

An Ideal Single-phase Source, 240 V, 50 Hz, Supplies Power To A Load Resistor $R = 100\ \Omega$ Via A Single

An Ideal Single-phase Source, 240 V, 50 Hz, Supplies Power To A Load Resistor $R = 100\ \Omega$ Via A Single are fundamental concepts in electrical engineering, especially when analyzing simple power systems and circuits. Understanding how such sources interact with loads, particularly resistive loads, is essential for designing efficient electrical systems, troubleshooting, and ensuring safety. This article delves into the characteristics of an ideal single-phase power source, examines the specifics of the load resistor, and explores the electrical behavior of the circuit, including calculations of current, voltage, power, and energy transfer.

Understanding the Ideal Single-phase Power Source

Definition and Characteristics

An ideal single-phase power source is a theoretical model used to simplify the analysis of electrical circuits. It is characterized by the following features:

- Constant Voltage: The source maintains a fixed voltage level of 240 V, regardless of the load connected or the current drawn.
- Zero Internal Resistance: Unlike real power sources, which have internal resistance or impedance, an ideal source has no internal impedance, meaning it can supply any amount of current without voltage drop.
- Purely Sinusoidal Voltage: The voltage waveform is a perfect sine wave at a frequency of 50 Hz, with no harmonic distortion or fluctuations.
- No Power Losses: Since it is ideal, there are no losses within the source itself, making it a perfect energy supplier.

Significance in Circuit Analysis

Using an ideal source allows engineers to focus on the load and the circuit's behavior without accounting for source limitations or inefficiencies. It simplifies calculations, such as:

- Determining current and power consumption.
- Analyzing voltage drops and power factor.
- Designing protective devices and ensuring compliance with standards.

The Load Resistor $R = 100\ \Omega$

Resistive Load Characteristics

A resistor $R = 100\ \Omega$ connected across the source represents a purely resistive load, which has the following properties:

- Resistive Behavior: The load opposes the flow of current proportionally to the applied voltage, following Ohm's Law.
- Power Dissipation: The resistor converts electrical energy into heat, dissipating power given by $(P = V \times I)$.

Calculations of Current and Power

Given the source voltage $(V_s = 240\text{V})$ and resistance $(R = 100\,\Omega)$:

- Current through the resistor:

$$I = \frac{V_s}{R} = \frac{240\text{V}}{100\,\Omega} = 2.4\text{A}$$

- Power consumed by the resistor:

$$P = V \times I = 240\text{V} \times 2.4\text{A} = 576\text{W}$$

Alternatively, using $(P = I^2 R)$:

$$P = (2.4\text{A})^2 \times 100\,\Omega = 5.76 \times 100 = 576\text{W}$$

or $(P = \frac{V^2}{R})$:

$$P = \frac{(240\text{V})^2}{100\,\Omega} = \frac{57600}{100} = 576\text{W}$$

Voltage and Current Waveforms

Since the source voltage is sinusoidal at 50 Hz:

$$v(t) = V_{\text{max}} \sin(2\pi f t)$$

where (V_{max}) is the peak voltage:

$$V_{\text{max}} = V_{\text{rms}} \times \sqrt{2} = 240\text{V} \times \sqrt{2} \approx 339.4\text{V}$$

The current waveform is:

$$i(t) = \frac{v(t)}{R} = \frac{V_{\text{max}}}{R} \sin(2\pi f t) \approx 3.394 \sin(2\pi \times 50 t)\text{A}$$

The phase relationship between voltage and current is in phase for a purely resistive load.

Electrical Power and Energy Considerations

Average Power Delivered

The average power supplied to the load per cycle is:

$$P_{\text{avg}} = V_{\text{rms}} \times I_{\text{rms}} = 240\text{V} \times 2.4\text{A} = 576\text{W}$$

which matches the power dissipation calculated earlier.

Power Factor

For a purely resistive load, the power factor is unity:

$$\text{PF} = \cos \phi = 1$$

where ϕ is the phase angle between voltage and current.

Energy Transfer Over Time

In steady state, the energy transferred per second is equal to the power:

$$E = P_{\text{avg}} \times t$$

For continuous operation, the total energy delivered over time t is simply:

$$E(t) = 576\text{W} \times t$$

This straightforward calculation simplifies energy budgeting and efficiency analysis.

Implications for Circuit Design and Safety

Component Ratings and Safety Measures

Given that the resistor dissipates 576 W, the component must be rated accordingly:

- Use of a resistor with a power rating of at least 600 W to ensure safe operation.
- Proper heat sinking and ventilation to prevent overheating.

Protective Devices

- Fuses or circuit breakers should be rated slightly above the operating current to protect against overloads.
- Ground fault protection is essential to prevent shocks and equipment damage.

