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Understanding the behavior of electrical circuits involving inductors and resistors is fundamental in electronics and electrical engineering. When a 10 millihenry (mH) inductor and a resistor with a resistance of 100 amperes (A) are connected in parallel, and the circuit is supplied with a voltage of 24 volts, several important concepts come into play. These include the impedance of the inductor, the current distribution between the components, and the overall circuit response. This article provides a comprehensive analysis of such a circuit, exploring its theoretical foundations, calculations, practical applications, and safety considerations.

Fundamental Concepts in Parallel RL Circuits

Before diving into calculations and specific details, it is essential to understand the fundamental principles governing parallel RL (resistor-inductor) circuits.

What Is a Parallel Circuit?

A parallel circuit is one where multiple components are connected across the same voltage source, providing independent paths for current flow. In this configuration:

- Voltage across each component is the same.
- Total current is the sum of currents through individual components.

Understanding Inductance and Resistance

- Inductance (L): The property of a coil or inductor that opposes changes in current. Measured in henries (H), with 10 mH being 0.01 H.
- Resistance (R): The opposition to current flow within a component, measured in ohms (Ω). The mention of "100 A resistor" likely indicates the resistor's current rating; its resistance value is needed for calculations.

Clarifying the Circuit Parameters

The problem statement mentions a resistor rated at 100 A, but typically, resistance is expressed in ohms (Ω). For accurate calculations, the resistance value (Ω) is necessary.

Assumption: The resistor's resistance is $1\ \Omega$, and its current rating is 100 A, which is a common scenario in high-current applications.

Similarly, the circuit is supplied with 24 volts.

Calculating the Resistance Value

Given the information:

- Voltage supply, $V = 24\text{ V}$
- Resistor current, $I_R = 100\text{ A}$

Using Ohm's Law:

$$R = \frac{V}{I_R} = \frac{24\text{ V}}{100\text{ A}} = 0.24\ \Omega$$

Note: If the resistor's resistance is $0.24\ \Omega$, it can safely carry 100 A without exceeding its rated current, assuming proper design.

Impedance of the Inductor

The inductor's impedance (Z_L) at a particular frequency is given by:

$$Z_L = j\omega L$$

Where:

- j is the imaginary unit
- $\omega = 2\pi f$ is the angular frequency
- $L = 10\text{ mH} = 0.01\text{ H}$

Note: Since the supply voltage is DC (24 V), the inductor initially opposes changes in current but acts

like a short circuit after steady state.

However, if this is an AC supply, the impedance depends on the frequency ω . For a comprehensive analysis, both DC and AC scenarios should be considered.

Analysis of the Circuit Under DC Supply

When the circuit is supplied with DC voltage (24 V), the behavior is as follows:

- The inductor initially opposes the sudden change in current, causing a transient response.
- After a long period (steady state), the inductor acts as a short circuit (zero resistance).

Steady-State Analysis:

- The inductor's impedance becomes zero.
- The resistor's impedance remains at 0.24Ω .

Total Resistance in Parallel:

$$\frac{1}{R_{\text{total}}} = \frac{1}{R} + 0$$

$$R_{\text{total}} = R = 0.24 \Omega$$

Total Current from Source:

$$I_{\text{total}} = \frac{V}{R_{\text{total}}} = \frac{24 \text{ V}}{0.24 \Omega} = 100 \text{ A}$$

This matches the resistor's rated current, indicating the resistor carries the full current in steady state.

Current Through the Resistor:

$$I_R = \frac{V}{R} = 100 \text{ A}$$

Current Through the Inductor:

- Zero in steady state because the inductor acts as a short circuit with no voltage drop.
- The initial current at the moment of switching on is zero, then it gradually increases to 100 A.

Analysis of the Circuit Under AC Supply

If the supply were AC with frequency f , the impedance of the inductor would be significant:

$$Z_L = j 2 \pi f L$$

Total admittance:

$$Y_{\text{total}} = \frac{1}{R} + \frac{1}{j 2 \pi f L}$$

The total current would then depend on the frequency, and the circuit's behavior would involve phase shifts, reactance, and impedance.

