

1- For The Circuit Given Below, Calculate The Voltage Across The Capacitor. (2 Points) -j2 N 1 20 1:2,

1- For The Circuit Given Below, Calculate The Voltage Across The Capacitor. (2 Points) -j2 N 1 20 1:2,

Understanding how to analyze and calculate the voltage across a capacitor in a complex circuit is fundamental in electrical engineering. Whether you're a student preparing for exams or a professional designing circuits, mastering this concept is essential. In this article, we will explore step-by-step how to determine the voltage across a capacitor in a given circuit, emphasizing the importance of impedance, phasor analysis, and circuit simplification techniques.

Introduction to Circuit Analysis with Capacitors

Before delving into the specific problem, it's important to understand the basic principles involved in AC circuit analysis, especially as they pertain to capacitors.

Capacitors in AC Circuits

A capacitor is a passive electronic component that stores electrical energy in an electric field. In AC circuits, capacitors oppose changes in voltage, and their behavior is characterized by their impedance, which varies with frequency.

The impedance (Z_C) of a capacitor (C) in an AC circuit is given by:

$$Z_C = \frac{1}{j\omega C}$$

where:

- (j) is the imaginary unit ($j^2 = -1$)
- $(\omega = 2\pi f)$ is the angular frequency
- (C) is the capacitance in Farads

The magnitude of the impedance is:

$$|Z_C| = \frac{1}{\omega C}$$

And the phase angle is (-90°) , meaning the current leads the voltage by 90 degrees.

Understanding the Given Circuit

Given the notation, the circuit involves a complex impedance and possibly a combination of resistors, inductors, and capacitors. The notation "-j2 N 1 20 1:2" suggests an impedance element with a reactive component (inductive or capacitive) associated with a complex impedance of $(-j2)$ ohms, and other circuit parameters.

While the problem statement appears abbreviated, typical steps to analyze such a circuit include:

- Identifying the source voltage
- Recognizing all impedance elements
- Simplifying the circuit to a Thevenin equivalent or a series/parallel combination
- Calculating the total impedance
- Finding the current through the circuit
- Calculating the voltage across the capacitor

In the absence of a detailed circuit diagram, the general methodology remains the same.

Step-by-Step Approach to Calculate the Voltage Across the Capacitor

Let's outline a systematic approach to solving these types of problems.

Step 1: Clarify Circuit Parameters

- Determine the source voltage (V_s) (magnitude and phase)
- Identify all circuit elements and their impedances
- Recognize the frequency (f) at which the circuit operates

Step 2: Convert All Circuit Elements to Impedances

- Resistors: $(Z_R = R)$
- Inductors: $(Z_L = j\omega L)$
- Capacitors: $(Z_C = \frac{1}{j\omega C})$

Given the complex impedance "-j2," it suggests a capacitive reactance:

$$Z_C = -j2\omega$$

which implies:

$$C = \frac{1}{40}$$

$$|Z_C| = 2\omega \quad \text{and phase angle} = -90^\circ$$

This indicates a capacitor with reactance $(X_C = 2\omega)$.

Step 3: Simplify the Circuit

- Combine series and parallel impedances
- Use the rules:

$$Z_{\text{series}} = Z_1 + Z_2$$

$$\frac{1}{Z_{\text{parallel}}} = \frac{1}{Z_1} + \frac{1}{Z_2}$$

This helps in reducing the circuit to a single equivalent impedance seen from the source.

Step 4: Calculate Total Impedance

- Sum all impedances in the circuit to find the total impedance (Z_{total}) .

Step 5: Find the Circuit Current

- Use Ohm's Law in phasor form:

$$I_{\text{total}} = \frac{V_s}{Z_{\text{total}}}$$

- The magnitude and phase of (I_{total}) can be calculated once (Z_{total}) is known.

Step 6: Determine the Voltage Across the Capacitor

- The voltage across a specific element like the capacitor is:

$$V_C = I_{\text{element}} \times Z_C$$

- Since the current flows through the capacitor in series, the voltage across it is:

$$V_C = I_{\text{total}} \times Z_C$$

- Convert the phasor (V_C) back to its magnitude and phase to interpret the real-world voltage.

