

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

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Introduction to Single-Phase Power Systems

In modern electrical engineering, understanding the behavior of single-phase power systems is fundamental, especially in residential and small commercial applications. A single-phase power system, characterized by a single sinusoidal voltage waveform, efficiently supplies electrical energy to various loads with relative simplicity. Among the typical parameters defining such a system are the voltage magnitude, frequency, and the load connected to the source.

This article focuses on an ideal single-phase power source rated at 240 V and 50 Hz, supplying power to a load resistor of 100 ohms (Ω) via a single conductor. Through this discussion, we will explore the electrical characteristics of such a system, analyze the current and power flow, and understand the implications of having an ideal source in the circuit.

Understanding the Ideal Single-Phase Power Source

What Is an Ideal Power Source?

An ideal power source provides a constant voltage or current regardless of the load connected to it. In the context of an ideal voltage source:

- It maintains a fixed voltage across its terminals at all times.
- Its internal impedance is zero (zero internal resistance), meaning it supplies or absorbs any amount of current without voltage variation.
- It does not dissipate energy internally and has no limitations on current supply.

This idealization simplifies circuit analysis and serves as a baseline for understanding real-world systems, which always have some internal resistance and limitations.

Specifications of the Given Power Source

The specific parameters of our ideal source are:

- Voltage (V_{source}): 240 V (RMS)
- Frequency (f): 50 Hz
- Type: Single-phase AC source
- Nature: Ideal (no internal impedance or losses)

This source provides a sinusoidal voltage waveform that oscillates at 50 Hz, which is the standard frequency in many regions.

Analyzing the Load Resistor $R = 100\ \Omega$

Load Characteristics

The load resistor $R = 100\ \Omega$ is a purely resistive load, meaning:

- The current through the resistor is in phase with the applied voltage.
- Power is dissipated as heat within the resistor.
- No reactive components (inductance or capacitance) are present, simplifying analysis.

Calculating the Current Through the Load

Since the source is ideal and provides a sinusoidal voltage of 240 V RMS, the current flowing through the resistor can be calculated using Ohm's Law:

$$I_{\text{rms}} = \frac{V_{\text{rms}}}{R}$$

Substituting the known values:

$$I_{\text{rms}} = \frac{240\text{ V}}{100\text{ }\Omega} = 2.4\text{ A}$$

Thus, the load draws an RMS current of 2.4 A.

Instantaneous Voltage and Current Waveforms

The voltage across the resistor:

$$v(t) = V_{\text{peak}} \sin(\omega t)$$

Where:

$$V_{\text{peak}} = V_{\text{rms}} \times \sqrt{2} \approx 240 \times 1.414 \approx 339.4 \text{ V}$$

$$\omega = 2\pi f = 2\pi \times 50 \approx 314.16 \text{ rad/sec}$$

The current:

$$i(t) = \frac{v(t)}{R} = \frac{V_{\text{peak}}}{R} \sin(\omega t) \approx \frac{339.4}{100} \sin(\omega t) = 3.394 \sin(\omega t) \text{ A}$$

The phase relationship indicates that voltage and current are in phase for a purely resistive load.

Power Calculations in the Circuit

Instantaneous and RMS Power

The power dissipated in the resistor:

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

Since the load is purely resistive:

$$\cos \phi = 1$$

Therefore:

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

The resistor consumes approximately 576 watts of real power.

Peak Power

Peak power (instantaneous maximum):

$$p_{\text{max}} = v_{\text{peak}} \times i_{\text{peak}} = V_{\text{peak}} \times I_{\text{peak}}$$

Where:

$$I_{\text{peak}} = I_{\text{rms}} \times \sqrt{2} = 2.4 \times 1.414 \approx 3.394\text{A}$$

Thus:

$$p_{\text{max}} = 339.4\text{V} \times 3.394\text{A} \approx 1150\text{W}$$

This indicates the maximum instantaneous power during the sinusoidal cycle.

Implications of Using an Ideal Power Source

Advantages of an Ideal Source

- Constant Voltage Supply: Ensures the load receives a stable voltage, leading to predictable operation.
- Simplified Analysis: Zero internal impedance simplifies calculations, making theoretical analysis straightforward.
- Unlimited Power Delivery: Can supply any current required by the load without voltage drop or internal losses.

Limitations in Practical Applications

While ideal sources are useful for analysis, real power supplies exhibit:

- Internal resistance or impedance.
- Voltage regulation limits.
- Power limitations and safety features.

Understanding the ideal case helps engineers design systems that approach these ideals while accounting for real-world constraints.

Practical Considerations in Real-World Systems

Voltage Regulation and Variations

- Actual power supplies have internal impedance, causing voltage drops under load.
- Voltage regulation techniques are employed to maintain supply voltage within acceptable limits.

Load Types and Power Factor

- Real loads often include reactive components, causing phase shifts.
- Power factor correction may be necessary to improve efficiency.

Safety and Standards

- Electrical systems are designed with safety margins.
- Adherence to standards like IEC and NEC ensures safe operation.

