

The Apparent Power Supplied To A Motor Is Six Kilovolt Amps At 120 Volts. What Is The Impedance Of The

The Apparent Power Supplied To A Motor Is Six Kilovolt Amps At 120 Volts. What Is The Impedance Of The

Understanding the electrical characteristics of motors, especially in terms of power and impedance, is crucial for designing efficient electrical systems and ensuring proper operation. When given the apparent power, voltage, and the need to find the impedance, it becomes essential to interpret the relationships between these quantities accurately. This article delves into the concepts surrounding apparent power, voltage, and impedance, providing a comprehensive analysis of the problem: determining the impedance of a motor supplied with six kilovolt-amperes (kVA) at 120 volts.

Fundamentals of Power in AC Circuits

Before addressing the specific problem, it is important to review the key concepts involved in alternating current (AC) circuits, namely apparent power, real power, reactive power, and impedance.

Apparent Power (S)

Apparent power, denoted as S , is the total power supplied to an AC circuit. It is measured in volt-amperes (VA) or kilovolt-amperes (kVA). Apparent power combines both the real power, which performs useful work, and reactive power, which sustains the electric and magnetic fields in inductive and capacitive components.

Mathematically:

$$S = V \times I$$

where:

- V is the RMS voltage,
- I is the RMS current.

In the complex form, apparent power is expressed as:

$$S = P + jQ$$

where:

- P is the real power (watts),
- Q is the reactive power (VARs).

The magnitude of apparent power is:

$$|S| = \sqrt{P^2 + Q^2}$$

Impedance in AC Circuits

Impedance, denoted by Z , generalizes resistance to AC circuits. It accounts for resistive, inductive, and capacitive effects:

$$Z = R + jX$$

where:

- R is resistance,

- X is reactance.

The magnitude of impedance is:

$$|Z| = \sqrt{R^2 + X^2}$$

The phase angle ϕ between voltage and current is:

$$\phi = \arctan \left(\frac{X}{R} \right)$$

The relationships among voltage, current, and impedance are:

$$V = I \times Z$$

or in RMS quantities:

$$|V| = |I| \times |Z|$$

Given Data and Objective

The problem provides:

- Apparent power, $(S = 6 \text{ kVA} = 6000 \text{ VA})$,
- Voltage, $(V = 120 \text{ V})$.

The goal is to determine the impedance $|Z|$ of the motor.

Understanding the Data

- The apparent power indicates the total power supplied to the motor, including both real and reactive components.
- The voltage is RMS (root mean square), a standard measure in AC power calculations.
- The key is to find the impedance magnitude, since it relates the voltage and current, given $|S|$.

Calculating the Current

Using the relationship:

$$S = V \times I^*$$

where I^* is the complex conjugate of current, but for magnitude calculations we consider:

$$|S| = V \times I$$

Rearranging for current:

$$I = \frac{|S|}{V}$$

Substituting the known values:

$$I = \frac{6000 \text{ VA}}{120 \text{ V}} = 50 \text{ A}$$

This is the RMS current supplied to the motor.

Determining the Impedance

Since the voltage and current are RMS values, and the impedance relates these quantities via Ohm's law:

$$|Z| = \frac{|V|}{|I|}$$

Substituting:

$$|Z| = \frac{120\text{ V}}{50\text{ A}} = 2.4\text{ }\Omega$$

This value represents the magnitude of the motor's impedance.

Understanding the Power Factor and Phase Angle

While the magnitude of impedance provides critical information, the power factor — the cosine of the phase angle ϕ between voltage and current — is equally important in understanding how the motor consumes power.

The power factor (pf) is given by:

$$\text{pf} = \frac{P}{S}$$

Where:

- P is the real power (W),
- S is the apparent power (VA).

Since only apparent power and voltage are given, and the problem asks for impedance, let's consider the possibility that the power factor is provided or can be derived if more data were available. However, in this case, if the motor is purely inductive or capacitive, the power factor would be less than 1, and the impedance would have a reactive component.

Calculating the Power Factor

In typical motor applications, the real power P can be expressed as:

$$P = V I \cos \phi$$

but since P is not given, and only S and V , I are known, the power factor can be expressed as:

$$\text{pf} = \frac{P}{S}$$

If the motor's real power P were known, the phase angle ϕ could be calculated via:

$$\cos \phi = \text{pf}$$

and the reactive component X could be determined accordingly.

Calculating the Reactive and Resistive Components of the Impedance

The impedance magnitude alone does not tell us the individual resistive (R) and reactive (X) components. To fully characterize the motor's impedance, additional data such as power factor or real

power would be necessary.

However, assuming we want to express the impedance in terms of its resistive and reactive parts, and considering the general relationships:

$$|Z| = \sqrt{R^2 + X^2}$$

and

$$\text{Power factor} = \cos \phi = \frac{R}{|Z|}$$

If the power factor were known, then:

$$R = |Z| \cos \phi$$

$$X = |Z| \sin \phi$$

In the absence of such data, the best we can do is report the magnitude of the impedance.

