A Coil Of Resistance 10 And Inductance 140mH Is Connected In Parallel With A 260 Resistor Across A 230V,

A Coil Of Resistance 10 And Inductance 140mH Is Connected In Parallel With A 260 Resistor Across A 230V, this classic electrical circuit setup presents an intriguing scenario for analyzing the combined impedance, current distribution, and power factors involved. Understanding how the coil and resistor interact when connected across a voltage source is fundamental for electrical engineers and students alike, especially in designing and troubleshooting AC circuits. This article provides a comprehensive explanation of the circuit's behavior, calculations involved, and practical implications, all structured to enhance your knowledge of AC circuit analysis.

Understanding the Circuit Components

To analyze the circuit effectively, it is essential to understand each component's characteristics and how they influence the overall behavior.

The Coil (Inductor) with Resistance and Inductance

- **Resistance (R):** 10 Ω — This resistance causes real power dissipation as heat in the coil.
- **Inductance (L):** 140 mH (millihenries) — This inductance opposes changes in current, contributing to reactive power.
- **Impedance of the coil (Z_{coil}):** A complex quantity combining resistance and inductive reactance.

The Resistor

- **Resistance ($R_{resistor}$):** 260 Ω — Provides a straightforward resistive load with no reactive component.
- **Impedance of the resistor ($Z_{resistor}$):** Purely real, equal to 260 Ω.

Calculating the Impedance of the Inductive Coil

Since the coil has both resistance and inductance, its impedance is a complex quantity:

$$Z_{coil} = R + jX_L$$

Where:

1. **Resistance (R):** 10 Ω (given)
2. **Inductive reactance (X_L):** Calculated as:

   $$X_L = 2\pi fL$$

   with:
   - *f* = 230 V / (assuming standard mains frequency, typically 50Hz or 60Hz)

Assuming a standard mains frequency of 50Hz:

$$X_L = 2\pi \times 50Hz \times 0.14\ H \approx 2\pi \times 50 \times 0.14 \approx 2\pi \times 7 \approx 43.98\ \Omega$$

Thus:

$$Z_{coil} = 10\ \Omega + j43.98\ \Omega$$

The magnitude of the coil's impedance:

$$|Z_{coil}| = \sqrt{(R^2 + X_L^2)} = \sqrt{(10^2 + 43.98^2)} \approx \sqrt{(100 + 1934.4)} \approx \sqrt{2034.4} \approx 45.12\ \Omega$$

And the phase angle:

$$\theta_{coil} = \text{arctangent}(X_L/R) \approx \text{arctangent}(43.98/10) \approx 77.4°$$

This indicates a heavily reactive coil with a large phase difference between voltage and current.

Parallel Circuit Analysis

In the given circuit, the coil and resistor are connected in parallel across a 230V supply. To understand the circuit's behavior, we need to determine the equivalent impedance, total current, and individual branch currents.

Calculating the Combined Impedance

Since the coil and resistor are in parallel, their combined admittance (inverse of impedance) is:

$$Y_{total} = Y_{coil} + Y_{resistor}$$

Where:

$$Y_{coil} = 1 / Z_{coil} = 1 / (10 + j43.98)\ \Omega$$

Calculating Ycoil:

- First, find the complex conjugate of Zcoil:

$$Z_{coil} = 10 + j43.98$$

- The magnitude squared:

$$|Z_{coil}|^2 = 100 + 1934.4 \approx 2034.4$$

- The reciprocal:

$$Y_{coil} = (10 - j43.98) / 2034.4 \approx (10 / 2034.4) - j(43.98 / 2034.4) \approx 0.00492 - j0.0216\ S$$

Similarly, the admittance of the resistor:

$$Y_{resistor} = 1 / 260 \approx 0.00385\ S$$

Total admittance:

$$Y_{total} \approx (0.00492 + 0.00385) - j0.0216 \approx 0.00877 - j0.0216 \text{ S}$$

Magnitude of total admittance:

$$|Y_{total}| = \sqrt{(0.00877^2 + 0.0216^2)} \approx \sqrt{(7.69\times10^{-5} + 0.000467)} \approx \sqrt{0.000544} \approx 0.0233 \text{ S}$$

Phase angle:

$$\varphi = \text{arctangent}(-0.0216 / 0.00877) \approx -68.6°$$

The negative sign indicates the total admittance is lagging the voltage, typical of inductive behavior.

