

If The Current In A 110 Mh Coil Changes Steadily From 27.0 A To 13.0 A In 250 Ms , What Is The Magnitude

If The Current In A 110 Mh Coil Changes Steadily From 27.0 A To 13.0 A In 250 Ms , What Is The Magnitude is a fundamental question in electromagnetism that involves understanding the relationship between current, magnetic fields, and inductance. When dealing with coils and inductors, the rate of change of current directly influences the induced emf (electromotive force) and the energy stored within the magnetic field. This article aims to explore this problem comprehensively, providing a step-by-step approach to calculating the magnitude of the change in current, understanding the underlying physics, and applying relevant formulas.

Understanding the Problem Statement

The problem involves a coil with an inductance of 110 millihenrys (mH), and the current flowing through it changes steadily over a specified period. The key parameters given are:

- Initial current, $(I_i = 27.0\text{ A})$
- Final current, $(I_f = 13.0\text{ A})$
- Time interval, $(\Delta t = 250\text{ ms} = 0.250\text{ s})$
- Inductance, $(L = 110\text{ mH} = 0.110\text{ H})$

The question asks: What is the magnitude of the change?

While it may seem straightforward - the change in current is simply the difference $(I_f - I_i)$ - the context suggests that the focus is on understanding how this change relates to induced emf, magnetic energy, and the physical implications.

Key Concepts in Electromagnetism Related to the Problem

Before delving into calculations, it is essential to understand the core concepts:

Inductance and Magnetic Fields

- Inductance (L): A property of a coil that quantifies its ability to oppose changes in current.

Measured in henrys (H).

- Magnetic field energy (W): The energy stored in the magnetic field created by the current in the coil, given by $W = \frac{1}{2} L I^2$.

Faraday's Law of Electromagnetic Induction

- Any change in magnetic flux through a coil induces an emf proportional to the rate of change of flux.

- For a coil with inductance (L) and current $(I(t))$:

$$\mathcal{E} = -L \frac{dI}{dt}$$

- The negative sign indicates the emf opposes the change in current (Lenz's Law).

Calculating the Rate of Change of Current

Given the steady change in current over a specific period, the average rate of change:

$$\frac{\Delta I}{\Delta t} = \frac{I_f - I_i}{\Delta t}$$

Step-by-Step Calculation of the Current Change

The primary goal is to determine the magnitude of the current change and understand its implications.

1. Calculate the Change in Current (ΔI)

$$\boxed{\Delta I = I_f - I_i = 13.0\text{A} - 27.0\text{A} = -14.0\text{A}}$$

Since the problem asks for magnitude, the absolute value:

$$|\Delta I| = 14.0\text{A}$$

\]

This indicates a decrease of 14 amperes in the current through the coil over 250 milliseconds.

2. Calculate the Average Rate of Change of Current ($\frac{dI}{dt}$)

\[

$$\frac{dI}{dt} \approx \frac{\Delta I}{\Delta t} = \frac{-14.0\text{ A}}{0.250\text{ s}} = -56\text{ A/s}$$

\]

The negative sign reflects a decrease in current, but since we're interested in the magnitude, we take:

\[

$$\left| \frac{dI}{dt} \right| = 56\text{ A/s}$$

\]

Implications of the Rate of Change: Induced emf and Energy

Understanding the magnitude of current change enables us to compute the induced emf and the energy stored in the magnetic field.

1. Calculating the Induced emf ($\mathcal{E}$)

Using Faraday's Law:

\[

$$\mathcal{E} = L \left| \frac{dI}{dt} \right|$$

\]

Substituting the known values:

\[

$$\mathcal{E} = 0.110\text{ H} \times 56\text{ A/s} = 6.16\text{ V}$$

\]

Interpretation: The coil experiences an induced emf of approximately 6.16 volts opposing the change in current.