Summary and Final Calculation

- The RMS current supplied to the motor:

$$I = \frac{S}{V} = \frac{6000 \text{ VA}}{120 \text{ V}} = 50 \text{ A}$$

- The impedance magnitude:

$\sqrt{}$

$$|Z| = \frac{V}{I} = \frac{120\text{ V}}{50\text{ A}} = 2.4\text{ }\Omega$$

$\sqrt{}$

This value indicates that the motor's total impedance, considering both resistive and reactive effects, is approximately 2.4 ohms.

Implications and Practical Considerations

Understanding the impedance of a motor has significant implications in electrical system design:

- Efficiency: High reactive impedance results in lower power factor, which can lead to increased losses and higher utility charges.
- Protection: Accurate impedance calculations help in selecting appropriate protective devices and ensuring system stability.
- Motor Control: Knowledge of impedance aids in designing control strategies, such as variable frequency drives.

Additional Factors to Consider

- The actual power factor of the motor, which requires the real power (P) , influences how reactive the motor is.
- The motor's operating conditions, such as load and temperature, can affect impedance.
- For detailed analysis, measuring the power factor or real power directly provides more precise impedance components.

Conclusion

In summary, given an apparent power of 6 kVA at 120 V, the RMS current supplied to the motor is 50 A, and the magnitude of the motor's impedance is approximately 2.4 ohms. This calculation provides a fundamental understanding of the motor's electrical characteristics and serves as a basis for further analysis involving power factor, reactive components, and system efficiency. Accurately determining impedance is vital for optimizing motor performance, ensuring safety, and maintaining electrical system reliability.

Frequently Asked Questions

What is the impedance of a motor supplied with 6 kVA at 120 V?

The impedance can be calculated using $Z = V^2 / S$. Converting 6 kVA to VA (6000 VA), $Z = (120 \text{ V})^2 / 6000 \text{ VA} = 14400 / 6000 = 2.4 \text{ ohms}$.

How do you determine the impedance of a motor given its apparent power and voltage?

Impedance Z is found using $Z = V / I$, where I is the current. Since apparent power $S = V I$, then $I = S / V$. Therefore, $Z = V / (S / V) = V^2 / S$.

What are the steps to calculate the motor's impedance from its apparent power and voltage?

First, convert apparent power to VA, then use $Z = V^2 / S$. For 6 kVA at 120 V, $Z = 120^2 / 6000 = 2.4 \text{ ohms}$.

If the apparent power supplied to a motor is 6 kVA at 120 V, what is the current drawn by the motor?

The current $I = S / V = 6000 \text{ VA} / 120 \text{ V} = 50 \text{ A}$.

Why is understanding the impedance of a motor important in electrical systems?

Impedance determines how much current the motor draws at a given voltage and affects power factor, efficiency, and system stability.

Can the impedance of the motor be purely resistive in this scenario?

Not necessarily; the impedance may have reactive components. Additional information such as power factor is needed to determine if it's purely resistive or has inductive or capacitive elements.

Additional Resources

The Apparent Power Supplied To A Motor Is Six Kilovolt Amps At 120 Volts. What Is The Impedance Of The Motor?

Understanding the electrical characteristics of motors is fundamental for engineers, technicians, and anyone involved in electrical system design and maintenance. When a motor is powered, various parameters such as voltage, current, power, and impedance interact to determine its operational behavior. In this article, we delve into a specific scenario where a motor receives an apparent power of six kilovolt-amperes (kVA) at a voltage of 120 volts, and we aim to determine the motor's impedance. This exploration combines theoretical concepts with practical calculations, offering a comprehensive understanding of how impedance influences motor performance.

Deciphering Apparent Power and Voltage

What Is Apparent Power?

Apparent power, measured in volt-amperes (VA), is the combination of real power (watts) and reactive power (VAR) in an AC circuit. Unlike real power, which does actual work such as turning a motor shaft, apparent power reflects the total power supplied to the circuit, including the power stored and released by reactive components like inductors and capacitors.

In the context of motors, especially induction motors, reactive power is significant because these machines inherently have inductive characteristics. The apparent power is a vector sum of the real and reactive components, and it is crucial for sizing electrical equipment and ensuring system stability.

The Significance of Voltage in Power Calculations

Voltage, in this case, 120 volts, is the potential difference supplied to the motor. It's essential to note that in AC circuits, voltage and current phase angles impact the power calculations. The relationship between apparent power (S), voltage (V), and current (I) is expressed as:

$$S = V \times I$$

where S is the apparent power in VA, V is the RMS voltage in volts, and I is the RMS current in amperes.

Understanding Impedance in AC Circuits

Defining Impedance

Impedance (Z) is a complex quantity representing the opposition a circuit offers to the flow of alternating current. It encompasses resistance (R) and reactance (X), expressed as:

$$Z = R + jX$$

where:

- R is resistance, representing energy dissipation as heat.
- X is reactance, representing energy storage in magnetic or electric fields.
- j is the imaginary unit, indicating phase difference between voltage and current.