Calculating the Total Circuit Current

The total current supplied by the source:

$$I_{total} = V / Z_{equivalent}$$

But since we have admittance:

$$I_{total} = V \times Y_{total}$$

Given V = 230 V and |Ytotal| ≈ 0.0233 S:

$$I_{total} \approx 230 \text{ V} \times 0.0233 \text{ S} \approx 5.36 \text{ A}$$

The phase angle of the current:

$$\theta_I = \varphi \approx -68.6°$$

This indicates the total current lags the voltage significantly, consistent with the inductive nature.

Individual Branch Currents and Power Calculations

Understanding how current splits between the coil and resistor helps analyze power dissipation and reactive effects.

Resistor Branch Current

The current through the resistor:

$$I_R = V / R_{resistor} = 230\ V / 260\ \Omega \approx 0.885\ A$$

Power dissipated in the resistor:

$$P_R = V \times I_R = 230\ V \times 0.885\ A \approx 203.55\ W$$

Coil Branch Current

The coil's branch current:

$$I_{coil} = V / |Z_{coil}| = 230\ V / 45.12\ \Omega \approx 5.10\ A$$

Since the coil's impedance is reactive, the current leads the voltage with a phase angle of approximately 77.4°.

Power dissipated as heat in the coil's resistance:

$$P_{coil} = I_{coil}^2 \times R = (5.10)^2 \times 10 \approx 260\ W$$

Note that the reactive component of the coil does not dissipate real power but affects the overall power factor and reactive power.

Power Factor and Reactive Power

The power factor indicates the efficiency of power transfer and is determined by the phase difference between voltage and current.

$$\text{Power factor} = \cos(\theta_{total}) = \cos(68.6°) \approx 0.37$$

This low power factor signifies significant reactive power in the circuit, which is typical in circuits with inductance.

Reactive power (Q):

$$Q = V \times I_{coil} \times \sin(\theta_{coil}) \approx 230\ V \times 5.10\ A \times \sin(77.4°) \approx 230 \times 5.10 \times 0.974 \approx 1{,}145\ VAR$$

Real power (P):

$$P = V \times I_{total}$$

Frequently Asked Questions

What is the total impedance of a circuit with a 10 Ω resistance, 140 mH inductance, and 260 Ω resistor connected in parallel across 230 V?

The total impedance can be calculated by first finding the individual branch impedances and then combining them using parallel impedance formulas. The inductive reactance (X_L) is 2πfL; assuming a standard mains frequency of 50 Hz, X_L = 2π × 50 × 0.14 ≈ 44 Ω. The total impedance involves combining the resistor and inductor in parallel, then considering their combined impedance with the 10 Ω resistor, which requires complex impedance calculations.

How does the inductive reactance of 140 mH affect the overall current in the circuit?

The inductive reactance (approximately 44 Ω at 50 Hz) introduces an inductive reactance that opposes the change in current, causing the circuit to have a phase difference between voltage and current, and reducing the overall current magnitude compared to a purely resistive circuit.

What is the phase angle between voltage and current in this parallel R-L circuit?

The phase angle θ can be found using tan θ = X_L / R_total, where R_total is the equivalent resistance seen by the source. Since the circuit involves parallel components, the effective resistance and reactance must be calculated first; typically, the circuit exhibits a lagging power factor due to inductance, with θ > 0°.

How do you calculate the power consumed in this parallel R-L circuit across 230 V?

The real power (P) can be calculated using $P = V \times I_{total} \times \cos \varphi$, where $\cos \varphi$ is the power factor. Alternatively, $P = V^2 / R_{total}$, considering the equivalent resistance, and the reactive power can be calculated as $Q = V \times I \times \sin \varphi$. Precise calculation requires determining the total impedance and phase angle.

