Find The Average Power Delivered By The Ideal Current Source In The Circuit If Ig=20cos1250tma .

Find The Average Power Delivered By The Ideal Current Source In The Circuit If Ig=20cos1250tma

---

Introduction

In the realm of electrical engineering, understanding how power is distributed and consumed within circuits is fundamental. One of the key aspects of circuit analysis involves calculating the power delivered or absorbed by circuit components, especially sources. Today, our focus centers on an ideal current source with a sinusoidal current waveform, specifically given by $I_g = 20 \cos 1250 t \, \text{mA}$. The goal is to determine the average power delivered by this ideal current source in a specific circuit configuration.

This problem not only tests your grasp of AC circuit analysis but also enhances your ability to interpret sinusoidal signals, calculate instantaneous, peak, and average power, and understand the implications of ideal sources within circuits. Let’s explore this problem step-by-step, starting with the fundamental concepts involved, then moving toward the detailed calculation process.

Understanding the Circuit and the Current Source

The Nature of the Current Source

The current source specified is:

$$I_g(t) = 20 \cos 1250 t \, \text{mA}$$

- Amplitude (Peak Current): 20 mA
- Angular Frequency (ω): 1250 rad/sec
- Type: Ideal current source (provides a specified current regardless of voltage)

An ideal current source supplies a precise current to the circuit, unaffected by the load. When analyzing power, the key is to understand the voltage across and the current through the source.

Assumptions and Circuit Setup

While the problem statement doesn't specify the rest of the circuit components explicitly, typical analysis involves:

- Load Resistance (or Impedance): The circuit could be a resistor, reactive components like inductors or capacitors, or a combination.

- Series or Parallel Connection: Usually, the current source is connected in a particular configuration, but for the purpose of this calculation, we assume the circuit is arranged such that the current source is the main element, with a load impedance connected across it.

Objective

Calculate the average power delivered by the ideal current source over one full cycle of the sinusoidal waveform.

Fundamental Concepts for Power Calculation

Instantaneous Power

The instantaneous power $p(t)$ supplied by the source is:

$$p(t) = v(t) \times i(t)$$

where:

- $v(t)$ is the instantaneous voltage across the source
- $i(t)$ is the instantaneous current, given by $I_g(t)$

Since the source is ideal, the voltage across it is determined by the load impedance and the current.

Average Power

The average power over one cycle is:

$$P_{avg} = \frac{1}{T} \int_{0}^{T} p(t) \, dt$$

Or, equivalently:

$$P_{avg} = V_{rms} \times I_{rms} \times \cos \phi$$

where:

- V_{rms} is the root mean square voltage
- I_{rms} is the root mean square current
- ϕ is the phase difference between voltage and current

In scenarios where the load is purely resistive, the voltage and current are in phase ($\phi=0$), and the power simplifies to:

$$P_{avg} = V_{rms} \times I_{rms}$$

Given the current waveform and assuming a purely resistive load, the calculation becomes straightforward.

Step-by-Step Calculation

Step 1: Convert the Current to RMS

Given the peak current:

$$ I_{peak} = 20 \, \text{mA} = 0.02 \, \text{A} $$

The RMS value of a sinusoidal current is:

$$ I_{rms} = \frac{I_{peak}}{\sqrt{2}} $$

$$ I_{rms} = \frac{0.02}{\sqrt{2}} \approx 0.01414 \, \text{A} $$

Step 2: Determine the Load Impedance

Since the problem involves an ideal current source, the voltage across it depends on the load impedance Z. To find the power delivered, we need the voltage across the source, which can be expressed as:

$$ v(t) = i(t) \times Z $$

If the circuit is purely resistive (common assumption unless specified otherwise), then:

$$ Z = R $$

The instantaneous voltage:

$$ v(t) = I_g(t) \times R $$

The RMS voltage:

$$ V_{rms} = I_{rms} \times R $$

Step 3: Calculate the Power

The average power delivered by the source:

$$ P_{avg} = V_{rms} \times I_{rms} \times \cos \phi $$

In a purely resistive load, $\phi = 0$, so:

$$ P_{avg} = V_{rms} \times I_{rms} = I_{rms}^2 \times R $$

Alternatively, if the load impedance is known, then:

$$ P_{avg} = I_{rms}^2 \times R $$

or

$$ P_{avg} = V_{rms} \times I_{rms} $$

Step 4: Special Case — Known Load Resistance

Suppose, for example, the load resistance is R. Without a specified load, the general approach is to analyze the power in terms of the load impedance.

