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THE DIFFERENT APPROACHES TO THE TRANSFORMATION OF REACTIVE POWER INTO AN ACTIVE POWER

The relevance of the development of modern problems of the electric power industry in connection with the depletion of the planet's natural resources is undeniable and initiates the development of new physical and technical solutions with the practical use of known natural phenomena. The method of this work is to propose, justifying the expediency of a possible scheme of a resonant converter of reactive power into activity and conducting an analysis of the electromagnetic processes occurring in them. The proposed schemes combine the presence of resonant parallel and resonant circuit complexes. The difference is in the way they are implemented. For the data of the joint circuit, the feature is the presence of two inductively coupled active-reactive circuits, but different in the ways of creating resonance conditions. For a circuit without an additional power source, it is shown that the successful implementation of resonance conditions is possible by choosing the appropriate element base. For a circuit with an additional source of harmonic voltage, it is shown that for a suitable setting it is possible to completely eliminate the negative influence of the converter circuit on the source of reactive power. Calculations for the experimental model show that with the appropriate selection of the element base, it is possible to obtain a conversion factor of ~ 1.0 with a minimal effect on the current in reactive power sources. Given the calculated ratios, the mathematical apparatus of the theory of electric circuits was used to substantiate the principle possibility of resonant transformation of electrical energy. Thus, methods of calculating the characteristics of transient processes in closed circuits with active-reactive elements. For the first time, with the justification of practical power, we offer the possibilities of the scheme of resonant transformation of reactive power into active power, and an analysis of the electromagnetic processes occurring in them is carried out. The proposed work was initiated by the current needs of the electric power industry, caused by the depletion of natural resources and the rapidly growing needs of the world economy. The results of the work illustrate the practical possibilities of creating real schemes for converting reactive electricity into active electricity.

Keywords: electric power industry, resonant active-reactive electrical circuits, electrical power conversion.

БАТИГІН ЮРІЙ, ШИНДЕРУК СВІТЛАНА, ЧАПЛИГІН ЄВГЕН, ФЕНДРИКОВ ДЕНІС
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РІЗНІ ПІДХОДИ ДО ПЕРЕТВОРЕННЯ РЕАКТИВНОЇ ПОТУЖНОСТІ В АКТИВНУ

Актуальність вирішення сучасних проблем електроенергетики у зв'язку з виснаженням природних ресурсів планети є беззаперечною та ініціює розробку нових фізико-технічних рішень із практичним використанням відомих природних явищ. Метою даної роботи є запропонувати та обґрунтувати доцільність можливої схеми резонансного перетворювача реактивної потужності в активну та провести аналіз електромагнітних процесів, що відбуваються в них. Запропоновані схеми поєднують наявність резонансного паралельного та резонансного послідовного контурів. Різниця полягає в способі їх виконання. Для цих ланцюгів спільною ознакою є наявність двох індуктивно пов'язаних активно-реактивних ланцюгів, але різних за способами створення резонансних умов. Для схеми без додаткового джерела живлення показано, що успішна реалізація умов резонансу можлива шляхом вибору відповідної елементної бази. Для схеми з додатковим джерелом гармонічної напруги показано, що при відповідній настройці можна повністю усунути негативний вплив схеми перетворювача на джерело реактивної потужності. Розрахунки для експериментальної моделі показують, що при відповідному підборі елементної бази можна отримати коефіцієнт перетворення ~ 1,0 з мінімальним впливом на струм в джерелі реактивної потужності. Для обґрунтування принципової можливості резонансного перетворення електричної енергії при виведенні розрахункових співвідношень використано математичний апарат теорії електричних кіл. Зокрема, методи розрахунку характеристик перехідних процесів у замкнутих колах з активно-реактивними елементами. Вперше запропоновано можливі схеми резонансного перетворення реактивної потужності в активну з обґрунтуванням практичної потужності та проведено аналіз електромагнітних процесів, що відбуваються в них. Дана робота була ініційована поточними потребами електроенергетики, викликаними виснаженням природних ресурсів і стрімко зростаючими потребами світової економіки. Результати роботи ілюструють практичні можливості створення реальних схем перетворення реактивної електроенергії в активну.

Ключові слова: електроенергетика, резонансні активно-реактивні електричні ланцюги, перетворення електроенергії.