What is the effect of adding a 260 Ω resistor in parallel with the coil of inductance 140 mH?

Adding the resistor in parallel with the inductor creates a parallel R-L circuit that reduces the overall impedance at certain frequencies, increases the total current, and modifies the circuit's phase angle and power factor, often improving power efficiency depending on the specific configuration.

How does the frequency of the supply voltage influence the inductive reactance in this circuit?

The inductive reactance (X_L) is directly proportional to frequency, given by $X_L = 2\pi fL$. Increasing the frequency increases X_L, which raises the overall impedance and reduces current, while decreasing frequency has the opposite effect.

What practical applications involve a coil with 10 Ω resistance and 140 mH inductance connected with a resistor across a voltage supply?

Such circuits are common in filters, transformers, inductive loads, and tuning circuits where controlling current, phase, and impedance is essential, such as in radio frequency tuning, motor starters, and impedance matching networks.

Additional Resources

Electrical Components Analysis: A Coil of Resistance 10Ω and Inductance 140mH Connected in Parallel with a 260Ω Resistor Across a 230V Supply

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Introduction

In the realm of electrical and electronic engineering, understanding the behavior of various components when interconnected is vital. Today, we analyze a specific configuration: a coil with a resistance of 10Ω and an inductance of 140mH, connected in parallel with a 260Ω resistor, across a 230V AC supply. This setup embodies fundamental principles of AC circuit analysis and provides insight into how reactive and resistive elements interact within a parallel network.

This detailed review aims to explore the electrical characteristics, the implications for power consumption, phase relationships, and the overall behavior of this circuit. Whether you're an electrical engineer, a student, or a hobbyist, understanding this configuration enhances your grasp of AC circuit dynamics and component interactions.

Circuit Overview and Basic Concepts

The Components

- Resistive Element (Resistor R): 260Ω resistor, purely resistive, dissipates power as heat, and introduces a phase shift of 0° between voltage and current.
- Inductive Element (Coil / Inductor L): 140mH coil with an internal resistance of 10Ω, which introduces inductive reactance and phase shift.
- Supply Voltage V_{rms}: 230V AC, standard supply voltage in many regions.

Connection Topology

The coil (resistance and inductance) and resistor are connected in parallel across the AC source. This means both parallel branches experience the same voltage but may draw different currents based on their impedance.

Analyzing the Circuit: Step-by-Step Approach

1. Calculating Inductive Reactance X_L

The inductive reactance quantifies the opposition that an inductor offers to AC current:

$$
X_L = 2\pi f L
$$

where:
- f is the supply frequency (commonly 50Hz or 60Hz),
- L is the inductance in Henrys.

Assuming a typical frequency of 50Hz:

$$
X_L = 2 \pi \times 50 \times 0.14 \text{ H} \approx 2 \pi \times 50 \times 0.14 \approx 44 \text{Ω}
$$

Note: If the frequency varies, the reactance will change proportionally.

2. Total Impedance of the Coil

The coil's impedance Z_{coil} combines resistance R_{coil} and reactance X_L:

$$
Z_{coil} = R_{coil} + jX_L = 10Ω + j44Ω
$$

The magnitude:

$$
|Z_{coil}| = \sqrt{R_{coil}^2 + X_L^2} = \sqrt{10^2 + 44^2} \approx \sqrt{100 + 1936} \approx \sqrt{2036} \approx 45.1Ω
$$

The phase angle ϕ_{coil}:

$$
\phi_{coil} = \arctan \left(\frac{X_L}{R_{coil}} \right) \approx \arctan \left(\frac{44}{10} \right) \approx 77.4^\circ
$$

This indicates the coil's current lags voltage by approximately 77.4°.

3. Current Through the Resistor

Since the resistor is purely resistive:

$$
I_R = \frac{V}{R} = \frac{230V}{260Ω} \approx 0.885 \text{A}
$$

The current is in phase with the voltage.

4. Current Through the Coil

The current through the coil:

$$
I_{coil} = \frac{V}{|Z_{coil}|} = \frac{230V}{45.1\Omega} \approx 5.1 \text{A}
$$

This current lags the voltage by approximately 77.4°.