- If load resistance R is known, plug in the value into the formula to find the average power.

- If the load is purely resistive, then:

$$ P_{avg} = I_{rms}^2 \times R $$

- If the load includes reactive components, phase difference ϕ must be considered, and power would be:

$$ P_{avg} = V_{rms} \times I_{rms} \times \cos \phi $$

Additional Considerations: Power in Reactive Loads

In AC circuits with reactive components, the power calculation becomes more nuanced:

- Reactive Power: Represents energy oscillating between source and reactive elements.
- Real Power: Represents the actual work done or heat dissipated, which is the average power we seek.
- Power Factor: $\cos \phi$ indicates the efficiency of power transfer.

If the circuit contains only reactive components, the average power delivered over a full cycle is zero, as the energy stored in reactive elements is returned to the source.

Practical Example: Calculating Power for a Resistor Load

Suppose the load resistance R is 100 Ω.

1. RMS current:

$$ I_{rms} = 0.01414 \, \text{A} $$

2. RMS voltage:

$$ V_{rms} = I_{rms} \times R = 0.01414 \times 100 = 1.414 \, \text{V} $$

3. Average power:

$$ P_{avg} = V_{rms} \times I_{rms} = 1.414 \times 0.01414 \approx 0.02 \, \text{W} $$

or 20 milliwatts, which matches the peak current magnitude scaled appropriately.

Final Remarks and Summary

- The average power delivered by an ideal current source depends heavily on the load impedance and the phase relationship between voltage and current.
- In purely resistive loads, power calculation simplifies to using RMS values of current and voltage.
- The sinusoidal nature of the current waveform allows us to easily compute RMS values from peak values.
- The phase difference (ϕ) is crucial in reactive circuits; it determines whether the source delivers real power, reactive power, or a combination.

Conclusion

Calculating the average power delivered by an ideal current source $I_g = 20 \cos 1250 t \, \text{mA}$ involves understanding the waveform, converting peak current to RMS, identifying load impedance, and considering phase differences. By following these steps, engineers can accurately determine power flow in AC circuits, optimize designs, and ensure safe and efficient operation.

Key Takeaways:

- RMS conversion is essential for power calculations.
- The load impedance or circuit configuration significantly affects the power delivered.
- In purely resistive loads, power calculation is straightforward; reactive loads require phase considerations.
- Understanding sinusoidal signals and their properties is fundamental in AC circuit analysis.

SEO Keywords and Phrases

- Average power in AC circuits
- Ideal current source power calculation
- Sinusoidal current waveform analysis
- RMS value of sinusoidal current
- Power delivered by AC sources
- Circuit analysis with sinusoidal signals
- Reactive vs resistive loads power
- Power factor in AC circuits
- How to calculate average power in AC circuits
- Electrical engineering power analysis

Note: For precise calculations in real-world applications, knowing the exact load impedance and circuit configuration is essential. Always consider the phase relationship and reactive components when analyzing AC power.

Frequently Asked Questions

What is the expression for the current supplied by the ideal current source in the circuit?

The current supplied by the ideal current source is given as $I_g(t) = 20 \cos 1250 t$ mA, which simplifies to $I_g(t) = 0.02 \cos 1250 t$ A.

How do you calculate the average power delivered by the ideal current source?

The average power is calculated using $P_{avg} = V_{rms} I_{rms}$, where V_{rms} is the RMS voltage across the load and I_{rms} is the RMS current supplied by the source. For an ideal current source, the power depends on the load impedance.

What is the RMS value of the current $I_g(t) = 20 \cos 1250 t$ mA?

The RMS value of the current is $I_{rms} = I_{peak} / \sqrt{2} = 20 \text{ mA} / \sqrt{2} \approx 14.14$ mA.

How does the load impedance affect the power delivered by the ideal current source?

The power delivered depends on the load impedance. For a purely resistive load, power is $P = I_{rms}^2 R$. For reactive loads, the power varies with phase angle, but the average power can be calculated considering the impedance's real part.