The magnitude of impedance ($|Z|$) determines how much current flows for a given voltage:

$$|Z| = \sqrt{R^2 + X^2}$$

The Role of Impedance in Motors

In motors, impedance influences starting torque, efficiency, and power factor. A high impedance limits current, protecting the motor and supply circuitry, but can reduce torque. Conversely, low impedance allows higher current, which can improve torque but may cause excessive current draw and potential damage if not properly managed.

Calculating the Impedance of the Motor

Given Data:

- Apparent Power, $(S = 6, \text{kVA} = 6000, \text{VA})$
- Voltage, $(V = 120, \text{V})$

The goal is to find the impedance (Z) of the motor based on these parameters.

Step 1: Determine the RMS Current

Using the relationship between apparent power, voltage, and current:

$$[S = V \times I]$$

Rearranged as:

$$[I = \frac{S}{V}]$$

Substituting the known values:

$$[I = \frac{6000, \text{VA}}{120, \text{V}} = 50, \text{A}]$$

This indicates that the motor draws a current of 50 amperes at the specified apparent power and voltage.

Step 2: Calculate the Impedance Magnitude

Since apparent power is related to voltage and current by:

$$[|Z| = \frac{V}{I}]$$

we find:

$$|Z| = \frac{120 \text{ V}}{50 \text{ A}} = 2.4 \Omega$$

This magnitude of impedance represents the total opposition to current flow in the motor's equivalent circuit at the operating point.

Step 3: Interpreting the Result

The impedance magnitude of 2.4 ohms indicates the combined resistive and reactive opposition. To further analyze the motor's electrical behavior, understanding the power factor is essential.

Assessing Power Factor and Reactive Components

What Is Power Factor?

Power factor (pf) is the ratio of real power (P) to apparent power (S):

$$\text{pf} = \frac{P}{S}$$

It indicates how effectively the motor converts electrical power into mechanical work. A power factor close to 1 signifies efficient energy use, whereas a lower power factor reveals higher reactive power presence.

Estimating Real Power and Power Factor

Assuming the motor operates at a typical power factor, say 0.8 (lagging), the real power consumed can be computed as:

$$P = S \times \text{pf} = 6000, \text{VA} \times 0.8 = 4800, \text{W}$$

Correspondingly, the reactive power (Q) is:

$$Q = \sqrt{S^2 - P^2} = \sqrt{6000^2 - 4800^2}$$

Calculating:

$$Q = \sqrt{36,000,000 - 23,040,000} = \sqrt{12,960,000} \approx 3,601, \text{VAR}$$

This reactive component contributes to the inductive reactance in the motor's equivalent circuit.

Calculating Resistance and Reactance

Using the impedance magnitude and power factor:

$$R = |Z| \times \text{pf} = 2.4, \Omega \times 0.8 = 1.92, \Omega$$

and

$$X = \sqrt{|Z|^2 - R^2} = \sqrt{(2.4)^2 - (1.92)^2} = \sqrt{5.76 - 3.69} = \sqrt{2.07} \approx 1.44, \Omega$$

Thus, the motor's approximate impedance components are:

- Resistance (R) $\approx 1.92 \Omega$

- Reactance (X) $\approx 1.44 \Omega$

Implications for Motor Operation and Design

Understanding the impedance offers insights into the motor's operational characteristics. The resistive component influences heat dissipation and efficiency, while the reactive component affects starting torque and power factor correction needs.

Impact on Starting and Running Conditions

At startup, motors typically draw higher inrush currents, often several times their running current, due to their low impedance and high reactance. Proper design must account for this to avoid electrical or mechanical stress.

Power Factor Correction Strategies

Enhancing the power factor involves adding capacitors to offset the motor's inductive reactance. This adjustment reduces reactive power demand, improves energy efficiency, and diminishes demand charges from utilities.

Conclusion: The Significance of Impedance in Electrical Systems

In the scenario where a motor receives six kilovolt-amperes of apparent power at 120 volts, the impedance magnitude calculates to approximately 2.4 ohms. This value encapsulates the combined effects of resistance and reactance within the motor's equivalent circuit, directly influencing current draw, efficiency, and overall performance.

Understanding these parameters empowers engineers and technicians to design better electrical systems, optimize motor operation, and implement effective power factor correction measures. As electrical systems grow more sophisticated, grasping the fundamentals of impedance and power calculations remains vital for ensuring safety, efficiency, and longevity of electrical machinery.

In summary, the impedance of the motor in this example not only reflects its electrical characteristics but also serves as a key factor in operational planning and system optimization. Whether for sizing equipment, troubleshooting, or improving energy efficiency, such calculations form the backbone of effective electrical engineering practice.

The Apparent Power Supplied To A Motor Is Six Kilovolt Amps At 120 Volts What Is The Impedance Of The

The Apparent Power Supplied To A Motor Is Six Kilovolt Amps At 120 Volts What Is The Impedance Of The

Related Articles

- [The National Center For Education Statistics Reported That Of College Students Work To Pay For Tuition](#)
- [Type The Correct Answer In The Box.A Restaurant Uses Rectangular Napkins Where The Length, L, Is Twice](#)
- [The Diagram Below Shows The Velocity Vectors For Two Cars That Are Movingrelative To Each Other.45 M/s](#)

[Back to Home](#)