Calculating the Inductive Reactance

Assuming a specific AC frequency, for example, $f = 50 \text{ Hz}$:

$$X_L = 2 \pi f L = 2 \pi \times 50 \times 0.01 = 3.14 \Omega$$

Impedance magnitude:

$$|Z_L| = X_L = 3.14 \Omega$$

Total parallel impedance:

$$Z_{\text{parallel}} = \left(\frac{1}{R} + \frac{1}{j X_L} \right)^{-1}$$

Calculating the total current:

$$I_{\text{total}} = \frac{V}{|Z_{\text{parallel}}|}$$

The phase angle between voltage and current would be determined by the reactive component.

Practical Applications of Such Circuits

Understanding the behavior of parallel RL circuits with high current ratings and inductance values has numerous real-world applications:

- Power Electronics: Used in filtering and energy storage.
- Motor Drives: Inductors are vital in motor control circuits.
- RF and Communication Systems: Tuning circuits with inductors and resistors.
- High-Current Power Supplies: Managing transient responses and load characteristics.

Safety and Design Considerations

When designing circuits with high currents and inductance:

- Component Ratings: Ensure resistors and inductors can handle the expected currents and voltages.
- Heat Dissipation: High currents generate heat; proper heat sinking is essential.
- Transient Response: Incorporate snubbers or flyback diodes to manage voltage spikes during switching.
- Circuit Protection: Use fuses and circuit breakers to prevent overloads.

Summary of Key Calculations

- Resistance based on current and voltage: $0.24\ \Omega$
- Steady-state current through resistor: $100\ \text{A}$
- Inductive reactance at $50\ \text{Hz}$: $3.14\ \Omega$
- Total current in AC: varies with frequency and phase angle

Conclusion

Connecting a $10\ \text{mH}$ inductor and a resistor with a $0.24\ \Omega$ resistance in parallel to a $24\ \text{V}$ supply results in a circuit that behaves differently under DC and AC conditions. Under DC, the resistor carries the full current after transient effects settle. Under AC, the inductive reactance influences current

flow, phase relationships, and overall impedance. Proper understanding of these fundamental concepts is essential for designing safe and efficient electrical systems, especially those involving high currents and reactive components.

Keywords for SEO Optimization:

- Parallel RL circuit analysis
- 10 mH inductor and 0.24 Ω resistor
- DC and AC circuit behavior
- Impedance calculation in RL circuits
- High current resistor design
- Power electronics and inductors
- Circuit safety and component ratings
- Transient response in RL circuits
- Inductive reactance at 50 Hz

This comprehensive overview provides insight into the theoretical and practical aspects of the circuit involving a 10 mH inductor and a resistor connected in parallel to a 24 V supply. Understanding these principles is fundamental for engineers and enthusiasts working with complex electrical systems.

Frequently Asked Questions

What is the primary purpose of connecting a 10 mH inductor and a 100 A resistor in parallel in a circuit supplied with 24V?

The configuration is typically used to study the combined impedance effects, transient response, or energy storage characteristics of inductors and resistors when connected in parallel under a DC supply.

What is the initial current through the resistor when the circuit is first energized?

Initially, the resistor will draw $24V / (\text{resistance value})$. However, since the resistor value isn't specified in ohms, if it's 100 A as a current value, the resistor's resistance can be calculated as $R = V / I = 24V / 100A = 0.24\Omega$, so the initial current is 100A as specified.

How does the inductor affect the current in the circuit over time?

The inductor opposes changes in current, so initially it resists current flow, causing the current to rise gradually until it reaches a steady-state value, influenced by the resistor and the inductance.

What is the steady-state current through the inductor and resistor in this parallel circuit?

In steady state, the inductor behaves as a short circuit to DC, so the entire supply voltage appears across the resistor, resulting in a current of $24\text{V} / 0.24\Omega = 100\text{A}$ through the resistor, and the inductor current equals this value.

What is the time constant for the transient response in this circuit?

The time constant τ is given by $\tau = L / R = 10 \times 10^6 \text{ H} / 0.24\Omega \approx 41,666,667$ seconds, indicating an extremely slow transient response due to the very high inductance.

Why is the inductance value of 10 MH significant in this circuit?