If the circuit contains a resistor R, how can we find the average power delivered by the current source?

If the resistor R is connected, the RMS voltage across R is $V_{rms} = I_{rms} R$. Therefore, the average power delivered is $P_{avg} = V_{rms} I_{rms} = I_{rms}^2 R$.

What assumptions are made when calculating the average power in this circuit?

Assumptions include that the current source is ideal, the circuit is sinusoidal steady-state, and the load impedance is known and linear, allowing use of RMS values for power calculation.

How would the calculation change if the current source was not ideal but had some internal resistance?

If the current source has internal resistance, the power calculation must account for voltage drops across this resistance. The power delivered to the load would then be less, and the total power supplied by the source includes power dissipated internally, requiring a more detailed analysis.

Additional Resources

Find The Average Power Delivered By The Ideal Current Source In The Circuit If Ig=20cos1250tma

Understanding the power delivered by sources in electrical circuits is fundamental for electrical engineers and students alike. In particular, analyzing the average power delivered by an ideal current source provides insights into energy transfer, circuit efficiency, and the behavior of AC signals. The problem statement, "Find the average power delivered by the ideal current source if $I_g = 20 \cos 1250 t\, \text{mA}$," introduces a sinusoidal current source, which is typical in AC circuit analysis. This article aims to thoroughly explore the concepts, methods, and calculations involved in solving such problems, providing a comprehensive understanding of how to determine average power in AC circuits, specifically for ideal current sources.

Understanding the Circuit and the Current Source

Before diving into calculations, it's vital to understand the nature of the current source and the associated circuit.

What is an Ideal Current Source?

An ideal current source is a theoretical device that delivers a constant current regardless of the voltage across its terminals. Its defining features include:

- Constant current output: The current remains unchanged irrespective of load variations.
- Zero internal resistance in the ideal case.
- Ability to supply or absorb power depending on the circuit conditions.

In AC circuits, an ideal current source provides a sinusoidal current with a specified amplitude and frequency, as given in the problem.

Specification of the Given Current Source

The current source is:

$$
I_g(t) = 20 \cos 1250 t\, \text{mA}
$$

- Amplitude: 20 mA (milliamps)
- Angular frequency: $\omega = 1250\, \text{rad/sec}$

This sinusoidal current varies with time, and understanding its behavior is crucial in calculating power.

Fundamentals of Power in AC Circuits

The key to calculating power delivered by AC sources lies in understanding RMS (Root Mean Square) values, instantaneous power, and average power.

Instantaneous Power

The instantaneous power $p(t)$ associated with a current $i(t)$ and voltage $v(t)$ across a component is:

$$
p(t) = v(t) \times i(t)
$$

In the case of an ideal current source, the power delivered depends on the voltage across the source, which is not specified directly. However, if the current source is connected to a load or a circuit with known impedance, the voltage can be determined.

Average Power in AC Circuits

The average power over a period T is:

$$
P_{avg} = \frac{1}{T} \int_0^T p(t) \, dt
$$

For sinusoidal voltages and currents, this simplifies to:

$$
P_{avg} = V_{rms} \times I_{rms} \times \cos \phi
$$

where:

- V_{rms} and I_{rms} are the RMS voltage and current.
- ϕ is the phase difference between voltage and current.

In purely resistive loads, $\phi = 0$, meaning voltage and current are in phase, and the power factor is 1.

Calculating the RMS Values of the Current Source

Given the sinusoidal current:

$$
I_g(t) = 20 \cos 1250 t\, \text{mA}
$$

The RMS value of a sinusoid $I(t) = I_{max} \cos \omega t$ is:

$$
I_{rms} = \frac{I_{max}}{\sqrt{2}}
$$

So,

$$
I_{rms} = \frac{20\, \text{mA}}{\sqrt{2}} \approx 14.14\, \text{mA}
$$

This RMS value is essential for calculating power, assuming the load and the source are purely resistive or the load characteristics are known.

Assumptions and Conditions for Power Calculation

Since the problem states an ideal current source without specifying the load, several assumptions are necessary:

- The circuit is purely resistive, meaning the voltage and current are in phase ($\phi = 0$).
- The source delivers power directly to a load with known impedance.
- The voltage across the source can be derived or is known.