Introduction

Resonance as a key to "energetic spike" in oscillatory systems of any physical nature was first pointed out in the works of Nikola Tesla. As it follows from his publications the main problem which demanded immediate solution was the problem not only resonant generation but and wireless transportation of the electrical energy on the long distances. With this goal N. Tesla built and successfully tested so named "Wardenclyffe Tower". It was the first telecommunication facility which was intended for commercial transatlantic telephony, broadcasting, and demonstration of the energy wireless transfer. No less important problem of our time is a problem of the effective conversion of the energy different kinds (solar, wind, thermal) in the electrical energy which is the indisputable factor of the Humanity comfortable existence. In this connection, it should be noted the obvious interest of the world scientific community to all practically possible technical elaborations which are directed on the solution of the above-marked problem of the modern electrical power engineering.

Brief literature review, the investigation purpose

The first type of patented electrical energy converter this is widely known as the "Tesla transformer" which is the super effective resonant amplifier of high voltage with the transformation factor – k > 1000 [1]. Many works dedicated to the investigation of this device, for example [2–4]. Among them, a search can be distinguished of determined optimal solutions of further increasing efficiency the "Tesla transformer" proper [2]. The publication [3] represents itself a practical manual for designing and creating the powerful many aim electrical energy converter for different fields of application. The investigations of the transient processes in the inductive coupled resonant circuits of the "Tesla transformer" with the attraction of the electrical circuit methods were conducted by authors of the work [4]. The got results and the numerical estimates agree fully with the inventor qualitative conclusions which were formulated else at the last century beginning. The articles [5–8] are dedicated to the non-traditional methods of conversion the different kinds of energy. So, the innovative approaches to the cosmic apparatuses energetic have been formulated on a base of the theoretical investigations of the vacuum quant states, substance stability and gravitation [5]. Technically based suggestions to convert a heat in the electrical energy are defended by Patents [6, 7]. The workable and quite effective resonant converters of electrical energy are represented in the works [9, 10]. At last, the appearance of the Patent [11] with a quite high area of application is conditioned by the practical interest to the resonant reactive power amplifying. The invention subject is related to the impact excitation systems in the power engineering but can find application in the uninterrupted feeding sources and the electromagnetic oscillations transmitters for creating the super-power probing signals.

The essential demerit of the known suggestions of the energy conversion based on the resonant phenomena in the electrical engineering systems (also and in the Tesla transformer!) is the reactive power output what is very problematic for a practical usage. In this connection, a transformation of the reactive power in an active one which can be used for different works fulfilling has the practical interest. A practical solution of this problem can be realized with help of scheme from two inductively coupled resonant circuits. The first of them is the parallel one and the second circuit is the serial circuit. The physical essence of the present suggestion consists in following. The reactive power from a source is fed to an input of the first parallel circuit. The latter one is excited in the "current resonance" regime when the currents in the reactive power source outputs equal to zero and when their influence on this source is excepted fully. At the expense of the inductive coupling, the signal is transmitted to the second serial circuit tuned on the "voltage resonance" what allows to maximize the output electrical power in resistor which is the converter active load.

In the converter represented variant the conditions for "the current resonance" in the input parallel circuit are being created at the expense of its parameters corresponding choice which is directed on what to exclude the converter influence on the processes into the reactive power source and to stabilize the device operation in whole.

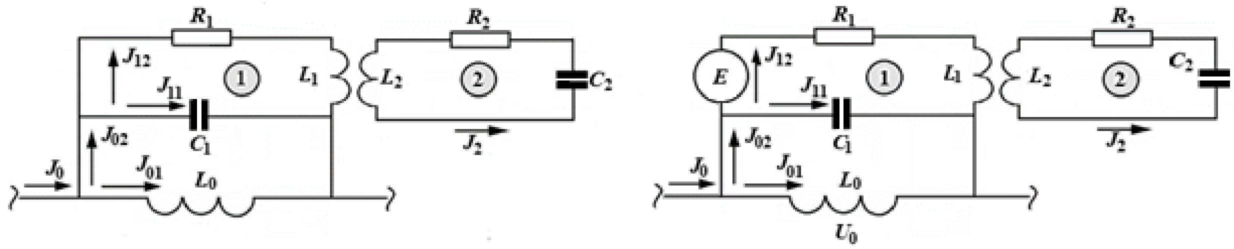
The other method of the resonant conditions creation in the input parallel circuit is possible. With this goal, the additional source of the harmonic voltage is being introduced. The appointment of the latter one analogically to the previous variant consists in what to exclude the energy interchange between the converter and the reactive power source.