Sample Calculation with Assumed Values

Suppose, for illustration, the circuit comprises:

- An AC source $(V_s = 20\text{V})$ at a frequency $(f = 50\text{Hz})$
- A resistor $(R = 1\Omega)$
- A capacitor with reactance $(X_C = 2\Omega)$, hence $(Z_C = -j2\Omega)$

The impedance of the resistor:

$$Z_R = 1\Omega$$

Total impedance in series:

$$Z_{\text{total}} = Z_R + Z_C = 1 - j2\Omega$$

Calculating the magnitude:

$$|Z_{\text{total}}| = \sqrt{1^2 + (-2)^2} = \sqrt{1 + 4} = \sqrt{5} \approx 2.236\Omega$$

Phase angle:

$$\theta = \arctan\left(\frac{-2}{1}\right) \approx -63.43^\circ$$

Current:

$$I_{\text{total}} = \frac{20\text{V}}{2.236\Omega} \approx 8.944\text{A}$$

with phase:

$$\phi = -63.43^\circ$$

Voltage across the capacitor:

$$V_C = I_{\text{total}} \times Z_C = 8.944 \text{ A} \times (-j2 \Omega) = 8.944 \times 2 \angle -90^\circ + \phi$$

Calculating:

$$V_C = 17.89 \text{ V} \angle (-90^\circ + -63.43^\circ) = 17.89 \text{ V} \angle -153.43^\circ$$

The magnitude of (V_C) is approximately 17.89 V, and its phase indicates the voltage leads the current by 90° , as expected for a capacitor.

Interpreting the Results

The key takeaway from such calculations is understanding how the impedance of the capacitor influences the voltage distribution in the circuit. The voltage across the capacitor can be higher or lower than the source voltage depending on the circuit configuration, frequency, and impedance values.

Practical Applications and Importance

Calculating the voltage across capacitors is crucial in various practical scenarios:

- Designing filters (low-pass, high-pass)
- Tuning resonant circuits
- Power factor correction
- Signal processing
- Impedance matching in communication systems

Understanding how to perform these calculations enhances the ability to troubleshoot, optimize, and innovate in electrical and electronic engineering.

Conclusion

In summary, calculating the voltage across a capacitor in a given circuit involves understanding the impedance of circuit elements, simplifying the circuit, computing total impedance, and applying Ohm's law in the phasor domain. Though the initial problem statement appears complex, breaking it down into manageable steps makes the analysis straightforward. Mastery of these techniques is fundamental for effective circuit analysis and design, enabling engineers to predict circuit behavior accurately and optimize performance.

Remember: Always verify your assumptions about the circuit parameters, and if a circuit diagram becomes available, revisit the calculations for precise results. Whether analyzing simple RC circuits or complex networks, the core principles remain consistent.

Frequently Asked Questions

What is the primary method to calculate the voltage across a capacitor in a circuit with given impedance values?

The primary method involves using the impedance of the capacitor and the source voltage, applying Ohm's law in the AC domain: $V_C = I \times Z_C$, where Z_C is the capacitive impedance, and then calculating the voltage across the capacitor based on the current and impedance.

How do you determine the impedance of a capacitor in an AC circuit with a reactance of $-j2$ ohms?

The impedance of a capacitor is given by $Z_C = 1 / (j\omega C)$. If the reactance is $-j2$ ohms, it indicates that the capacitor's impedance magnitude is 2 ohms with a phase angle of -90° , representing a capacitive reactance.

What role does the given reactance ($-j2$) play in calculating the voltage across the capacitor?

The reactance ($-j2$) determines the capacitor's impedance, which affects the current flow and consequently the voltage across the capacitor. Using the impedance, you can find the current in the circuit and then compute the voltage drop across the capacitor.

In the circuit with a voltage source and impedance components, how do you find the voltage across the capacitor?

First, find the total circuit impedance, then calculate the circuit current using Ohm's law. Finally, multiply the current by the capacitor's impedance to find the voltage across the capacitor.

Are phasor diagrams useful in solving for the voltage across the capacitor in this circuit?

Yes, phasor diagrams help visualize the phase relationships between voltage and current, making it easier to compute the voltage across the capacitor by representing impedance and current phasors graphically.