2. Magnetic Energy Stored in the Coil

The energy stored in the magnetic field at the initial and final currents can be calculated:

$$W = \frac{1}{2} L I^2$$

- Initial energy:

$$W_i = \frac{1}{2} \times 0.110 \text{ H} \times (27.0 \text{ A})^2 = 0.055 \times 729 = 40.1 \text{ J}$$

- Final energy:

$$W_f = \frac{1}{2} \times 0.110 \text{ H} \times (13.0 \text{ A})^2 = 0.055 \times 169 = 9.3 \text{ J}$$

- Change in magnetic energy:

$$\Delta W = W_f - W_i = 9.3 \text{ J} - 40.1 \text{ J} = -30.8 \text{ J}$$

This indicates that approximately 30.8 joules of energy are released as the current decreases from 27 A to 13 A.

Real-World Applications and Significance

Understanding the change in current and associated parameters in inductors like the 110 mH coil has vital applications in various fields:

1. Electrical Engineering and Circuit Design

- Designing inductors for filters, transformers, and energy storage devices.
- Managing transient responses in power systems to prevent voltage spikes.

2. Power Systems and Energy Storage

- Utilizing inductors in energy storage systems, such as in inductive kickback protection.

3. Electromagnetic Compatibility and Noise Suppression

- Knowing induced emf helps in minimizing electromagnetic interference (EMI).

4. Magnetic Field and Energy Calculations

- Estimations of stored magnetic energy are crucial in designing inductive components to ensure safety and efficiency.

Additional Considerations and Advanced Topics

While the above calculations provide a clear picture, more advanced analysis might include:

1. Non-Linear Changes and Transients

- Real systems might not have perfectly steady current changes; instead, transient effects may need to be modeled with differential equations.

2. Resistance Effects

- The coil's resistance introduces resistive voltage drops and affects energy dissipation.

3. Self-Induction and Mutual Induction

- In complex circuits, mutual inductance between components can influence the current change and emf.

4. Practical Measurement and Instrumentation

- Using oscilloscopes and current sensors to measure rapid current changes accurately.

Summary and Final Thoughts

To summarize:

- The current in a 110 mH coil decreases steadily from 27.0 A to 13.0 A over 250 ms.
- The magnitude of the change in current is 14.0 A.
- The average rate of change of current is 56 A/s.
- The induced emf opposing the change is approximately 6.16 V.
- The energy stored in the magnetic field decreases by about 30.8 J during this process.

Understanding these parameters is essential for designing efficient electromagnetic systems, managing transient responses, and ensuring the safety and stability of electrical devices.

Conclusion

The detailed analysis of the change in current in a 110 mH coil over a specific interval highlights the fundamental principles of electromagnetism. By applying basic formulas and concepts such as Faraday's Law, inductance, and energy storage, engineers and students can predict and analyze electromagnetic behavior effectively. Whether designing transformers, inductors, or energy storage systems, grasping how current variations influence emf and stored energy is crucial for innovation and safety in electrical engineering.

Keywords: inductance, electromagnetic induction, current change, magnetic energy, emf, inductor, coil, 110 mH coil, steady current change, energy stored, Faraday's Law, transient response, electrical engineering

Frequently Asked Questions

What is the primary goal when calculating the magnitude of the induced emf in a coil with changing current?

The primary goal is to determine the magnitude of the emf induced in the coil due to the change in current over a specific time interval, using Faraday's law of electromagnetic induction.

Which formula relates the induced emf to the change in current and the coil's inductance?

The induced emf (V) is given by $V = L (\Delta I / \Delta t)$, where L is the inductance, ΔI is the change in current, and Δt is the time over which the change occurs.

How do you calculate the inductance of the coil if the number of turns, length, and core properties are known?

Inductance L can be calculated using the formula $L = \mu_0 \mu_r N^2 A / l$, where μ_0 is the permeability of free space, μ_r is the relative permeability of the core, N is the number of turns, A is the cross-sectional area, and l is the length of the coil.

Given the current change from 27.0 A to 13.0 A in 250 ms, what is the total change in current?

The total change in current is $\Delta I = 27.0 \text{ A} - 13.0 \text{ A} = 14.0 \text{ A}$.

How do you convert milliseconds to seconds for the calculation?

To convert milliseconds to seconds, divide by 1000: $250 \text{ ms} = 0.250 \text{ seconds}$.

What is the formula for the magnitude of the induced emf in this scenario?

Using Faraday's law, $V = L \times (\Delta I / \Delta t)$, where L is the inductance, ΔI is 14.0 A, and Δt is 0.250 s.