Conclusion

An ideal single-phase power source rated at 240 V and 50 Hz provides a stable and predictable power supply to a resistive load of 100 Ω . The analysis shows that such a source delivers approximately 576 W of real power to the load, with a current of 2.4 A RMS flowing through the resistor. The sinusoidal

waveforms for voltage and current are in phase due to the purely resistive nature of the load.

While ideal sources serve as valuable theoretical models, practical systems must account for internal impedance, voltage regulation, reactive loads, and safety considerations. Nonetheless, understanding the behavior of an ideal single-phase source provides a foundational basis for designing and analyzing real-world electrical power systems.

By mastering these concepts, engineers and technicians can optimize power distribution, improve efficiency, and ensure reliable operation across various applications, from residential electricity to industrial power systems.

Keywords: single-phase power system, ideal power source, 240 V, 50 Hz, resistive load, load resistor, Ohm's law, power calculation, RMS voltage, sinusoidal waveform, electrical engineering, power analysis

Frequently Asked Questions

What are the key characteristics of an ideal single-phase power source in this context?

An ideal single-phase power source provides a constant voltage of 240 V at 50 Hz without any internal resistance, reactance, or losses, ensuring a perfect sinusoidal output to supply the load.

How does the load resistor $R = 100\ \Omega$ affect the current drawn from the power source?

The load resistor of $100\ \Omega$ determines the current according to Ohm's law: $I = V / R = 240\text{ V} / 100\ \Omega = 2.4\text{ A}$, assuming an ideal source without internal impedance.

What is the power consumed by the load resistor R ?

The power consumed is $P = V^2 / R = (240\text{ V})^2 / 100\ \Omega = 576\text{ W}$.

How would the current change if the source was not ideal and had internal resistance?

If the source had internal resistance, the total circuit resistance would increase, resulting in a lower current than calculated for an ideal source, and the voltage across the load might also drop slightly depending on the internal resistance.

What is the significance of the frequency (50 Hz) in this power supply setup?

The 50 Hz frequency defines the rate at which the voltage and current sinusoidally oscillate, affecting the reactive components in the system if present, and is standard for power systems in many regions.

How would the circuit behavior change if an inductive or capacitive load replaced the resistor?

Replacing the resistor with an inductive or capacitive load would introduce reactance, causing phase shifts between voltage and current, and potentially affecting the power factor and the overall power transfer efficiency.

What safety considerations are important when working with a 240 V single-phase supply?

Safety considerations include proper insulation, grounding, use of circuit breakers or fuses, avoiding contact with live parts, and ensuring equipment is rated for 240 V to prevent electric shock or fire hazards.

Additional Resources

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

In the realm of electrical engineering, understanding the behavior of power sources and their interaction with loads is fundamental. An ideal single-phase source, 240 V, 50 Hz, supplying power to a load resistor of $100\ \Omega$ offers an excellent model to analyze basic power transfer, voltage regulation, and current flow in simple electrical circuits. This article delves into the characteristics of such an ideal power source, exploring the theoretical foundations, practical implications, and analytical calculations to provide a comprehensive understanding of this fundamental configuration.

Understanding the Ideal Single-Phase Power Source

Definition and Characteristics

An ideal single-phase power source is a theoretical construct that supplies a

perfect sinusoidal voltage or current without any internal resistance, inductance, or capacitance. Its primary characteristics include:

- Constant Voltage Output: Maintains a fixed voltage (in this case, 240 V RMS) regardless of the load connected.
- Zero Internal Impedance: No internal resistance, inductance, or capacitance, which means it does not cause voltage drops internally.
- Perfect Sinusoidal Waveform: Produces a pure sinusoid at the specified frequency (50 Hz).
- Unlimited Power Capacity: Theoretically, it can supply any amount of current without voltage variation or power limitation.

In practical scenarios, real sources deviate from this idealization; however, modeling an ideal source simplifies analysis and provides foundational insights into circuit behavior.

Significance in Circuit Analysis

Using an ideal source allows engineers and students to:

- Isolate the behavior of the load without considering source internal elements.
- Understand fundamental relationships like Ohm's Law, power calculations, and impedance matching.
- Develop initial intuition before considering real-world source limitations such as internal resistance, voltage regulation issues, and transient responses.

Specification Details: 240 V, 50 Hz

Voltage Specification

The specified 240 V RMS indicates the root mean square voltage delivered by the source, a standard mains voltage in many countries. RMS voltage is a measure of the effective power delivered and relates to the peak voltage (V_{peak}) via:

$$\begin{aligned} & \backslash[\\ & V_{\text{peak}} = V_{\text{rms}} \times \sqrt{2} \approx 240 \times 1.4142 \approx 339.4 \text{ V} \\ & \backslash] \end{aligned}$$

This peak voltage is relevant when analyzing voltage waveforms and transient phenomena.

Frequency Specification

The 50 Hz frequency indicates the sinusoid's oscillation rate, corresponding to the standard mains frequency in many regions. Frequency influences the reactance of inductive and capacitive elements in real circuits, but in the context of a purely resistive load, it affects only the timing of voltage and current waveforms.