Voltage Regulation and Stability

While the ideal source maintains a constant voltage, real-world sources have limitations:

- Voltage regulation ensures minimal variation in supply voltage.
- Fluctuations can impact power dissipation and circuit performance.

Practical Applications and Real-World Considerations

From Ideal to Real Systems

In practice, power sources are not ideal:

- They exhibit internal impedance, causing voltage drops under load.
- Voltage may fluctuate due to load changes, power supply quality, or network conditions.

Modeling Real Power Systems

Engineers often incorporate source impedance models to predict performance:

- Thevenin equivalent circuits help analyze complex systems.
- Impedance matching improves efficiency and reduces losses.

Scaling for Larger Loads

For larger or industrial loads:

- Multiple resistors or other components are used.
- Power factor correction may be necessary to optimize power delivery.

Summary and Key Takeaways

- An ideal single-phase source provides a stable 240 V at 50 Hz with no internal resistance.
- Connecting a $100\ \Omega$ resistor results in a current of 2.4 A and dissipates approximately 576 W.
- The circuit's behavior is straightforward, with voltage and current in phase, and power calculations are simple.
- Practical applications require considering non-idealities, component ratings, and safety measures.
- Understanding these fundamental principles supports effective circuit design, troubleshooting, and system optimization.

This comprehensive overview underscores the importance of idealized models in electrical engineering, providing a foundation for analyzing and designing real-world power systems that are both efficient and safe.

Frequently Asked Questions

What are the characteristics of an ideal single-phase power source?

An ideal single-phase power source provides a constant, sinusoidal voltage with zero internal resistance and no impedance, ensuring no power loss and a perfectly stable output voltage.

In the given scenario, what is the significance of the voltage being 240 V, 50 Hz?

The voltage of 240 V, 50 Hz indicates the RMS voltage supplied by the source and the frequency of the alternating current, which affects the load's behavior and power calculations.

How is the power supplied to the load resistor $R = 100\ \Omega$ calculated in this setup?

The power can be calculated using the formula $P = V_{\text{rms}}^2 / R$, where V_{rms} is 240 V. So, $P = (240)^2 / 100 = 576\ \text{W}$.

What is the current flowing through the resistor R in this ideal source setup?

The current I can be calculated using Ohm's law: $I = V / R = 240\ \text{V} / 100\ \Omega = 2.4\ \text{A}$.

Why is the source considered 'ideal' in this scenario?

Because it supplies a perfect sinusoidal voltage with no internal resistance or impedance, ensuring maximum and consistent power delivery to the load without losses.

What is the phase relationship between the source voltage and the current in this circuit?

Since the source is ideal and the load is purely resistive, the current is in phase with the voltage.

How does the frequency of 50 Hz affect the power delivery in this circuit?

At 50 Hz, the power delivery is stable for resistive loads; frequency primarily impacts reactive components, but in a purely resistive load, it doesn't affect the power calculation directly.

What would happen if the load resistor R changed to a higher value in this setup?

Increasing R reduces the current and power drawn from the source, following Ohm's law and power formula, resulting in lower power consumption.

Can this ideal single-phase source supply reactive power in addition to real power?

No, in this ideal scenario with a purely resistive load, only real power is supplied; reactive power would require reactive components like inductors or capacitors.

What safety considerations are important when working with a 240 V, 50 Hz power source connected to a resistor load?

Safety measures include ensuring proper insulation, avoiding contact with live parts, using appropriate circuit protection devices like fuses or circuit breakers, and following electrical codes to prevent shocks or fires.

Additional Resources

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Introduction

In the realm of electrical engineering, the concept of an ideal single-phase source serves as a fundamental idealization used to analyze and understand power systems, circuits, and their behaviors. When paired with typical parameters such as 240 V and 50 Hz, this model offers insights into how real-world electrical components perform under ideal conditions. This article delves deeply into the characteristics, implications, and practical considerations of an ideal single-phase source supplying power to a load resistor of $100\ \Omega$, emphasizing the importance of understanding ideal models in the context of real-world applications.

Defining the Ideal Single-Phase Source

What Is an Ideal Single-Phase Source?

An ideal single-phase source is a theoretical power supply that provides a perfectly stable voltage or current with no internal resistance, no internal impedance, and no fluctuations. It is characterized by:

- Constant Voltage: The voltage remains steady at a specified magnitude (e.g., 240 V) regardless of the load connected.
- Zero Internal Resistance: The source can supply any amount of current without voltage drop or internal power losses.
- Pure Sinusoidal Output: The voltage (or current) waveform is a perfect sine wave with a specified frequency (here, 50 Hz).
- No Harmonics or Distortions: The output waveform is free from harmonic distortions or noise.

In practical terms, such a source does not exist; all real sources have internal impedance and limited capacity. However, ideal sources serve as a baseline for analysis, design, and understanding of system behaviors.