Physically, the action of the additional source in the input parallel circuit with the real parameters can be interpreted as introducing some conditioned "negative" impedance which removes the influence of the active resistance and inductive coupling with the output circuit on the "resonance current" excitation in the converter input circuit [12].

The aim of the present work is the possible schemes suggestion of the resonant converter of the reactive power into the active one and the processes analysis in them. These schemes are united by the existence of the resonant parallel circuit and resonant serial circuit. The difference between the schemes consists in the realization methods of their principle action. In the first scheme, this is the choice of the corresponding element base. In the second one, this is the introduction of the additional auxiliary source of the harmonic voltage.

Problem formulation, calculation expressions

Electrical schemes. Two possible schemes of the suggested resonant conversion of the reactive power into active one are represented on Fig. 1.



a) b)

Fig. 1. Electrical schemes of the resonant converter of the reactive power into the active one
a) the scheme without the additional auxiliary source of the voltage;
b) the scheme with including the additional auxiliary source of the voltage – *E*

They are united by the availability of two inductive coupled resonant circuits – 1 and 2. The first of them is excited in the "current resonance" regime, the second one is excited in the "voltage resonance" regime [11]. The load of the converter suggested schemes is a resistor in the second resonant circuit. The reactive power source is the inductance – (with current and with voltage) fed by a current. Difference between the schemes represented variants consists in the methods of the "current resonance" excitation in the circuit – 1. In the scheme (on Fig. 1. a) a creation of the necessary conditions is realized at the expense of its element base choice. In the scheme (on Fig. 1. b) this problem is solved by the introduction of the additional harmonic voltage.

Action Principle. Naturally, electromagnetic processes in the converter circuits affect the current and voltage in the reactive power source. If the circuit – 1 is excited in "current resonance", it should not affect the processes in the inductance – L_0 because the current in the output conductors is zero $J_{02} = 0$ and the potential difference at the output of the source should determine the voltage – U ot on the capacitors without distortion – C_2 Next, the electromagnetic energy in circuit – 1 due to the inductive connection $L_1 - L_2$ is transferred to circuit – 2. The latter is excited in the "voltage resonance" mode, which allows to minimize losses and obtain output active power. current flowing in the load of the converter – R_2 .

The relation of the active power on the output to the input reactive power is the quantitative transformation index of one kind of the electromagnetic energy in another with help of the resonant converter suggested schemes.

It should be marked the common distinguished particularities of the suggested electrical schemes. The first of them consists in the application of the parallel circuit with the "current resonance" what allows to minimize the influence on the processes in the reactive power source. The second one consists in the application of the "serial circuit" with the "voltage resonance" what allows to maximize the output active power in the converter load.

Let us consider each represented scheme separately.

The reactive power converter to the active one the scheme of which consists of two resonant RLC circuits without the voltage additional source (Fig. 1 a).

As it was pointed out, the necessary conditions creation for the "current resonance" in the parallel circuit is realized at expense of the according element base choice.

For the solution of the formulated problem we shall accept the following statements.

1. The suggested scheme of the converter consists of two inductive coupled resonant circuits: parallel and serial.

2 The frequencies of these circuits equal between to each other and $\omega_1 = \omega_2 = \omega$ – is the resonant frequency of all converter scheme.

3 The first resonant circuit – 1 is connected in parallel to the reactive power source (the inductance coil – L_0) with the harmonic current and voltage – $U_0(t) = U_m \sin(\omega \cdot t)$ (U_m – is the amplitude, ω – is the frequency, t – is the time).

The calculation relationships for theoretical justification of the accepted schemes workability are based on the physically "transparent" phenomenological statements and on the strict mathematical approach with the use methods of the theory electrical circuit [11].