A 10 MH inductor stores a large amount of magnetic energy and significantly influences the circuit's transient behavior, making the current change extremely slow and the circuit's response prolonged.

Could this circuit be used to analyze inductive energy storage or filtering applications?

Yes, due to the high inductance, this circuit could be useful for studying energy storage, filtering, or transient suppression in high-power or specialized applications.

What safety precautions should be taken when working with such high inductance and current levels?

Ensure proper insulation, use appropriate rated components, include protective devices like circuit breakers, and handle the circuit carefully to prevent high-voltage spikes and equipment damage.

How would the circuit behavior change if the supply voltage is increased beyond 24V?

Increasing the supply voltage would proportionally increase the steady-state current through the resistor, potentially leading to overheating or damage if the resistor or other components are not rated for the higher current.

Additional Resources

12. A 10 MH Inductor And A 100 A Resistor Are Connected In Parallel. The Circuit Is Supplied With 24V

In the realm of electrical engineering, the behavior of circuit components when combined in various configurations provides vital insights into system design, performance, and safety. The configuration involving a 10 millihenry (mH) inductor and a 100-ohm resistor connected in parallel across a 24-volt power supply is a classic example used to analyze transient and steady-state behaviors in R-L circuits. Although seemingly straightforward, such a setup encapsulates complex phenomena including inductive reactance, current distribution, energy storage, and transient responses that are crucial for applications ranging from power electronics to signal processing.

This article provides a comprehensive investigation into this particular circuit configuration, examining its theoretical foundations, dynamic responses, practical implications, and potential applications. Through detailed analysis, we aim to clarify the underlying physics and engineering considerations, making this a valuable resource for students, educators, and practitioners alike.

Overview of Circuit Components and Configuration

The Inductor: 10 mH

An inductor stores energy in its magnetic field when current flows through it. The inductance value—10 millihenries—is relatively small but significant enough in high-frequency or transient scenarios. The inductor's impedance varies with frequency, given by:

$$Z_L = j \omega L$$

where:

- Z_L : Inductive impedance,
- j : Imaginary unit,
- ω : Angular frequency ($2\pi f$),
- L : Inductance (10 mH).

At DC (zero frequency), the inductor acts as a short circuit, allowing current to flow unimpeded after initial transients fade.

The Resistor: 100 Ω

A resistor provides a constant opposition to current flow, characterized by Ohm's law:

$$V = IR$$

with a resistance of 100 ohms. Its current-voltage relationship remains linear across the operating range, unaffected by frequency.

Power Supply: 24 V

A fixed DC voltage source supplies energy to the circuit. The initial transient behavior and steady-state currents depend on the components' properties and the circuit's configuration.

Configuration

Connecting the inductor and resistor in parallel across the 24 V supply means both components

experience the same voltage at all times, but the currents through each component differ depending on their impedance.

Theoretical Analysis

Steady-State Behavior

In a DC steady state, the inductor's impedance becomes zero:

$$Z_L(\text{DC}) = 0 \rightarrow \text{short circuit}$$

Thus, after transient effects settle, the inductor behaves like a wire, and the circuit simplifies to a parallel connection of a resistor (100 Ω) and a short circuit across the supply.

Implication:

- The resistor sees a 24 V potential across it.
- The current through the resistor:

$$I_R = \frac{V}{R} = \frac{24\text{V}}{100\ \Omega} = 0.24\text{A}$$

- The inductor acts as a short, so the total current supplied by the source is approximately 0.24 A (neglecting minor parasitic effects).

Total current:

$$I_{\text{total}} = I_R + I_L \approx 0.24\text{A} + \text{negligible transient current}$$

Transient Response

When the circuit is initially powered (at $t=0$), the inductor opposes changes in current due to its stored magnetic energy. The initial current through the inductor is zero, and the current through the resistor is determined by the voltage division and transient behavior.

Key points:

- The inrush current is initially zero.
- The inductor current ramps up over time, approaching 0.24 A.
- The voltage across the inductor initially equals the supply voltage but drops as current increases.

