

ANALYSIS OF THE USE OF COMPLEX NUMBERS IN THE CALCULATION OF INDUCTOR, RESISTOR, AND CAPACITOR SERIES CIRCUITS

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ABSTRAK

Konsep matematika sebenarnya mempunyai relevansi dengan kehidupan sehari-hari. Penerapan konsep matematika bilangan kompleks dapat ditemukan dalam berbagai aspek, seperti dalam menghitung rangkaian resistor, induktor, dan kapasitor. Penelitian ini bertujuan untuk menyelidiki bagaimana rangkaian seri resistor, induktor dan kapasitor digunakan dalam aplikasi bilangan kompleks. Pendekatan yang digunakan dalam penelitian ini adalah penelitian kualitatif melalui studi kasus pada rangkaian resistor, induktor dan kapasitor. Sumber data yang digunakan adalah data sekunder yang diperoleh melalui artikel jurnal ilmiah, buku dan tinjauan pustaka yang sesuai dan mendukung penelitian ini. Teknik keabsahan data yang digunakan adalah triangulasi. Teknik keabsahan data melalui tahapan kondensasi data, penyajian data, dan penarikan kesimpulan. Hasil penelitian menunjukkan bahwa bilangan kompleks dapat diterapkan dengan baik pada rangkaian seri resistor, induktor, dan kapasitor, yaitu berhasil menyelesaikan permasalahan pada rangkaian seri resistor, induktor, dan kapasitor. Manfaat dari penelitian ini adalah Anda dapat memperoleh pemahaman dan penerapan bilangan kompleks dalam menyelesaikan perhitungan pada rangkaian seri resistor, induktor dan kapasitor.

Kata Kunci: Sirkuit Series RLC, Matematika, Bilangan Kompleks

ABSTRACT

Mathematical concepts actually have relevance to everyday life. The application of complex number mathematical concepts can be found in various aspects, such as in calculating resistor, inductor and capacitor circuits. This research aims to investigate how series circuits of resistors, inductors and capacitors are used in complex number applications. The approach used in this research is qualitative research through case studies on series of resistors, inductors and capacitors. The data sources used are secondary data obtained through scientific journal articles, books and literature reviews that are appropriate and support this research. The data validity technique used is triangulation. The data validity technique goes through the stages of data condensation, data display, and drawing conclusions. The research results show that complex numbers can be applied well in series circuits of resistors, inductors and capacitors, namely successfully solving problems in series of resistors, inductors and capacitors. The benefit of this research is that you can gain an understanding and application of complex numbers in completing calculations on series circuits of resistors, inductors and capacitors.

Keywords: RLC Series Circuit, Mathematics, Daily life, Complex numbers.

INTRODUCTION

The RLC circuit is an electronic system composed of three main components: resistor (R), inductor (L), and capacitor (C) (Sari & Nurhamidah, 2022). These components can be connected in parallel or series to produce a variety of unique electrical characteristics. One of the important configurations in an RLC circuit is a series arrangement. In this arrangement, resistors, inductors and capacitors are connected sequentially, so that the current flowing through the circuit is the same (Sari & Nurhamidah, 2022). Each component exerts a different influence on the current and voltage in the circuit, depending on the value and frequency of the applied signal. The behavior of an RLC series arrangement is determined by a combination of resistance (R), inductance (L), and capacitance (C).

According to Gómez et al., (2017) RLC circuits, the workhorses of electronics, telecommunications, and power systems, have traditionally relied on real number algebra for analysis. However, this approach can become a tangled mess when dealing with high-frequency circuits or complex designs.

These mathematical concepts, which were introduced in the 18th century, brought a new perspective to the analysis of RLC circuits (Kang, 2018). They enabled engineers to represent impedance, voltage, and current in a single, streamlined package, which not only improved the aesthetic appeal of the analysis but also provided a foundation for the development of powerful new analysis tools. The impedance and phasor methods, which were built on the foundation of complex numbers, became the cornerstones of modern AC circuit analysis. With these tools, engineers were able to analyze complex circuits and high-frequency behavior with greater efficiency, laying the foundation for the ever-evolving field of electronics.

Kang JS (2018) describes that the analysis of electrical circuits traditionally relied on real number algebra methods. While effective for simple circuits, this approach becomes cumbersome and unintuitive when applied to more intricate ones, particularly Resistor-Inductor-Capacitor (RLC) circuits. Furthermore, Tampubulon (2019) explained that complex analysis becomes invaluable in understanding the phenomenon of resonance in RLC circuits. Resonance occurs at

a specific frequency where the circuit exhibits a maximum response. Complex numbers allow for the easy calculation of the resonant frequency and quality factor, which are difficult to achieve with real number algebra methods.