Significance in Power System Analysis

The ideal source model simplifies complex calculations, enabling engineers to:

- Understand fundamental relationships between voltage, current, and power.
- Analyze the behavior of loads under simplified conditions.
- Develop control strategies and system protections.
- Benchmark real system performances against an idealized standard.

System Parameters and Setup

Voltage and Frequency Specification

- Voltage: 240 V (RMS)
- Frequency: 50 Hz

The choice of 240 V aligns with standard single-phase supply voltages in many regions, such as Europe, Australia, and parts of Asia. The 50 Hz frequency is the typical mains frequency in these regions, influencing the reactive components and power factor considerations in AC circuits.

Load Resistor ($R = 100 \, \Omega$)

The load is modeled as a purely resistive element with a resistance of $100 \, \Omega$. This simplifies power calculations because:

- The current and voltage are in phase.
- Power calculations involve straightforward relationships without reactive components.

Power Calculation and Circuit Behavior

Basic Circuit Description

The circuit under consideration involves:

- An ideal single-phase source providing 240 V RMS at 50 Hz.
- A load resistor $R = 100 \, \Omega$ connected directly across the source terminals.

This forms a simple series circuit, with the resistor directly supplied by the ideal source.

Voltage and Current Relationships

Given the parameters:

- Source Voltage (V): 240 V (RMS)
- Resistance (R): $100 \, \Omega$

The current (I) flowing through the resistor can be calculated using Ohm's Law:

$$I = \frac{V}{R} = \frac{240 \, \text{V}}{100 \, \Omega} = 2.4 \, \text{A}$$

Since the source is ideal, the voltage across the resistor remains at 240 V, and the current is steady at 2.4 A.

Power Dissipation

The power dissipated in the resistor:

$$P = V \times I = 240 \, \text{V} \times 2.4 \, \text{A} = 576 \, \text{W}$$

Alternatively, using the resistance:

$$P = I^2 R = (2.4 \, \text{A})^2 \times 100 \, \Omega = 5.76 \times 100 = 576 \, \text{W}$$

This calculation confirms that the resistor consumes 576 W of real power under these conditions.

Deep Dive into Power System Characteristics

Power Factor and Power Flow

In a purely resistive load, the power factor:

$$\text{Power Factor} = \cos \phi = 1$$

indicating that voltage and current are perfectly in phase. This simplifies power analysis, as

all the supplied power is real power.

Voltage Stability and Ideal Source Assumption

Because the source is ideal, the voltage remains constant at 240 V regardless of the load change or current drawn. In real systems, increasing load current causes voltage drops due to internal impedance, but the ideal model neglects these effects. This assumption allows us to focus on the fundamental relationships without considering voltage regulation or line losses.

Implications for Real-World Systems

Limitations of the Ideal Model

While the ideal source provides clarity, it does not account for:

- Internal Impedance: Real sources have internal resistance and reactance, affecting voltage regulation.
- Voltage Variations: Actual supply voltages fluctuate due to load changes, transmission line effects, and other factors.
- Harmonics and Distortion: Real-world power supplies contain harmonic distortions that impact power quality.
- Transient Behavior: Ideal sources do not model transient responses during switching or faults.

Understanding these limitations underscores the importance of designing systems that can operate reliably under less-than-ideal conditions.

Practical Applications and Considerations

In practice, engineers utilize the ideal source model to:

- Design load circuits assuming stable voltage.
- Calculate maximum load capacities.
- Develop control and protection schemes.
- Establish benchmarks for system efficiency and stability.

Advanced Topics: Variations and Extensions

Non-Ideal Sources

Real power supplies are characterized by an internal impedance $(Z_s = R_s + jX_s)$. The presence of internal resistance and reactance leads to:

- Voltage drops under load.
- Power factor deviations.
- Reduced efficiency.

Designing systems involves compensating for these effects using power factor correction, voltage regulation, and filtering.

Reactive Loads and Power Factor Correction

If the load were reactive (inductive or capacitive), the current would lead or lag the voltage, and the power factor would be less than 1. To optimize power transfer and minimize losses, systems often incorporate power factor correction devices such as capacitors or inductors.

Conclusion

The concept of an ideal single-phase source, 240 V, 50 Hz, supplies power to a load resistor $R = 100\ \Omega$ via a single source forms a cornerstone in electrical engineering education and practice. It provides a simplified framework to analyze fundamental circuit behaviors, calculate power flows, and understand the core principles of AC power systems. Although real-world sources deviate from this ideal, the model remains invaluable for designing, testing, and troubleshooting electrical circuits and systems. Recognizing the assumptions and limitations of the ideal model guides engineers to develop more robust, efficient, and reliable power solutions tailored to practical needs.

By exploring this fundamental setup in detail, engineers and researchers can better appreciate the complexities of real power systems and develop strategies to mitigate their limitations, ensuring safe, efficient, and stable power delivery in diverse applications.

End of Article

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