Load Resistance and Its Role in Power Transfer

Resistive Load $R = 100\ \Omega$

The load resistor, $R = 100\ \Omega$, is a purely resistive element, meaning it consumes power directly proportional to the square of the current flowing through it. Its simplicity makes it an ideal load for basic analysis.

Characteristics:

- Purely Resistive: No phase difference between voltage and current.
- Power Dissipation: Converts electrical energy into heat efficiently.
- Linear Behavior: Follows Ohm's law straightforwardly, $(V = IR)$.

Impact on Circuit Behavior

When connected to the ideal source:

- The current flowing through the resistor can be directly calculated.
- Power consumption can be determined using straightforward formulas.
- Voltage regulation and voltage drops are predictable due to the absence of reactive components.

Analytical Examination of the Circuit

Calculations of Current and Power

Given the ideal source voltage $(V_{\text{rms}} = 240\text{ V})$ and load resistance

($R=100\,\Omega$), the fundamental parameters are:

1. Current through the load:

$$I_{\text{rms}} = \frac{V_{\text{rms}}}{R} = \frac{240\,\text{V}}{100\,\Omega} = 2.4\,\text{A}$$

2. Power dissipated in the resistor:

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

Alternatively, using the formula:

$$P = \frac{V_{\text{rms}}^2}{R} = \frac{(240)^2}{100} = \frac{57600}{100} = 576\,\text{W}$$

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

3. Voltage across the resistor:

Since the source is ideal and connected directly, the voltage across R is the same as the source voltage: 240 V RMS.

Power and Voltage Waveforms in the Circuit

Sinusoidal Nature of Voltage and Current

In an ideal resistive load, the voltage and current waveforms are perfectly in phase. That is, their peaks and zero crossings occur simultaneously. The sinusoidal voltage waveform can be represented as:

$$v(t) = V_{\text{peak}} \sin(\omega t)$$

Where ($\omega = 2\pi f = 2\pi \times 50 = 100\pi$, rad/sec).

Correspondingly, the current waveform:

$$i(t) = I_{\text{peak}} \sin(\omega t)$$

$$i(t) = \frac{v(t)}{R} = \frac{V_{\text{peak}}}{R} \sin(\omega t) = 2.4 \sin(\omega t) \text{ A}$$

This phase alignment simplifies power calculations and indicates no reactive power component exists in this resistive load scenario.

Instantaneous Power

The instantaneous power delivered to the resistor is:

$$p(t) = v(t) \times i(t) = V_{\text{peak}} \times I_{\text{peak}} \times \sin^2(\omega t)$$

Since $(I_{\text{peak}} = V_{\text{peak}}/R = 339.4/100 = 3.394 \text{ A})$, the instantaneous power fluctuates sinusoidally between zero and a maximum value, averaging out to the RMS power calculated earlier.

Implications of an Ideal Source in Practical Contexts

Limitations and Real-World Deviations

While the ideal source model significantly simplifies analysis, real power supplies exhibit characteristics such as:

- Internal Resistance or Impedance: Causes voltage drops under load.
- Voltage Regulation Limits: Voltage may dip under heavy loads.
- Harmonics and Transients: Deviations from sinusoidality.
- Finite Power Capacity: Cannot supply infinite current.

Understanding the ideal model helps engineers isolate load effects and design systems accordingly, but actual power systems incorporate buffering, regulation, and filtering to manage these deviations.

Application in System Design and Testing

The ideal source model is instrumental in:

- Testing load responses without source limitations.
- Designing circuits where source internal impedances are negligible.
- Developing control strategies based on predictable behavior.

In practical applications, these insights guide the design of power supplies, load management, and safety considerations.

Variations and Extensions of the Basic Circuit

Inclusion of Reactive Components

Adding inductors or capacitors introduces reactive impedance, leading to phase shifts and reactive power considerations. The circuit's analysis then involves complex impedance:

$$Z = R + jX$$

where X is the reactance of inductance or capacitance.

Impacts include:

- Voltage and current phase differences.
- Power factor considerations.
- Need for power factor correction.

Effects of Non-Idealities

Real sources may have internal resistance, leading to:

- Voltage drops under load.
- Reduced voltage at load terminals.
- Power losses within the source.

These effects influence system efficiency and require compensation measures.

Conclusion: The Significance of the Ideal Model

The study of an ideal single-phase source, 240 V, 50 Hz, supplying power to a 100 Ω resistor forms a fundamental cornerstone in electrical engineering education and practice. It offers a simplified yet powerful framework to understand basic principles of voltage, current, power, and waveform behavior. While real-world systems introduce complexities such as internal resistance, reactive components, and transient phenomena, the ideal model provides clarity and a benchmark for analyzing more complex circuits.

Understanding this fundamental setup enables engineers to design efficient, reliable electrical systems, optimize power delivery, and develop robust control strategies. As technology advances, the principles derived from such idealized models continue to underpin innovations in power electronics, renewable energy systems, and smart grid management.

In essence, the study of this simple yet insightful circuit not only illuminates core electrical concepts but also lays the groundwork for tackling real-world challenges in power system design and analysis.

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