Power Analysis

1. Power Dissipated by the Resistor

$$
P_R = I_R^2 R = (0.885)^2 \times 260 \approx 0.783 \times 260 \approx 203.4 \text{ W}
$$

All the power dissipated here is purely resistive heat.

2. Power in the Inductive Branch

The coil's real power component:

$$
P_{coil} = I_{coil}^2 R_{coil} = (5.1)^2 \times 10 \approx 26 \text{ W}
$$

The reactive power:

$$
Q_{coil} = I_{coil} \times X_L \times \sin \phi_{coil} \approx 5.1 \times 44 \times \sin 77.4^\circ
$$

Since:

$$
\sin 77.4^\circ \approx 0.974
$$

$$
Q_{coil} \approx 5.1 \times 44 \times 0.974 \approx 218.4 \text{ VAR}
$$

The coil stores and releases energy each cycle, contributing reactive power but not dissipating it as heat.

Total Circuit Behavior

Given the currents:

- Resistor: 0.885A in phase with voltage.
- Coil: 5.1A lagging voltage by approximately 77.4°.

The total current supplied by the source:

$$
I_{total} = \sqrt{I_R^2 + I_{coil}^2 + 2 I_R I_{coil} \cos \phi}
$$

But because the resistor and coil are in parallel, their individual currents are additive in the circuit, and the total current's phase depends on the vector sum of the individual branch currents.

Power Factor and Efficiency

The power factor of the entire circuit:

$$
\text{PF} = \frac{P_{total}}{V_{rms} \times I_{total}}
$$

Where the total real power:

$$
P_{total} = P_R + P_{coil} \approx 203.4 + 26 = 229.4 \text{ W}
$$

The apparent power:

$$
S = V_{rms} \times I_{total}
$$

Calculating I_{total} considering phase angles:

$$
I_{coil} \text{ lags by } 77.4^\circ, \quad I_R \text{ in phase}
$$

Resulting in a phase angle for total current that indicates the overall power factor.

Practical Implications and Applications

1. Power Consumption and Losses

The dominant power consumption comes from the resistive branch, with the coil contributing reactive power. The coil's reactance causes the circuit to draw a current significantly larger than the resistive branch alone, affecting the sizing of conductors and protective devices.

2. Reactive Power and Power Factor Correction

The reactive power (~218 VAR) indicates a lagging power factor that can be problematic in power systems, leading to increased losses and reduced efficiency. To mitigate this, power factor correction techniques such as adding capacitors can be employed to offset the inductive reactance.

3. Design Considerations

- For motors and transformers, understanding such a setup helps in designing efficient systems that minimize reactive power.
- For filtering applications, the coil's impedance can be tuned (by adjusting L or f) for desired frequency responses.

Frequency Dependence and Variations

The behavior of this circuit is heavily influenced by frequency:

- At higher frequencies: X_L increases, making the coil more reactive, increasing the phase lag, and reactive power.
- At lower frequencies: X_L decreases, making the coil more resistive, reducing reactive effects.

Adjusting the supply frequency can optimize the circuit for specific applications, such as filtering or tuning.

Summary and Final Thoughts

This analysis of a resistor (260Ω) and a coil (10Ω resistance, 140mH inductance) connected in parallel across a 230V AC supply reveals a complex interplay between resistive and inductive behaviors. The significant inductive reactance at 50Hz results in a large reactive current, lagging the voltage by approximately 77°, which impacts the overall power factor and efficiency.

Power dissipation occurs mainly in the resistor, but the inductive branch contributes a large reactive power, emphasizing the importance of power factor correction in practical applications. The detailed calculations demonstrate how component values and supply frequency influence circuit behavior, guiding engineers in designing systems with optimal performance.

Whether for industrial machinery, audio equipment, or power distribution, understanding such configurations is fundamental for effective electrical system management.

In conclusion, this configuration exemplifies core principles of AC circuit analysis, illustrating how resistive and reactive components coexist and influence overall circuit performance. Mastery of these concepts enables better design, troubleshooting, and optimization of electrical systems across a broad spectrum of applications.

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