We start from the second serial active-reactive circuit. The state equation has the view [11]:

$$\left(i\left(\omega L_2 - \frac{1}{\omega C_2} \right) + R_2 \right) \cdot J_2 + i\omega\left(k_{12} \cdot \sqrt{L_1 L_2} \right) \cdot J_{12} = 0 \quad (1)$$

where $k_{12} \in [0,1]$ – is the electromagnetic coupling level coefficient between inductances – L_2 and L_1.

In the resonant regime with frequency – $\omega = \dfrac{1}{\sqrt{L_2 C_2}}$ the connection between the currents are being installed the expression:

$$J_2 = -\frac{i\omega\left(k_{12}\cdot\sqrt{L_1L_2}\right)}{R_2}\cdot J_{12} \tag{2}$$

In the first parallel active-reactive circuit the next equations system can be written:

$$\begin{cases} \left(i\omega L_1 + R_1\right)\cdot J_{12} + i\omega k_{12}\cdot\sqrt{L_1L_2}\cdot J_2 = U_{C_1}, \\ U_{C_1} = \dfrac{1}{i\omega C_1}\cdot J_{11}, \end{cases} \tag{3}$$

where U_{C_1} is the voltage on the parallel branches of the considered circuit.

From expressions (2) and (3) the currents in the parallel branches – J_{12} and J_{11} can be found.

$$\begin{cases} J_{12} = U_{C_1}\cdot\dfrac{1}{i\omega L_1 + \left(R_1 + \dfrac{k_{12}^2\cdot\left(\omega L_1\right)\cdot\left(\omega L_2\right)}{R_2}\right)}, \\ J_{11} = U_{C_1}\cdot i\omega C_1. \end{cases} \tag{4}$$

Their sum determines the current – J_{02} in the output conductors from the reactive power source to the parallel resonant circuit [11].

Skipping the mathematical transformations [12], we receive that

$$J_{02} = J_{11} + J_{12} = U_{C_1}\cdot\left(i\omega C_1 + \frac{1}{i\omega L_1 + \left(R_1 + \dfrac{k_{12}^2\cdot\left(\omega L_1\right)\cdot\left(\omega L_2\right)}{R_2}\right)}\right) \tag{5}$$

Dependencies (4) and (5) we shall re-write in the format which is comfortable for the next analysis.

$$\begin{cases} J_{02} = U_{C_1}\cdot\left(i\omega C_1 + \dfrac{1}{i\omega L_1 + R_1\cdot\left(1 + K_{12}^2\cdot Q_1\cdot Q_2\right)}\right), \\ J_2 = -ik_{12}\cdot\sqrt{\dfrac{L_1}{L_2}\cdot Q_2\cdot\dfrac{U_{C_1}}{i\omega L_1 + R_1\cdot\left(1 + k_{12}^2\cdot Q_1\cdot Q_2\right)}}, \end{cases} \tag{6}$$

where $Q_1 = \dfrac{\omega L_1}{R_1}, Q_2 = \dfrac{\omega L_2}{R_2}$ – are Q – factors of the resonant circuits of the converter, correspondingly.

It is obvious from the physical considerations the "current resonance" realization in the parallel circuit demands quite small of the active resistance and quite weak electromagnetic coupling with the serial circuit. These facts determine the converter minimal influence on the reactive power source.

Neglecting summands $\left(\dfrac{R_1}{\omega L_1}\right) \ll 1$ and $k_{12}^2 \ll 1$, we shall receive the next expressions from the formulas (6):

$$\begin{cases} J_{02} \approx U_{C_1}\left(i\omega C_1 + \dfrac{1}{i\omega L_1}\right), \\ J_2 \approx -U_{C_1}\cdot K_{12}\cdot\sqrt{\dfrac{L_1}{L_2}\cdot Q_2\cdot\dfrac{1}{\omega L_1}}, \end{cases} \tag{7}$$

In the resonant regime (with frequency $\omega = \dfrac{1}{\sqrt{L_1C_1}}$) the expressions (7) accept the view:

$$\begin{cases} J_{02} \approx 0, \\ J_2 \approx -U_{C_1}\cdot K_{12}\cdot\sqrt{\dfrac{L_1}{L_2}}\cdot Q_2\cdot\dfrac{1}{\omega L_1}. \end{cases} \tag{8}$$

It follows from (8), the current in the output wires from the reactive power source will equal to zero and the voltage on the parallel circuit branches will equal to the voltage on the terminals of this source, $U_{C_1} = U_0$.