According to Sari et al., (2022) the application of complex analysis to RLC circuits not only offers a more efficient solution but also opens the door to a deeper understanding of their behavior. The simplicity, ability to handle high frequencies and resonance, and visual representation make complex analysis an indispensable tool in the realm of electrical engineering.

According to Siregar (2016), the method used to apply complex numbers to resistor, inductor and capacitor circuits is to collect theory and data related to resistor, inductor and capacitor circuits and the complex numbers themselves. Armed with theory collected from various sources, various problems in the RLC power network can be overcome using complex numbers. The use of complex numbers in this method provides several significant advantages. Complex numbers enable an easier and more intuitive representation of the impedance of resistor, inductor and capacitor circuits, thereby simplifying mathematical analysis. In addition, complex numbers enable the analysis of the behavior of resistor, inductor and capacitor circuits under various conditions, such as steady state, transient and high frequency.

One application of mathematics as an example is the application of mathematics to complex numbers. The application of complex number mathematical concepts in everyday life can be found in various aspects, such as in engineering and science (Harahap & Yahfidzam, 2023). In everyday life, the use of complex numbers is not only limited to science and engineering, but also in various aspects of life, such as in measuring time, measuring temperature and pressure, electricity and developing more efficient and effective systems. The use of complex numbers in everyday life helps in the development of science and technology, and helps in the development of more efficient and effective systems.

Mathematical concepts actually have relevance to everyday life. Facts show that there are not many mathematical formulas or concepts that form the basis of every

daily activity. The application of mathematical concepts in everyday life is important to improve each individual's understanding and mathematical skills. The use of mathematics in everyday life is not only limited to education, but also in science, technology and culture.

Mathematics has a very important role in everyday life. According to Sadiq, quoted in Tampubolon et al., (2019), mathematics discusses patterns or regularities and levels. This shows that mathematics educators need to help students to develop thinking skills through understanding mathematical patterns, which requires a good education to achieve. Mathematics has a very important role as a basis for various other scientific disciplines and has many applications in everyday life, such as in education, science, technology and culture (Munasiah et al., 2020). Despite this, mathematics education in Indonesia still lags behind international standards, as can be seen from the results of the PISA 2022 research which shows the low mathematics abilities of Indonesian students (OECD, 2023). Therefore, efforts are needed to improve mathematics learning and the application of mathematical concepts in everyday life in Indonesia. One of them is the application of complex numbers in series circuits of resistors, inductors and capacitors.

This journal will discuss the application of complex numbers in determining impedance and voltage in resistor, inductor and capacitor circuits. This research aims to investigate how series circuits of resistors, inductors and capacitors are used in complex number applications. The benefit of this research is that you can gain an understanding and application of complex numbers in completing calculations on series circuits of resistors, inductors and capacitors.

The approach used in this study is qualitative research through case studies in the RLC series. The data sources used are secondary data obtained through scientific journal articles, books, and literature reviews that are appropriate and support this research. This method is easy to use because it involves collecting various secondary sources or data i.e. from several books or journals as references. According to Mestika Zed, quoted in Harahap & Yahfidzam (2023), this can be interpreted as a series of activities related to collecting data from libraries, reading and taking notes, and analyzing research materials. The data validity technique used

is triangulation. According to Mekkarisce (2020), Triangulation is carried out to strengthen qualitative research in three main aspects, namely theory, methodology, and interpretation. This is done by verifying data through various sources, data collection techniques, and data collection times. Data validity techniques through the stages of data condensation, data display, and conclusions.

DISCUSSION

One type of electrical circuit consists of resistors, inductors and capacitors. Because it consists of a resistor (R), inductor (L), and capacitor (C), the circuit is called an RLC circuit. This circuit forms harmonic oscillations and will resonate in the same way as an LC circuit. Before going into the discussion of the RLC circuit, the author will first explain the components of the RLC circuit:

1. Resistance

Resistance is the resistance provided by a resistor. Reactance is resistance that reacts to changes in current and voltage. The value changes depending on the phase difference of the current and voltage. Meanwhile, impedance is the overall nature of resistance to current, including resistance, reactance, or both. Impedance is often also called internal resistance. The unit for these three types of resistance is the ohm. (Ω)

$$I_R = I \sin(\omega t)$$

$$E_T = I_R \cdot R = I \sin(\omega t) \cdot R = I \cdot R \sin(\omega t) = E \sin(\omega t)$$

