain of a telecommunication object is as follows:

$$S^2 = P^2 + Q^2 + T^2, \qquad (1)$$

where $T -$ the power of "distortions" that occur in the electric circuit in the presence of a non-dropping forms of voltage and current.

Thus, the optimization of the mode of transmission of electricity at nonlinear voltages is reduced to ensuring the uniformity of the forms of current and voltage and the equality of their phases.

This mode is characterized by the maximum average power entering the load, the circle $T = 0$, $Q = 0$.

Under conditions of non-harmonic current in its spectrum the harmonics of higher frequencies, which cause the change in the shape of the current are combined. Provided the harmonic voltage of the source of electric energy:

$$u(t) = V_m \cos(\omega t + \Psi_n);$$

$$i_n(t) = \ell_0 + \\ + \ell_{m1}\cos(\omega t + \Psi_1) + \ell_{m2}\cos(\omega t + \Psi_2) + \cdots .$$

In this case, the active power is determined only by the basic harmonic

$$P = U_1 \cdot \ell_1 \cdot \cos\varphi_1, \qquad (2)$$

At the same time, we have:

$$\ell = \sqrt{\ell_0^2 + \ell_1^2 + \ell_2^2 + \cdots}; \quad U = U_1. \qquad (3)$$

Expressing active power through voltage and current, we obtain:

$$P = U_1 \cdot \ell_1 \cdot \cos\varphi_1 = U \cdot I \cdot \frac{I_1}{I} \cdot \cos\varphi_1 = \\ = U \cdot I \cdot d \cdot \cos\varphi_1 = U \cdot I \cdot \lambda, \qquad (4)$$

where

$$\lambda = k_d \cdot \cos\varphi_1 < \cos\varphi_1;$$

$k_d -$ is called the distortion factor, since

$$k_d = I_1 / I.$$

So, we can make intermediate conclusions:

1. During the transmission of electric energy in a nonlinear load, the appearance of higher harmonics of current leads to a decrease in active power.

2. In order to increase the efficiency of the transmission of electricity, it is necessary to increase the basic harmonic I1, or to reduce the currents of higher harmonics.

With a nonlinear load, the optimization scheme may look like it is shown in Fig. 1.

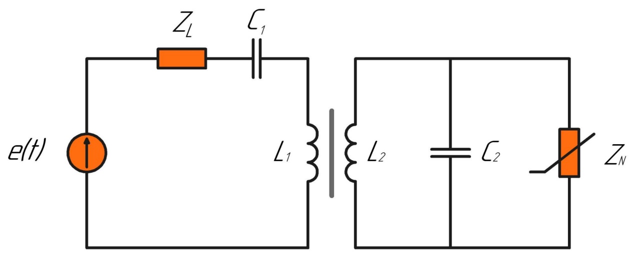

Fig. 1. Optimization of electric power transmission to nonlinear load

In the conditions of setting the contours C_1-L_1 and C_2-L_2 in resonance to the frequency of the first harmonic, in the transmission line of the electric energy, the amplitude of the first harmonic I_1 increases, in comparison with the amplitude of the harmonics of higher frequencies (J_2, J_3…). As a result, the active power that is passed to the consumer increases.

To optimize the transmission of electricity in a nonlinear load, we will also proceed from the possibility of implementing special current sources that are additionally included in the electric circuit and provide an optimal mode of operation (Fig. 2), where:

$$i(t) = \mathrm{I}_{m1}\cos(\omega t + \psi_1);$$

$$j_0 = I_0;$$

$$j_2 = \mathrm{I}_{m2}\cos(2\omega t + \psi_2);$$

$$j_k = \mathrm{I}_{mk}\cos(k\omega t + \psi_k).$$

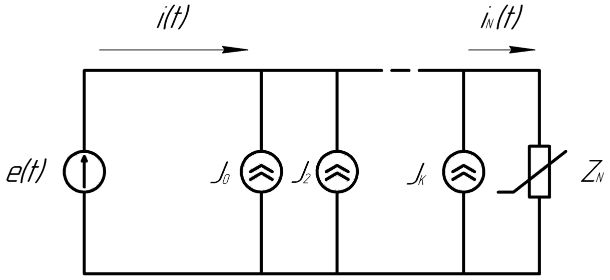

Fig. 2. Optimizer of transmission of electricity to nonlinear load with constant parameters

According to the first law of Kirchhoff we have:

$$i(t) = i_n - j_0 - j_2 - \cdots - j_k = \\ = \mathrm{I}_{m1}\cos(\omega t + \psi_1).$$

The principle of the optimizer is based on the introduction of harmonic current to reduce the harmonics in this network. The current form $i_n(t)$ becomes close to the form (t), which helps to optimize the transfer of energy from the power supply to the load.

The quality of transmission optimization and the use of electric energy will depend on the number of compensating current sources (active filters) and on the degree of compliance with the parameters of their currents, parameters of higher harmonics.

Over time, the nonlinear load parameters can vary widely, which leads to a change in the parameters of harmonics of non-harmonic current.