The ratio of the output active power and the input reactive power (the conversion coefficient) can be written in the following way:

$$K = \frac{P_2}{P_0} = k_{12}^2 \cdot \left(\frac{L_0}{L_1}\right) \cdot Q_2. \tag{9}$$

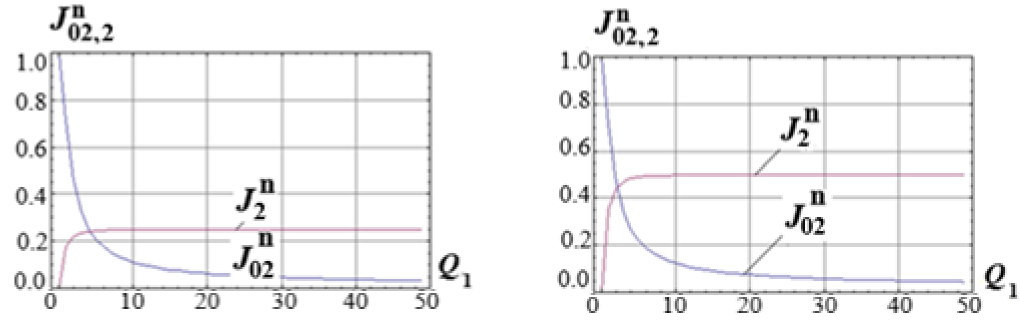
The got dependency is the main result of the accepted idealization. According to (9), if $k_{12}^2 \cdot \left(\frac{L_0}{L_1}\right) \cdot Q_2 > 1$, then not simply conversion but even the resonant amplifying the electrical power will have a place.

For the numerical estimates, we transform the dependencies (6) with normalizing to the current amplitude in the reactive power source inductance.

We receive that

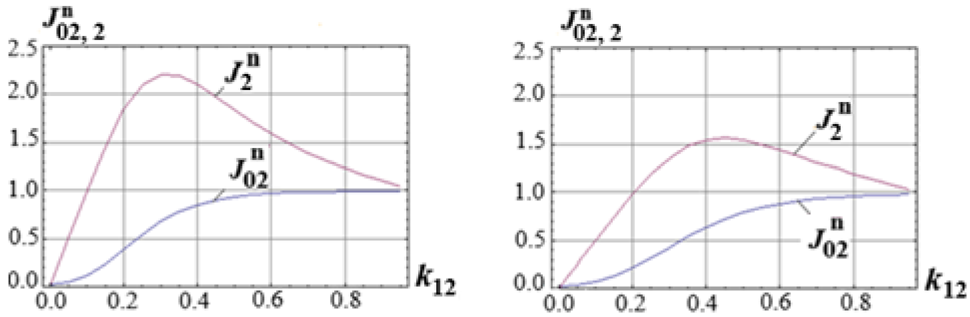
$$\begin{cases} J_{02}^n = \dfrac{J_{02}}{J_{01}} = \left(\dfrac{L_0}{L_1}\right) \cdot \left(\dfrac{\left(1 + k_{12}^2 \cdot Q_1 \cdot Q_2\right)}{\sqrt{Q_1^2 + \left(1 + k_{12}^2 \cdot Q_1 \cdot Q_2\right)^2}}\right); \\ J_2^n = \dfrac{J_2}{J_{01}} = \dfrac{k_{12} \cdot \dfrac{L_0}{\sqrt{L_1 L_2}} \cdot Q_1 \cdot Q_2}{\sqrt{Q_1^2 + \left(1 + k_{12}^2 \cdot Q_1 \cdot Q_2\right)^2}}. \end{cases} \tag{10}$$

The calculated graphical dependencies for the converter experimental model with the considered electrical scheme are represented on Fig. 2 – Fig. 4.



a) b)

Fig. 2. The graphical dependencies of the excited currents on the Q-factor of the parallel circuit under $L_0 = L_1 = L_2 = 14.8$ μH
a) $Q_2 = 5$, $k_{12} = 0.05$; b) $Q_2 = 10$, $k_{12} = 0.05$



a) b)

