The Undisclosed Chapter of the Textbook on Electrical Engineering

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Abstract:A special point was found in the frequency characteristics of the oscillatory circuit, which was not mentioned earlier in textbooks on electrical engineering and radio engineering. The module of complex resistance of the circuit does not depend on the value of the active resistance at a frequency less than times that of the resonance. The material is of interest to all engineers and scientists specializing in electrical engineering. On its basis, new methods for measuring the parameters of electrical circuits can be developed. Physical interpretation of the phenomenon doesn't exist at the moment.

Keywords:RLC circuit; resonance of current; resonance of voltage

1. Introduction

One of the basic elements of the radio engineering devices is the oscillatory contour.Millions (and maybe tens of millions) of people who taught and studied electrical engineering and radio engineering did not notice an interesting phenomenon - the existence of a singular point in the frequency characteristics of the oscillatory circuit. At a frequency of $\sqrt{2}$ lower than the resonance frequency, the impedance modulus of the circuit does not depend on the value of the active loop resistance. All the frequency characteristics of this circuit pass through a point at which the modulus of complex resistance in $\sqrt{2}$ is greater than the characteristic impedance of the circuit.

Two models of a RCL circuit normally analyzed in numerous textbooks and reference books on electrical engineering –serial and parallel. Models where all three elements are connected in the same way have a constant resonance frequency, which minimizes the resistance of the circuit with the serial connection of the elements and the conductivity of the circuit with parallel connection. Sometimes a parallel loop is considered, where the inductor is modeled by a series-connected active and reactive resistors. In this case, a decrease in the resonant frequency with an increase in resistance is noted. In [1-7], a singular point was found in the frequency characteristics of the contours, in which the modulus of complex resistance remains constant in the entire range of changes in the active resistance. The purpose of this article is to draw the attention of the electrical engineering community to the detected effect, on the basis of which new methods for measuring the parameters of electrical circuits can be proposed. The question remains of the unknown at the present time the physical nature of the phenomenon.

2. Module impedance

Figure 2 shows two contour models in the frequency characteristics of which there is a singular point. Both mod-els are described by a single formula, but for the left one calculates the impedance, and for the right the complex conductivity modulus. We will consider only the model RCL circuit with impedance calculation

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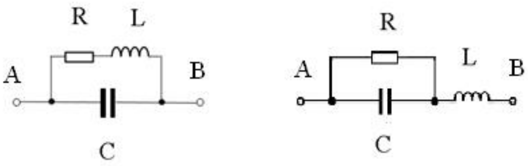

Figure 1. Two models of a contour with a singular point

The impedance of a such contour can be presented in the form:

$$\overline{Z} = \frac{j\,\overline{\omega}+\overline{r}}{(1-\overline{\omega}^2)+j\,\overline{\omega}\overline{r}} \qquad (1)$$

where $\overline{Z}$- relation of the impedance to the characteristic resistance of a contour, equal $\sqrt{L/C}$,

$\overline{\omega}$ - the frequency relation to resonant frequency,

$\overline{r}$ - the relation of active resistance to the contour characteristic resistance contour.

The frequency characteristic of an impedance is presented on the figure 2. The existence region of the impedance module is limited by two asymptotes noted on the figure by dashed lines:

1. asymptote $\frac{\overline{\omega}}{|(1-\overline{\omega}^2)|}$ ($\overline{r}$ =0),