If the inductance of the coil is unknown, what additional information is needed to find the induced emf?

You need to know the inductance of the coil; if not provided, it can be calculated from the coil's physical parameters or given directly.

What is the significance of the steady change in current in calculating the emf?

A steady change in current allows the use of a simple linear relation in Faraday's law, making it straightforward to calculate the induced emf as a function of the change over time.

Assuming the inductance is known to be 0.5 H, what is the magnitude of the induced emf during the current change?

$V = 0.5 \text{ H} \times (14.0 \text{ A} / 0.250 \text{ s}) = 0.5 \times 56 = 28 \text{ volts}$. So, the magnitude of the induced emf is 28 V.

Additional Resources

Understanding the Magnitude of the Induced Voltage in a 110 mH Coil During a Changing Current

When exploring the dynamics of electromagnetic phenomena, one of the fundamental concepts is Faraday's Law of electromagnetic induction. This law states that a changing magnetic flux through a

coil induces an electromotive force (EMF) or voltage across the coil. In practical applications and theoretical analyses, understanding how the change in current affects the induced voltage is critical, especially in inductors like the 110 mH coil mentioned here.

In this detailed review, we will analyze the problem: If the current in a 110 mH coil changes steadily from 27.0 A to 13.0 A in 250 milliseconds, what is the magnitude of the induced emf? We will break down the problem step-by-step, delve into the physics involved, and explore related concepts to provide a comprehensive understanding.

Fundamental Concepts and Theoretical Background

Inductance and Its Role in Electromagnetic Induction

- Definition of Inductance (L):

Inductance is a property of a coil (or inductor) that quantifies its ability to oppose changes in current flowing through it. It is measured in henrys (H).

$$L = \frac{\text{magnetic flux linkage}}{\text{current}}$$

- Magnetic Field and Flux:

When current flows through a coil, it produces a magnetic field. The magnetic flux (Φ) linked with the coil is proportional to the current (I):

$$\Phi = L \times I$$

- Faraday's Law of Induction:

The induced emf ($\mathcal{E}$) in an inductor due to a change in magnetic flux is:

$$\mathcal{E} = -\frac{d\Phi}{dt}$$

Since magnetic flux linkage is related to current:

$$\mathcal{E} = -L \frac{dI}{dt}$$

The negative sign indicates Lenz's Law, which states the induced emf opposes the change in current.

Problem Breakdown and Data Analysis

Given data:

- Inductance, $L = 110 \text{ mH} = 0.110 \text{ H}$

- Initial current, $I_i = 27.0 \text{ A}$

- Final current, $I_f = 13.0 \text{ A}$

- Time interval, $\Delta t = 250 \text{ ms} = 0.250 \text{ s}$

Objective:

- Find the magnitude of the induced emf ($|\mathcal{E}|$) during this current change.

Calculating the Rate of Change of Current (dI/dt)

The rate at which current changes is essential because the emf is proportional to dI/dt :

$$|\mathcal{E}| \approx \frac{\Delta I}{\Delta t}$$

Where:

$$\begin{aligned} \Delta I &= I_f - I_i = 13.0 \text{ A} - 27.0 \text{ A} = -14.0 \text{ A} \\ \Delta t &= 0.250 \text{ s} \end{aligned}$$

Therefore:

$$\frac{dI}{dt} = \frac{-14.0 \text{ A}}{0.250 \text{ s}} = -56 \text{ A/s}$$

The negative sign indicates the current is decreasing, but for magnitude purposes, we focus on the absolute value:

$$\left| \frac{dI}{dt} \right| = 56 \text{ A/s}$$

Calculating the Induced EMF

Using Faraday's Law for an inductor:

$$|\mathcal{E}| = L \left| \frac{dI}{dt} \right|$$

Substituting known values:

$$|\mathcal{E}| = 0.110 \text{ H} \times 56 \text{ A/s} = 6.16 \text{ V}$$

Final answer:

```
\[
\boxed{
\textbf{The magnitude of the induced emf is approximately 6.16 volts}
}
\]
```

This is the instantaneous emf induced in the coil during the current change.