Fig. 3. The dependencies of the excited currents on the electromagnetic coupling level under $L_0 = L_1 = L_2 = 14.8$ μH and $k_{12} = 0.05$,

$a)\ Q_1 = 50,\ Q_2 = 10;$ b) $Q_1 = 50,\ Q_2 = 5$

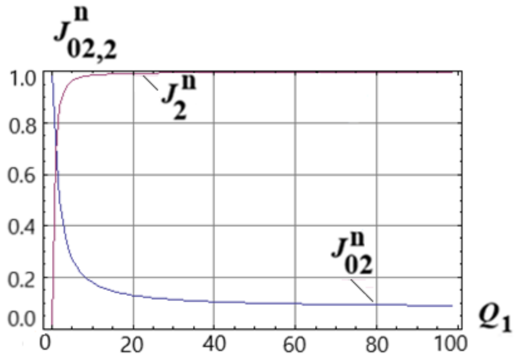


Fig. 4. The illustration of the electromagnetic processes characteristics in the converter optimal variant under $L_0 = L_1 = L_2 =$ 170 µH,

$$Q_2 = 12.5,\ k_{12} = 0.08,\ K = 1.0$$

The conducted calculations showed the effectiveness of the converter of the reactive power into the active one is determined by the following factors.

Increasing Q-factor of the parallel (the first) circuit allows decreasing its influence on the processes in the source what is explained by grows of this circuit inductive inductance relatively to its active resistance (the condition of the "current resonance").

The current limit value in the output from the source under the fixed Q-factor value of the serial (the second) circuit is determined by the relationship: $\lim\limits_{Q_1\to\infty} J^n_{02} = \left(\dfrac{L_0}{L_1}\right)\cdot k_{12}^2 \cdot Q_2$.

The current amplitude in the load beginning from some Q-factor value of the parallel (the first) circuit does not depend on its value and in limit will be equal to $\lim\limits_{Q_1\to\infty} J^n_2 = k_{12}\cdot\dfrac{L_0}{\sqrt{L_1 L_2}}\cdot Q_2$

A balance saves between the grows of the output current and decreasing the current in the output of the source demands quite small the electromagnetic coupling level between the circuits what is determined by fulfilling the "current resonance" conditions in the parallel circuit.

Finishing to comment the got results, it should be marked that the effective work of the investigated device means the maximum of the current and power in the load under the minimal influence on the inductance of the reactive power source.

As the calculations showed the optimal regime of the suggested converter of the reactive power into active one is the regime in which the circuits inductances are the same – $L_0 = L_1 = L_2$ = 14.8 µH, the Q-factors of the resonant circuits are $Q_1 = 100.0$, $Q_1 = 12.5$ and the level of the electromagnetic coupling between the circuits is $k_{12} = 0.08$ If the working frequency equals to ~ $25\,\text{kHz}$ then the active resistance of the parallel circuit has to be equaled to $R_1 \approx 0.27$ Om and the converter active load can equal to $R_1 \approx 2.14$ Om (it should be marked – low-resistance load).

The current distortion and, correspondingly, the influence index on the source amounts 8,5% – but the currents in the source and in the load are equaled to each other. And the input reactive power is transformed without losses in the output active electrical power in the load.

<u>The reactive power converter to the active one with the harmonic voltage additional source (Fig. 1. b)</u>

The corresponding conditions creation for the "current resonance" in the converter parallel circuit is realized at the expense of introduction of the harmonic voltage additional source.

The solution of the formulated problem will be conducted identically to the previous accordingly to the following assumptions.

The equivalent scheme of the converter consists of two inductively coupled resonant circuits: parallel and serial.

The frequencies of these circuits equal to between each other and $\omega_1 = \omega_2 = \omega -$ is the resonant frequency of all converter scheme.

The first resonant circuit – 1 is connected in parallel to the reactive power source (the inductance coil – L_0) with the harmonic current and voltage – $U_0(t) = U_m \sin(\omega \cdot t)$ (U_m – is the amplitude, $\omega -$ is the frequency, $t -$ is the time).

The additional harmonic voltage source – $E(t) = E \cdot \sin(\omega t)$ is connected in the parallel circuit in parallel to its capacitance.