What assumptions are typically made when calculating the

voltage across a capacitor in such a circuit?

Assumptions often include sinusoidal steady-state conditions, linear components, known source voltage and frequency, and that the circuit elements follow ideal impedance models without parasitic effects.

How does the frequency of the source influence the voltage across the capacitor in this circuit?

The frequency affects the capacitive reactance ($Z_C = 1 / j\omega C$). As frequency increases, reactance decreases, leading to a higher current and a different voltage drop across the capacitor. Conversely, at lower frequencies, the reactance increases, reducing the capacitor's voltage.

Additional Resources

Understanding the Circuit and Calculating the Voltage Across the Capacitor

When analyzing electrical circuits, especially those involving reactive components like capacitors and inductors, a thorough understanding of circuit theory, impedance, and phasor analysis is essential. The problem at hand involves a specific circuit configuration where we are asked to determine the voltage across a capacitor, given the circuit parameters. This comprehensive review will explore all relevant concepts, step-by-step calculations, and practical insights to effectively analyze such circuits.

Introduction to Circuit Analysis with Capacitors

Capacitors are fundamental reactive components in AC circuits, characterized by their ability to store energy in an electric field. Unlike resistors, which dissipate energy, capacitors temporarily hold electrical energy and influence the circuit's phase and magnitude responses.

Key features of capacitors in AC circuits:

- Impedance of a capacitor: $Z_C = \frac{1}{j\omega C}$
- The voltage across a capacitor leads the current by 90° , indicating a phase difference.
- The behavior of the capacitor depends on the frequency of the source and the capacitance value.

Understanding the Given Circuit Parameters

The problem statement provides a circuit with the following elements:

- An impedance notation: $-j2 \text{ N}$ (which likely refers to the impedance or a part of the circuit involving reactive components).

- A source or component labeled 1 20 1:2, which may represent a voltage source or a transformer ratio, though the notation is not standard and requires clarification.
- Circuit configuration: It seems to involve a combination of resistors, inductors, or capacitors, but without a visual diagram, we must rely on typical interpretations.

Assumptions for clarity:

- The circuit likely contains a sinusoidal AC source.
- The impedance $-j2\ \Omega$ suggests a reactive component with reactive impedance of $(-j2\ \Omega)$ ohms.
- The notation 1 20 1:2 could denote a transformer ratio or specific component values—possibly a transformer with a turns ratio of 1:2 or a voltage source with certain parameters.

Note: For precise calculations, the circuit diagram is essential. However, in the absence of it, we will interpret based on common circuit analysis principles.

Analyzing the Circuit Step-by-Step

Given the complexity, let's break down the typical approach:

1. Identify the Circuit Components and Configuration

- Determine the source voltage (V_s) .
- Identify the resistive and reactive components, including the capacitor.
- Examine the connections: series, parallel, or a combination.

2. Represent the Impedances

- Convert all reactive components to their impedance form.
- For a capacitor with capacitance (C) :

$$Z_C = \frac{1}{j\omega C}$$

- For an inductor with inductance (L) :

$$Z_L = j\omega L$$

- For resistors:

$$Z_R = R$$

3. Convert the Circuit to a Phasor Domain

- Express all voltages and currents as phasors.
- Use Ohm's law in the complex form:

$$V = I Z$$

4. Calculate Total Impedance

- For series components:

$$Z_{\text{total}} = Z_1 + Z_2 + \dots$$

- For parallel components:

$$\frac{1}{Z_{\text{parallel}}} = \frac{1}{Z_1} + \frac{1}{Z_2} + \dots$$

5. Determine the Current or Voltage

- From the source voltage (V_s) , calculate the current:

$$I = \frac{V_s}{Z_{\text{total}}}$$

- Find the voltage across the capacitor:

$$V_C = I \times Z_C$$

Step-by-Step Calculation (Hypothetical Example)

Since the exact circuit isn't provided, let's consider a representative example based on typical interpretations:

Suppose:

- The circuit has a source voltage $(V_s = 20 \text{ V})$ (assuming from the notation).
- The impedance $-j2 \text{ ohms}$ represents a reactive element, perhaps an inductor or capacitor.
- The capacitor's value is to be determined or is given indirectly.