2. asymptote $\frac{1}{\overline{\omega}}$ **(**$\overline{r}$ **→∞).**

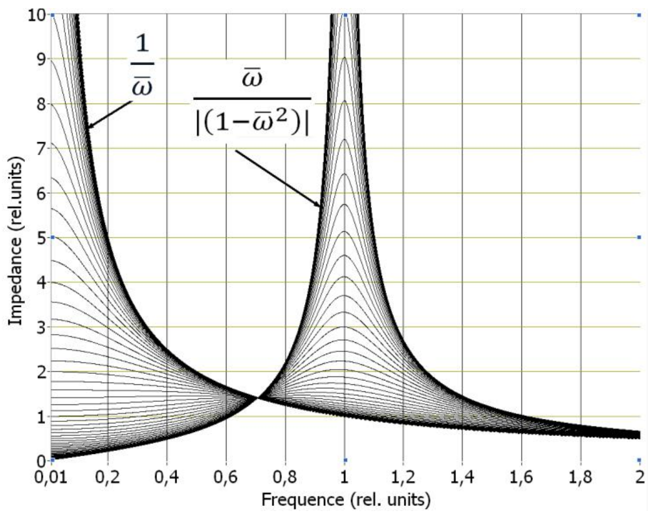

Figure 2. Existence region of the impedance module

All the curves of an impedance module (and asymptotes) have the general point with value of the relative module $\sqrt{2}$ at the relative frequency equal $1/\sqrt{2}$. The existence region of the module from above is limited by the second asymptote at low frequencies, and from below the first, and for frequencies is higher critical on the contrary.

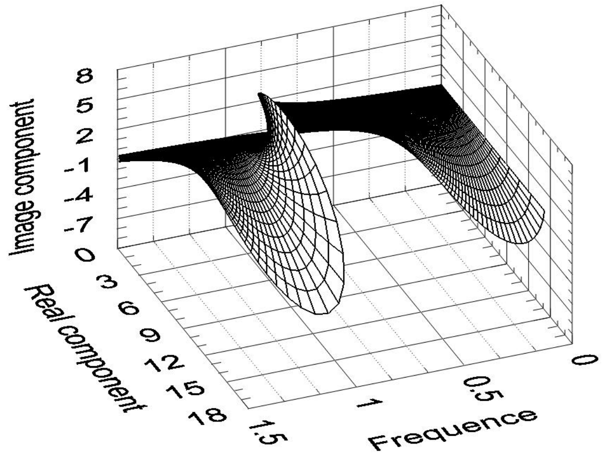

Figure 3. Surface of the phase charts

The phase surface of the impedance is given depending on the frequency on figure 3. The chart is formed by semi-circles which radius is equal $\frac{1}{|2\bar{\omega}(1-\bar{\omega}^2)|}$, and the center is displaced on the distance $\frac{2\,\bar{\omega}^2-1}{|2\bar{\omega}(1-\bar{\omega}^2)|}$.At the critical point the phase chart represents the notdisplaced semi-circle with a radius equal $\sqrt{2}$..

On the basis of the effect the mechanical model [9-10] was offered. The module of mechanical resistance of the model also didn't depend on the value of coefficient of viscosity at a certain frequency. Since the question of the physical nature of the effect remains unresolved, the author of this article do attempt the most detailed descriptions of the properties of a this system. Both types of circuit reviewed to identify major difference between the two models.

Results of calculations are given existence region of the relative module impedance. Circular charts various models are given in the wide range of frequencies. Formulas are given for the dependence of shift and radius of a phase semi-circle.

3. The imaginary part of impedance

The components of the impedance calculated depending on the relative frequency and the relative resistance in the course of studying this issue. The frequency was normalized by the resonance frequency and the resistance and impedance of components at

$$\mathrm{Im} = \frac{\bar{\omega}(1-\bar{r}^2-\bar{\omega}^2)}{(1-\bar{\omega}^2)^2+\bar{r}^2\,\bar{\omega}^2} \qquad (2)$$

where $\bar{\omega}$ is normalized frequency, $\bar{r}$- is the normalized resistance. The computation results are shown in Fig.4. Features include a special point located at the resonant frequency. The imaginary component does not depend on the resistance and equal to -1 at this point. The three asymptotes form the region of existence of imaginary components

1. asymptote $-\frac{1}{\omega}$,when $\bar{r} \to \infty$,

2. asymptote $\frac{\bar{\omega}}{1-\bar{\omega}^2}$,when $\bar{r} \to 0$,

3. cut the y-axis from 0 до -∞.