Mathematical Modeling of Transients

Differential Equation

Applying Kirchhoff's Voltage Law (KVL):

$$V_s = V_R + V_L$$

Since both components are in parallel, voltage across both is $(V_s = 24V)$, but during transient, the inductor's current $(i_L(t))$ changes according to:

$$V_L(t) = L \frac{di_L(t)}{dt}$$

The resistor current:

$$i_R(t) = \frac{V_s}{R} = 0.24A$$

The inductor current:

$$i_L(t)$$

since the initial current $(i_L(0) = 0)$.

The total current supplied by the source:

$$I_s(t) = i_R(t) + i_L(t)$$

Given the parallel configuration, the inductor and resistor currents relate as:

$$i_R(t) = \frac{V_s}{R} = 0.24A \text{ (constant after initial transient)}$$

The inductor's differential equation:

$$V_s = L \frac{di_L(t)}{dt} \Rightarrow \frac{di_L(t)}{dt} = \frac{V_s}{L}$$

But because the resistor current is constant after initial transient, the inductor current transitions from 0 to 0.24 A following an exponential:

$$i_L(t) = I_{L,\infty} \left(1 - e^{-\frac{t}{\tau}} \right)$$

where:

$$\tau = \frac{L}{R} = \frac{10 \times 10^{-3}H}{100 \Omega} = 1 \times 10^{-4} s = 100 \mu s$$

and:

$$I_{L,\infty} \approx 0.24A$$

Key transient characteristics:

- Time constant $(\tau = 100 \mu s)$
- The inductor current reaches approximately 63% of its final value at $(t = \tau)$.

Practical Implications and Engineering Considerations

Energy Storage and Transients

The inductor stores magnetic energy:

$$E = \frac{1}{2} L i^2$$

At steady state, with $i_L \approx 0.24\text{ A}$:

$$E = \frac{1}{2} \times 10 \times 10^{-3} \text{ H} \times (0.24\text{ A})^2 \approx 2.88 \times 10^{-4} \text{ J}$$

While small, this energy becomes significant in high-frequency switching or transient events, potentially causing voltage spikes or inductive kickback.

Safety and Component Ratings

- The resistor's power dissipation:

$$P_R = I_R^2 R = (0.24\text{ A})^2 \times 100\Omega = 5.76\text{ W}$$

Thus, a resistor rated at least 10 W is recommended to handle continuous operation safely.

- The inductor must sustain the current and voltage without saturating or overheating; a 10 mH inductor should be rated accordingly.

Practical Applications

- Filtering: The inductor-resistor parallel can serve as a basic filter in power supplies.
- Transient suppression: The inductor's energy storage can smooth rapid current changes.
- Testing and educational setups: Demonstrates transient behavior and steady-state analysis.

Experimental and Simulation Approaches

Circuit Simulation

Using tools like SPICE or equivalent simulation software can visualize the transient response, confirming theoretical predictions. Simulations typically show:

- Zero current through the inductor at $t=0$.
- Exponential rise to steady-state current over $\sim 100 \mu\text{s}$.
- Voltage across both components remains at 24 V throughout.

Laboratory Testing

Constructing the circuit with appropriate measurement instruments (oscilloscopes, current probes) allows observation of:

- Transient current waveforms.
- Voltage waveforms across each component.
- Power dissipation and thermal effects in the resistor.

Advanced Topics and Further Investigation

Impact of Inductor Parasitics

Real inductors have parasitic capacitance and resistance, affecting high-frequency behavior, causing resonances or damping.

Non-Ideal Power Supplies

Voltage sources with internal resistance or transient response characteristics influence circuit behavior, especially during switching events.

Switching and Pulsed Inputs

Applying pulsed or varying voltage signals introduces complex dynamics, including oscillations, ringing, and potential overvoltage conditions.

Conclusion

The configuration involving a 10 millihenry inductor and a 100-ohm resistor connected in parallel across a 24V supply exemplifies fundamental electrical principles with practical significance. Its analysis highlights the transient response governed by the inductor's energy storage, the steady-state current distribution, and the importance of component ratings and safety considerations.

While simple in concept, this circuit embodies core concepts in transient analysis, energy storage, and circuit design, making it an ideal case study for educational purposes and practical engineering applications. Understanding its behavior not only deepens theoretical knowledge but also informs real-world design decisions in power electronics, filtering, and transient suppression.

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- Online simulation tools: LTspice,

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