If these assumptions hold, the average power delivered by the source can be expressed solely in terms of the RMS current and the load resistance.

Calculating the Power Delivered by the Current Source

Given the above assumptions, the average power delivered by the source is:

$$
P_{avg} = I_{rms}^2 R
$$

\]

where \(R \) is the load resistance.

However, in many theoretical problems, the focus is on the power associated with the current source itself, especially in the context of sinusoidal current sources and their interaction with loads.

Case 1: The Load Resistance is Known

Suppose the load resistance \(R \) is known (say, \(R \) ohms). Then:

\[
P_{avg} = (14.14 \times 10^{-3})^2 R = 2 \times 10^{-4} R\, \text{W}
\]

The power delivered depends linearly on \(R \). For example:

- If \(R = 1\, \text{k}\Omega \), then

\[
P_{avg} = 2 \times 10^{-4} \times 1000 = 0.2\, \text{W}
\]

- If \(R = 10\, \Omega \), then

\[
P_{avg} = 2 \times 10^{-4} \times 10 = 2 \times 10^{-3} = 2\, \text{mW}
\]

Note: The actual power delivered by the source depends on the load's impedance and phase relationship, which is not specified here.

Case 2: Power Calculation in the Absence of Load Specification

If the circuit involves an ideal current source connected to a load and the voltage across the source is not specified, the problem becomes theoretical. In such cases, the instantaneous power is not directly computable without knowing the voltage.

In idealized problems, sometimes the focus is on the power associated with the source’s current waveform and assuming a resistive load or understanding the instantaneous power as a function of the current and the voltage across the source.

Power Delivered by the Ideal Current Source: General Approach

When analyzing such problems, the most common approach involves the following steps:

1. Identify the current waveform and compute its RMS value.
2. Determine the load impedance or voltage if specified.
3. Calculate the power as:

$$
P_{avg} = V_{rms} \times I_{rms} \times \cos \phi
$$

or, if the voltage is not specified, analyze the power in the context of the load impedance.

Special Case: Power in a Resistive Load

Assuming the load is purely resistive, the voltage across the load (or source) is:

$$
V(t) = I(t) \times R
$$

The RMS voltage:

$$
V_{rms} = I_{rms} \times R
$$

Thus, the average power:

$$
P_{avg} = V_{rms} \times I_{rms} = I_{rms}^2 R
$$

which aligns with the earlier expression.

Features and Limitations of the Calculation

Features:

- Straightforward calculation if load resistance and phase are known.
- Applicable to sinusoidal sources with known amplitude and frequency.
- Fundamental in AC power analysis.

Limitations:

- Assumes purely resistive load or known phase angle, which may not be valid in all cases.
- Cannot determine power without load impedance or voltage information for ideal current sources.
- Ideal current sources are theoretical; real sources have internal resistance and non-ideal behaviors.

Practical Considerations and Applications

In real-world applications, understanding the power delivered by sinusoidal current sources is critical in designing AC circuits, power systems, and signal processing devices.

Pros:

- Enables precise power calculations in AC systems.
- Helps in designing load matching and power transfer efficiency.
- Useful in analyzing AC power supplies, amplifiers, and communication systems.

Cons:

- Requires detailed circuit parameters; idealized models may oversimplify real behaviors.
- assumes sinusoidal waveforms; non-sinusoidal signals complicate calculations.
- Does not account for power losses or non-idealities.

Conclusion

The problem of finding the average power delivered by an ideal sinusoidal current source, $I_g = 20 \cos 1250 t\, \text{mA}$, hinges on understanding the current waveform, RMS calculation, load characteristics, and phase relationships. In the simplest case, assuming a purely resistive load and phase alignment

Find The Average Power Delivered By The Ideal Current Source In The Circuit If Ig 20cos1250tma

Find The Average Power Delivered By The Ideal Current Source In The Circuit If Ig 20cos1250tma

Related Articles

- Hr Managers Are Using Social Tools To Build Relationships With ________ Inside The Organization.
- In A Mixture Of The Nitric Acid And Sulfuric Acid, ____ Will Act As The "base" And Will Be ____
- Middle-aged People Show The Most Adaptability In The Face Of Separation Or Divorce Because They