Identically to the previous the state equations taking into account the voltage additional source can be written [11].

$$\begin{cases} R_2 \cdot J_2 + i\omega\left(k_{12} \cdot \sqrt{L_1 l_2}\right) \cdot J_{12} = 0; \\ \left(i\omega L_1 + R_1\right) \cdot J_{12} + i\omega\left(k_{12} \cdot \sqrt{L_1 L_2}\right) \cdot J_2 - E = U_{C_1}; \\ J_{11} = i\omega C_1 \cdot U_{C_1}; \end{cases} \tag{11}$$

where $Q_1 = \frac{L_1}{R_1}, Q_2 = \frac{\omega L_2}{R_2}$ are the Q – factors of the converter circuits, correspondingly.

The currents in the converter scheme elements are found from the algebraic equations system (11).

$$\begin{cases} J_2 = -\frac{i\omega\left(k_{12} \cdot \sqrt{L_1 L_2}\right)}{R_2} \cdot J_{12}; \\ J_{12} = \frac{U_{C_1} + E}{R_1 \cdot \left(iQ_1 + \left(1 + k_{12}^2 \cdot Q_1 \cdot Q_2\right)\right)}; \\ J_{11} = i\omega C_1 \cdot U_{C_1}. \end{cases} \tag{12}$$

The current in the output of the reactive power source is found summing the currents in the parallel circuit branches taking into account the resonance:

$$j_{02} = J_{11} + J_{12} = \frac{\left(E + i\frac{U_{C_1}}{Q_1} \cdot \left(1 + k_{12}^2 \cdot Q_1 Q_2\right)\right)}{R_1 \cdot \left(iQ_1 + \left(1 + k_{12}^2 \cdot Q_1 \cdot Q_2\right)\right)}. \tag{13}$$

As it follows from (13) in order to $J_{02} = 0$ it is necessary

$$E = -iU_{C_1} \cdot \left(\frac{1}{Q_1} + k_{12}^2 \cdot Q_2\right). \tag{14}$$

Taking into account that $U_{C_1} = U_0$ and under condition (14) the current in the converter load will equal to

$$J_2 = \frac{U_0}{R_2} \cdot \left(k_{12} \cdot \sqrt{\frac{L_2}{L_1}}\right) \cdot e^{-\frac{\pi}{2}}. \tag{15}$$

The conversion coefficient of the amplitude of the reactive power into active one is being found by the known manner [12]:

$$K = \frac{|P_2|}{|P_0|} = \left(\frac{L_0}{L_1}\right) \cdot k_{12}^2 \cdot Q_2, \tag{16}$$

where $P_0 = \frac{U_0^2}{\omega L_0}$ – is the power of the reactive power source.

It is obvious that for the converter maximal effectiveness in the whole the additional voltage source contribution in the “current resonance” realization in the parallel circuit has to be minimal value. For this, as it follows from dependencies (14) and (16) it is necessary to create the quite high Q-factor – $Q_1 \gg 1$ and the quite weak electromagnetic coupling with the serial circuit under its small Q-factor. Formally, the latter requirements will be determined by the inequality: $k_{12}^2 \cdot Q_2 \ll 1$. Under this, the dependence of the conversion power coefficient – (16) demands increasing parameter – $k_{12}^2 \cdot Q_2$.

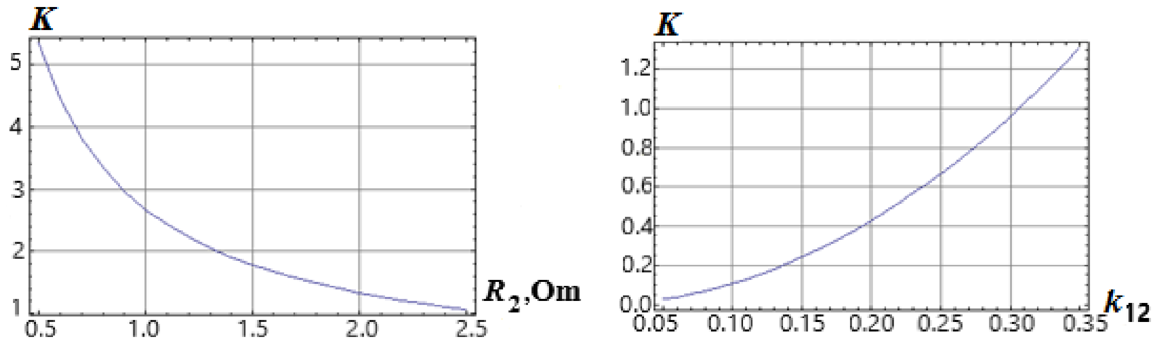
It is obvious from the practical considerations the main parameter in the effectiveness estimations of the suggested device is the voltage minimum of the additional source. The first, the coefficient conversion value is not so important because the formulated task consisted in the conversion of the reactive power into active one (but it was not the power amplify). The second, the coefficient of conversion depends on the relation – $\left(\frac{L_0}{L_1}\right)$, what permits regulating its value. In this connection the choice of the parameter – $k_{12}^2 \cdot Q_2$ have to be oriented on the dependence (14) in the first turn and already after this on dependence (16).