Deeper Insights and Additional Considerations

Significance of the Result

- The induced emf of about 6.16 V demonstrates how a substantial change in current over a short duration induces a significant voltage across the coil.
- Such voltages are critical in designing circuits involving inductors, especially in switching circuits, transformers, and motors where rapid current changes occur.

Impact of Changing Parameters

- Increasing the Inductance (L):
Higher inductance results in a proportionally higher emf for the same rate of current change.
- Faster Current Changes ($\frac{dI}{dt}$):
Shorter time intervals or larger current differences result in larger emf.
- Current Magnitude:
While the initial and final currents don't directly affect emf calculation except through $\frac{dI}{dt}$, they can influence the energy stored in the magnetic field.

Energy Stored in the Inductor

The energy stored (W) in the magnetic field of an inductor is:

```
\[
W = \frac{1}{2} L I^2
\]
```

Calculating for initial and final currents:

- Initial energy:

```
\[
W_i = \frac{1}{2} \times 0.110 \, \text{H} \times (27.0 \, \text{A})^2 \approx 40.1 \, \text{J}
\]
```

\]

- Final energy:

\[

$$W_f = \frac{1}{2} \times 0.110 \, \text{H} \times (13.0 \, \text{A})^2 \approx 9.25 \, \text{J}$$

\]

The decrease in stored magnetic energy (about 30.85 J) is released as the coil's magnetic field collapses, which correlates with the induced emf and current change.

Practical Implications and Real-World Applications

- Switching Power Supplies:

Rapid changes in current induce high voltages that can cause arcing or damage if not properly managed with snubbers or diodes.

- Transformers and Inductive Loads:

Sudden changes in current affect voltage levels and can induce voltage spikes, which are critical in circuit design and protection.

- Electromagnetic Compatibility (EMC):

High induced voltages can generate electromagnetic interference, affecting nearby electronics.

- Inductive Kickback:

When current through an inductor is suddenly interrupted, the collapsing magnetic field generates a high voltage spike. Managing this is vital in circuit design to prevent component damage.

Additional Factors and Complexities

While the calculation above assumes an ideal inductor with no resistive losses, real-world scenarios involve additional complexities:

- Resistance (R):

The coil's resistance causes energy dissipation as heat, affecting the effective emf and energy calculations.

- Self-Resonance:

At high frequencies, parasitic capacitance can cause resonant effects, complicating the simple linear analysis.

- Core Material and Geometry:

The magnetic properties and geometry influence the inductance value and flux linkage.

Summary and Key Takeaways

- The change in current from 27.0 A to 13.0 A in 250 ms in a 110 mH coil induces an emf of approximately 6.16 volts.
- The core principle hinges on Faraday's Law: $\mathcal{E} = L \times |dI/dt|$.
- The magnitude of the emf is directly proportional to both the inductance and the rate of current change.
- Rapid current changes can generate significant voltages, which must be managed carefully in practical circuit design.
- Understanding these principles is essential in fields such as power electronics, electromagnetic compatibility, and electrical engineering.

Final Thoughts

Grasping the interplay between inductance, current variation, and induced emf forms the backbone of electromagnetic circuit analysis. This problem exemplifies how a simple change in current over a specified time interval can produce measurable and sometimes substantial voltages, highlighting the importance of inductors in both theoretical and applied physics. Whether designing transformers, motor coils, or switching power supplies, engineers must consider these electromagnetic principles to ensure safe, efficient, and reliable operation of electrical systems.

Note: Always remember to consider real-world effects like resistance, parasitic inductances, and non-ideal behaviors when applying these calculations to practical scenarios.

If The Current In A 110 Mh Coil Changes Steadily From 27 0 A To 13 0 A In 250 Ms What Is The Magnitude

If The Current In A 110 Mh Coil Changes Steadily From 27 0 A To 13 0 A In 250 Ms What Is The Magnitude

Related Articles

- [Show That The Halting Problem, The Set Of \(M,w\) Pairs Such That M Halts \(with Or Without Accepting\) When](#)
- [Sketch The Region Enclosed By The Given Curves. Decide Whether To Integrate With Respect To X Or Y. Then](#)
- [Suppose A Single Price Monopolist With \$TC=20Q\$ Faces An Inverse Demand Curve \$P=120-Q\$](#)

[And Marginal Revenue](#)

[Back to Home](#)