Step 1: Express the source voltage as a phasor:

$$V_s = 20 \angle 0^\circ \text{ V}$$

Step 2: Impedance of the reactive element:

$$Z_{\text{reactive}} = -j2 \text{ } \Omega$$

Step 3: Calculate the total impedance in the circuit:

- If the circuit contains a resistor (R) and the reactive component:

$$Z_{\text{total}} = R + Z_{\text{reactive}}$$

Suppose $(R = 1 \text{ } \Omega)$ for simplicity:

$$Z_{\text{total}} = 1 - j2 \text{ } \Omega$$

Step 4: Compute the magnitude and phase of (Z_{total}) :

$$|Z_{\text{total}}| = \sqrt{1^2 + (-2)^2} = \sqrt{1 + 4} = \sqrt{5} \approx 2.236 \, \Omega$$
$$\angle Z_{\text{total}} = \tan^{-1}\left(\frac{-2}{1}\right) \approx -63.43^\circ$$

Step 5: Find the current in the circuit:

$$I = \frac{V_s}{Z_{\text{total}}} = \frac{20 \angle 0^\circ}{2.236 \angle -63.43^\circ} = 8.944 \angle 63.43^\circ \, \text{A}$$

Step 6: Voltage across the capacitor:

- The impedance of the capacitor (unknown (Z_C)) is:

$$Z_C = \frac{1}{j\omega C}$$

- The voltage across the capacitor:

$$V_C = I \times Z_C$$

- Alternatively, since the current phase is known, the capacitor voltage leads the current by 90° , so:

$$V_C = I \times \frac{1}{j\omega C} = I \times \left(-j \times \frac{1}{\omega C}\right)$$

Implications of Transformer Ratio and Other Parameters

The notation 1:2 suggests a transformer with a turns ratio of 1:2. Transformers affect the voltages and currents in the circuit according to their turns ratio:

- Voltage transformation:

$$V_{\text{secondary}} = \text{Turns ratio} \times V_{\text{primary}}$$

- Current transformation:

$$I_{\text{secondary}} = \frac{1}{\text{Turns ratio}} \times I_{\text{primary}}$$

In the context of the problem:

- If the circuit involves a transformer with ratio 1:2, then the voltage across the secondary is twice the primary voltage, and the current is halved.

This impacts voltage calculations:

- When analyzing the voltage across the capacitor, the transformer ratio must be incorporated into the impedance seen at the primary or secondary side.

Frequency Considerations and Their Impact

The frequency ω (radians per second) directly influences the impedance of reactive components:

$$Z_C = \frac{1}{j\omega C}$$

- At high frequencies, $Z_C \rightarrow 0$, acting almost like a short circuit.
- At low frequencies, $Z_C \rightarrow \infty$, acting like an open circuit.

Implication for voltage across the capacitor:

- The capacitor's voltage magnitude depends on both the current and the reactance.
- For a given circuit, changing frequency alters the voltage across the capacitor significantly, which is critical in filter design and tuning.

Complex Power and Phasor Relationships

Understanding the relationship between voltages and currents in reactive circuits involves complex power analysis:

- Complex Power S :

$$S = VI^* = P + jQ$$

where:

- P is the real power.
- Q is the reactive power.

- Since capacitors only store reactive energy, they contribute to reactive power Q but not to real power dissipation.

- The voltage across the capacitor can be expressed in phasor form as:

$$V_C = |V_C| \angle \theta_{V_C}$$

which relates to the magnitude of the capacitor's stored energy and phase difference with the

current.

Practical Considerations in Measurement and Design

When implementing such circuits in real-world applications, several practical factors influence the voltage across the capacitor:

- Component tolerances: Capacitance, inductance, and resistor values may vary from their nominal values.
- Frequency stability: The source frequency may fluctuate, affecting reactive impedance.
- Parasitic elements: Real components have parasitic inductance and resistance.
- Measurement methods:
 - Use of oscilloscopes with phase measurement capabilities.
 - Impedance analyzers for precise measurement of reactive components.

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1 For The Circuit Given Below Calculate The Voltage Across The Capacitor 2 Points J2 N 1 20 1 2

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