It is obviously the variations of the marked quantities and the correspondingly correct choice of the key parameters of the suggested scheme will allow to determine the demanded voltage of the additional source and the conversion coefficient of the reactive power into active one.

The numerical estimates which illustrate usage of the got dependencies and the qualitative analysis results we shall fulfill for the converter experimental model. Let us start from the following initial data: $k_{12}^2 \cdot Q_2 = 0.1$ $(k_{12} = 0,1, Q_2 = 10)$ the source reactive power inductance is $L_0 = 170\,\mu\text{H}$, the parallel circuit inductance is $L_1 = 17\,\mu\text{H}$, the working frequency is $\omega = 2\pi \cdot 25000\,\text{Hz}$. If $L_2 = L_0 = 170\,\mu\text{H}$ the acceptable value of the load active resistance will be equaled to $R_2 = \dfrac{\omega L_2}{Q_2} = 2.7\,\text{Om}$. Under the active resistance of the parallel circuit – $R_1 = 0.1\,\text{Om}$ its Q-factor will be equaled to $Q_1 = \dfrac{\omega L_1}{R_1} = 26.7.$

Now the conversion coefficient from the formula (16) will equal to – $K = 1.0$, the voltage of the additional source from the formula (14) will equal to – $|E| \approx 0.14 \cdot U_{C_1}$ what amounts to ~ 14% of the voltage of the reactive power source.

The functional dependencies – $K = K\left(R_2, k_{1,2}\right)$ are represented on Fig. 5.



a) **b)**

Fig. 5. The conversion coefficient of the reactive power into active one in the converter experimental model a) the dependence on the load resistance ($k_{12} = 0.1$),

b) the dependence on the electromagnetic coupling level between the circuits ($R_2 = 2.5\,\text{Om}$)

From dependencies on Fig. 5 the conclusion follows about the possibility work of the reactive power converter into active one as the electrical power amplifier. It is obvious from the graphic on Fig. 5 that under the quite real level of the electromagnetic coupling between the circuits – $k_{12} = 0.1$ and the active load value – $R_2 < 1.5\,\text{Om}$ the conversion coefficient amounts – $K > 1$.

The presented estimates suggest that the proposed converter circuit, with an appropriate choice of its parameters, makes it possible to obtain amplified active power in a low-resistance load at the output of the device under study.

It should be noted that in the converter experimental model the necessary voltage of the additional foreign source can be practically to install at expense variation of its amplitude-phase characteristics till receiving the zero current in conductors from the output clips of the reactive power source.

Conclusions

The possible schemes of the resonant converter of reactive power into active one the common thing for which is existence of two inductively coupled active-reactive circuits but different by the ways of the resonant conditions creation are suggested.

For the scheme where the resonance excitation is fulfilled by the corresponding choice of its parameters the conditions are determined the realization of which minimizes the suggested scheme influence on the processes in the reactive power source under the current maximum in the converter load.

The calculations for the experimental model showed that under the corresponding choice of the element base it is possible the real receiving the conversion coefficient ~ 1.0 under minimum influence on the current in the reactive power source (till ~ 8,5 %).

For the scheme with the additional source of the harmonic voltage it is shown that under corresponding tuning the negative influence of the converter scheme on the reactive power source can be fully excluded.

The numerical estimates for the experimental model with the additional source of the harmonic voltage showed its practical workability and the high effectiveness of the power conversion.

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