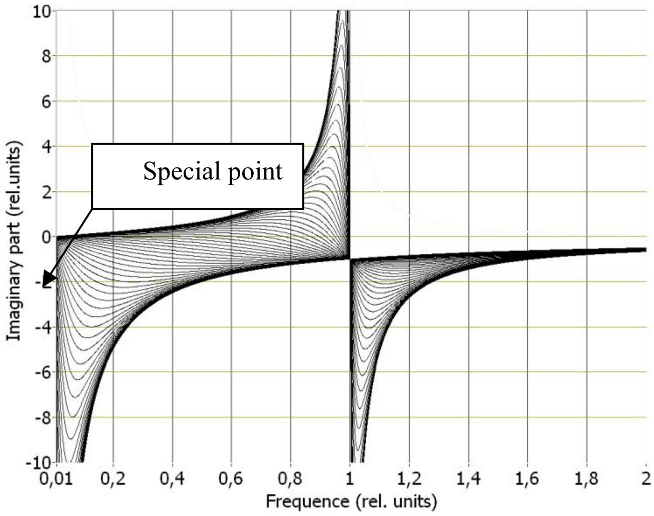

Figure 4. Dependence of the imaginary components of impedance against frequency and normalized resistance

Two asymptotes are marked by dashed lines in Fig.4.

4. The real part of the impedance

The real component of the impedance of such a circuit - Re, normalized by the characteristic loop resistance, is calculated according to the formula

$$\mathrm{Re} = \frac{\bar{r}}{(1-\bar{\omega}^2)^2 + \bar{r}^2\bar{\omega}^2}$$

where $\bar{\omega}$ and $\bar{r}$are the normalized parameters introduced earlier. The result of calculation (Fig.5).

The two asymptotes form the region of existence of real component:

1. asymptote - $\frac{1}{2\bar{\omega}|1-\bar{\omega}^2|}$
2. the x-axis,

The first asymptote has a local minimum at the relative frequency $\frac{1}{\sqrt{3}}$. The real part of the impedance is equal $\frac{3\sqrt{3}}{4}$at this frequency.

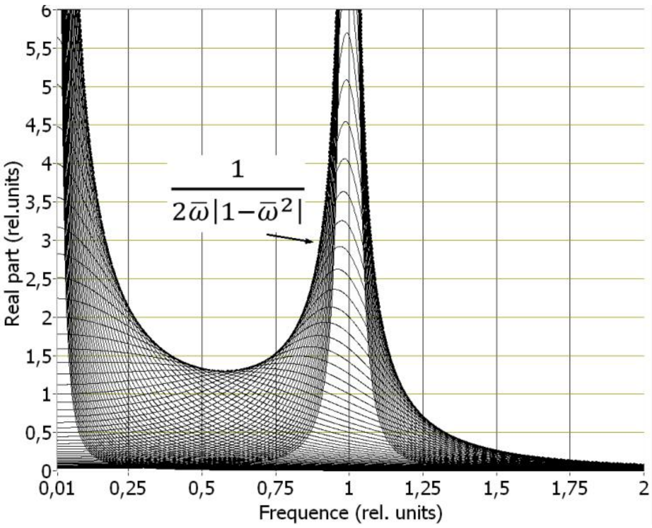

Figure 5. Real part of impedance RCL circuit

A local minimum occurs when the value of the relative resistance is equal to $\frac{2}{\sqrt{3}}$.

5. Mechnical model

Of particular interest is a simple mechanical contour model. The diagram of this model is shown in the figure 6.

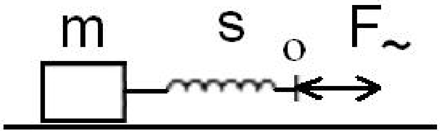

Figure 6. Scheme of the mechanical system

The speed of the displacement of point 0 (electrical analog of current) is the sum of the displacement of a massive body and a spring. Force applied to the body and spring is the same, due to the weightlessness of the spring. The variable speed of the point 0 is zero. As a result, a mechanical system with a sequential connection of elements is equivalent to a parallel contour. Moreover, a mechanical system of this type cannot in principle be realized as a direct electric equivalent, since it is impossible to imagine connecting a series-connected capacitor and inductor to a voltage source so that the currents in these elements are summed.

6. Conclusion

The properties of the system studied, which reveals the stability of the impedance on the path to understanding the nature of this effect. Regardless of the decision of the main question, obviously, was found the effect of a new fundamental knowledge in electrical engineering. It deserves to be known to specialists in this field.

Basic distinction of the the phase charts is revealed for the contour different models. This results is obviously important for researches of the chains containing the oscillatory contour and also when studying electrical equipment and radio engineering.

The founded effect may find application in measurement technology in the development of new techniques, for example, additional monitoring of the resonant frequency or measurement of the reactive component of the high-resistance resistors.

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