If

$$\sin(\omega t) = 1, \text{ so } E_T = I \cdot R$$

2. Inductors and Capacitors

An inductor is an electrical component that stores electrical energy in the form of magnetic energy. Inductors inhibit current by lowering the voltage, directly proportional to the rate of change of current. According to Lenz's law, the induced voltage is always in such a polarity that it keeps the current value the same as before. So, when the current increases, the induced voltage will oppose the flow of electrons. Meanwhile, when the current decreases, the polarity will reverse and encourage the flow of electrons. This is referred to

as reactance. In an inductor, energy is stored in its magnetic field. The following is the relationship between voltage and the rate of change of current through the inductor:

$$V = L \frac{di}{dt}$$

where V is the voltage, L is the inductor, and i is the current.

The symbol for inductive reactance is X_L . Inductive reactance can be calculated by the following equation:

$$X_L = 2\pi fL$$

with X_L in ohms, f (frequency) in Hertz, and in L Henry.

Capacitors are electrical components that store electric charge. Unlike inductors, capacitors actually allow current to pass through them, which is directly proportional to the rate of change of voltage. The current through a capacitor is a reaction to changes in voltage across the capacitor. In a capacitor, energy is stored in its electric field. The following is the relationship between current and the rate of change of voltage through the capacitor:

$$i = C \frac{dV}{dt}$$

Where V is the voltage, C is the capacitor, and i is the current.

The symbol for capacitive reactance is X_C . Capacitive reactance can be calculated by the following equation:

$$X_C = \frac{1}{2\pi fC}$$

With X_C in ohms, f (frequency) in Hertz, and C in Farads (F).

After we get the inductor reactance and capacitor reactance, the impedance in the circuit can be found using the equation

$$|Z| = \sqrt{R^2 + (X_L - X_C)^2}$$

Apart from impedance, we can also find the effective voltage in the circuit with the equation

$$V_{ef} = \sqrt{V_R^2 + (V_L - V_C)^2}$$

so the phase angle of the circuit is

$$\tan \varphi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{X_R}$$

The properties of an RLC circuit depend on the inductive reactance and capacitive reactance of the circuit. If the inductive reactance is greater than the capacitive reactance, then the circuit is inductive. Conversely, if the inductive reactance is smaller than the capacitive reactance, then the circuit is capacitive. Meanwhile, if the inductive reactance and capacitive reactance are the same, then the circuit is resistive and a resonance will occur whose frequency can be determined using the equation:

$$f_{res} = \frac{1}{2\pi} \sqrt{\frac{1}{L \cdot C}}$$

If the circuit is resistive, then the circuit impedance reaches a minimum and is equal to the value of the resistor. When the impedance is minimum, the current flowing reaches a maximum. In alternating current (AC), the sinusoidal voltage can be written in the form of a voltage equation as a function of time, namely:

$$V = V_m \sin (2\pi ft)$$

Complex numbers in RLC circuits are applied during calculations on the circuit. One of the calculations that use complex numbers is impedance. In the Basic Theory section, it has been explained that impedance is the overall nature of resistance. It has also been explained the equation to find the amount of impedance. However, to find the actual impedance using complex numbers, with the equation:

$$z = R + jX_L + jX_C$$

$$z = Ze^{i\theta}$$

To find out whether the current or voltage that vibrates first can be used Ohm's Law.

$$I = \frac{V}{z} = \frac{V_0}{Z} e^{j(\theta-\phi)}$$

Which shows the current is out of phase by ϕ from the voltage.

In solving RLC circuit problems, we have to change the form of complex numbers in order to perform the operations of addition subtraction multiplication and division. Therefore, the ability to transform rectangular complex number forms to polar and vice versa is needed. each addition and subtraction operation should be used rectangular form while multiplication and division operations are used polar form.

CONCLUSION

Discusses how complex numbers are a powerful tool for analyzing Alternating Current (AC) circuits containing resistors, inductors, and capacitors connected in series. A core concept in AC circuits is impedance, which combines resistance (from resistors) with reactance (opposition from inductors and capacitors). Complex numbers help represent the effects of both resistance and reactance in a single term. Complex numbers simplify calculations compared to traditional methods using trigonometry or differential equations for AC circuits. Complex numbers are a more efficient and elegant way to analyze and solve problems involving series circuits with resistors, inductors, and capacitors in AC conditions.

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