This circumstance necessitates the continuous control of the compensator of harmonics of the current of a nonlinear load [13, 14].

The scheme of optimizing the use of electricity by nonlinear load with variable parameters has the form presented in Fig. 3.

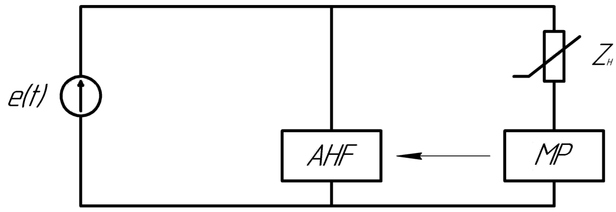

Fig. 3. Optimizer of transmission of electric energy nonlinear load with variational parameters

The metric of the harmonics parameters (MP) according to the Fourier transform algorithm determines the amplitude and the initial phase of each of the harmonics of the current of the nonlinear element and generates a control signal that is fed to an active harmonic filter (AHF).

The work of this filter corresponds to the work of controlled current sources (Fig. 2), which produce currents with parameters corresponding to the parameters of harmonics of current nonlinear load.

Consequently, the condition of optimizing the transmission and use of electric energy in the nonlinear load - to the consumer is fulfilled.

Conclusions

Due to the application of the method for optimizing the transmission and use of electric energy, which takes into account changes in the nonlinear load and harmonic current parameters, it has been shown that the quality of optimization of the use of electricity will depend on the number of current sources and the degree of compliance of their parameters with the higher harmonics.

Improving the quality of utilization of electric energy in telecommunication objects, in general, leads to the creation of conditions for their normal operation and the provision of telecommunication services to the proper quality.

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Оптимізація використання електроенергії в об'єктах телекомунікацій за умов нелінійного навантаження

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У статті розглядається удосконалений метод оптимізації використання електричної енергії в об'єктах телекомунікацій, за умов постійного та змінного нелінійного навантаження. Зазначений метод розв'язує протиріччя, котре полягає у необхідності збільшення основної гармоніки, що викликає проблеми під час практичної реалізації і зменшення струму вищих гармонік нелінійного варіативного навантаження. Встановлено, що вагома частка телекомунікаційного обладнання являє собою нелінійне навантаження, експлуатація котрого призводить до суттєвих мережевих спотворень. Наведена класифікація негативних факторів, пов'язаних із появою вищих гармонік струмів і напруг та методи їх пригнічення. Для оптимізації передачі електроенергії у нелінійне навантаження запропоновано використовувати спеціальні джерела струму, котрі додатково вмикаються в електричне коло і забезпечують компенсацію вищих гармонік. Наведені схемні рішення оптимізаторів передачі електроенергії до нелінійного навантаження із постійними та варіативними параметрами. Визначена структура та алгоритм методу оптимізації використання електроенергії, котрий полягає у визначенні амплітуди і фази гармонік нелінійного навантаження за методом швидкого перетворення Фур'є та формуванні сигналу керування активним фільтром гармонік. За рахунок застосування методу оптимізації передачі та використання електричної енергії, котрий враховує зміни нелінійного навантаження та параметри гармонійного струму, підвищується якості використання електричної енергії та забезпечується номінальний режим роботи об'єктів телекомунікацій.

Ключові слова: телекомунікації, нелінійне навантаження, активний фільтр, оптимізація, гармонійна складова.

Оптимизация использования электроэнергии в объектах телекоммуникаций в условиях нелинейной нагрузки

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В статье рассматривается усовершенствованный метод оптимизации использования электрической энергии в объектах телекоммуникаций, в условиях постоянной и переменной нелинейной нагрузки. Указанный метод решает противоречия, связанные с необходимостью увеличения основной гармоники, что вызывает проблемы при практической реализации, и уменьшением тока высших гармоник нелинейной вариативной нагрузки. Установлено, что значительная доля телекоммуникационного оборудования представляет собой нелинейную нагрузку, эксплуатация которого приводит к существенным сетевых искажениям. Приведена классификация негативных факторов, связанных с появлением высших гармоник токов и напряжений, а также методы их подавления. Для оптимизации передачи электроэнергии к нелинейной нагрузке, предложено использовать специальные источники тока, которые дополнительно включаются в электрическую цепь и обеспечивают компенсацию высших гармоник. Приведены схемные решения оптимизаторов передачи электроэнергии к нелинейной нагрузке с постоянными и вариативными параметрами. Определена структура и алгоритм метода оптимизации использования электроэнергии, который заключается в определении амплитуды и фазы гармоник нелинейной нагрузки по методу быстрого преобразования Фурье и формировании сигнала управления активным фильтром гармоник. За счет применения метода оптимизации передачи и использования электрической энергии, который учитывает изменения нелинейной нагрузки и параметры гармонического тока, повышается качество использования электрической энергии и обеспечивается номинальный режим работы объектов телекоммуникаций.

Ключевые слова: телекоммуникации, нелинейная нагрузка, активный фильтр, оптимизация, гармоническая составляющая.