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7. An R-l Series Circuit Has A Power Factor Of 73%. If The Apparent Power Is 560 Kva, What Is The True power delivered to the load? Understanding this question requires a solid grasp of electrical power concepts, particularly how apparent, real, and reactive power relate within AC circuits. This scenario is common in electrical engineering applications, especially when dealing with inductive loads such as motors, transformers, and other inductive components. In this article, we will explore the fundamentals necessary to solve this problem, including the definitions of key power types, how to calculate the true (or real) power, and the significance of power factor in AC circuits.

Understanding Power in AC Circuits

Before delving into calculations, it's essential to understand the different types of power in alternating current (AC) systems.

Apparent Power (S)

- Definition: The total power supplied to the circuit, measured in kilovolt-amperes (kVA).
- Significance: Represents the combined effect of real and reactive power and is the product of the RMS voltage and RMS current.
- In our problem: Given as 560 kVA.

Real Power (P)

- Definition: The actual power consumed by the load to perform work, measured in kilowatts (kW).
- Significance: Determines the useful work output such as turning motors, lighting, etc.
- Relation to apparent power: $P = S \times \text{Power Factor (pf)}$.

Reactive Power (Q)

- Definition: The power that oscillates between the source and reactive components (inductors and capacitors), measured in kilovolt-amperes reactive (kVAR).
- Significance: Does not perform any real work but affects the power factor and the efficiency of power transmission.

Power Factor and Its Role

Power factor (pf) is a dimensionless number between 0 and 1 that indicates the efficiency of power usage in an AC circuit.

Definition

- Power Factor (pf): The cosine of the phase angle (ϕ) between the voltage and current waveforms.
- Mathematically: $pf = P / S$, where P is real power, and S is apparent power.

Importance of Power Factor

- Higher power factors (closer to 1) indicate more efficient power usage.
- Low power factors lead to increased losses and higher costs for power utilities.

In our problem, the power factor is given as 73%, or 0.73.

Calculating the True Power (P)

Given data:

- Apparent Power, $S = 560 \text{ kVA}$
- Power Factor, $pf = 0.73$

Using the formula:

$$P = S \times pf$$

Calculations:

$$P = 560 \text{ kVA} \times 0.73$$

$$P = 408.8 \text{ kW}$$

Thus, the true (or real) power delivered to the load is approximately 408.8 kilowatts.

Understanding the Power Triangle

The relationship between apparent, real, and reactive power can be visualized using the power triangle.

Power Triangle Components

- Horizontal axis: Real Power (P)
- Vertical axis: Reactive Power (Q)
- Hypotenuse: Apparent Power (S)

Mathematically:

$$S^2 = P^2 + Q^2$$

$$\text{and } \cos \phi = \frac{P}{S}$$

Using the given data:

- $P \approx 408.8 \text{ kW}$
- $S = 560 \text{ kVA}$
- $\cos \phi = 0.73$

From these, reactive power Q can also be calculated, which is useful for understanding the circuit's reactive component.

Calculating Reactive Power (Q)

Using the Pythagorean theorem:

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

Calculations:

$$Q = \sqrt{(560)^2 - (408.8)^2}$$

$$Q = \sqrt{313600 - 167138.24}$$

$$Q = \sqrt{146461.76}$$

$$Q \approx 382.7 \text{ kVAR}$$

This reactive power indicates the amount of energy oscillating between the source and the reactive elements of the circuit.

Significance of the Results

The calculated true power, approximately 408.8 kW, represents the actual work being done by the circuit—be it lighting, motion, or other forms of energy transfer. The reactive power of about 382.7 kVAR reflects the energy stored and released by inductive components, which does not contribute to work but impacts the overall efficiency.

Practical Implications in Power Systems

Understanding and calculating true power in AC circuits have several practical implications:

- **Energy Efficiency:** Maximizing power factor reduces energy losses and lowers operational costs.
- **Equipment Sizing:** Accurate power calculations ensure appropriate sizing of generators, transformers, and other equipment.
- **Power Quality:** Maintaining a high power factor minimizes voltage drops and prevents overloads.
- **Cost Management:** Utilities often charge penalties for low power factor; hence, improving pf can reduce costs.

Improving Power Factor

In many industrial or commercial settings, the power factor is less than ideal. To improve it, various techniques can be employed:

Power Factor Correction Methods

1. **Adding Capacitors:** Capacitors supply reactive power locally, reducing the reactive power demand from the source.
2. **Synchronous Condensers:** Synchronous motors operated to adjust reactive power flow.
3. **Using Power Factor Correction Devices:** Specialized equipment installed in the circuit to optimize power factor.

By enhancing the power factor from 73% toward closer to 1, the efficiency of power transmission improves, and operational costs decrease.

Summary and Final Thoughts

In conclusion, given an apparent power of 560 kVA and a power factor of 73%, the true power delivered to the load is approximately 408.8 kW. This calculation is crucial for engineers and technicians to assess the efficiency of electrical systems, plan for appropriate equipment, and implement measures to optimize power usage. Understanding the interplay between apparent, real, and reactive power helps ensure reliable, efficient, and cost-effective electrical system operation.

Maintaining a high power factor is beneficial, not only for reducing energy costs but also for enhancing the longevity and performance of electrical components. Whether designing new systems or troubleshooting existing ones, these calculations form the foundation of sound electrical engineering practices.

References:

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Frequently Asked Questions

What is the formula to calculate true power in an R-L series circuit given the apparent power and power factor?

True power (P) = Apparent power (S) × Power factor (pf).

Given an apparent power of 560 kVA and a power factor of 73%, how do you find the true power in the circuit?

True power = 560 kVA × 0.73 = 408.8 kW.

What does a power factor of 73% indicate about an R-L series circuit's efficiency?

A power factor of 73% indicates that 73% of the apparent power is being converted into useful work, with the remaining 27% being reactive power, reflecting inefficiencies due to inductance.

How is reactive power calculated in an R-L circuit with given apparent power and true power?

Reactive power (Q) can be found using $Q = \sqrt{S^2 - P^2}$, where S is apparent power and P is true power.

If the apparent power is 560 kVA and the power factor is 73%, what is the reactive power in the circuit?

Reactive power $Q = \sqrt{(S^2 - P^2)} = \sqrt{(560^2 - 408.8^2)} \approx \sqrt{(313600 - 167056)} \approx \sqrt{146544} \approx 382.8 \text{ kVAR}$.

Additional Resources

7. An R-l Series Circuit Has A Power Factor Of 73%. If The Apparent Power Is 560 Kva, What Is The True Power?

Understanding the intricacies of electrical circuits is fundamental to optimizing power systems in both industrial and residential settings. Among the numerous electrical parameters, power factor stands out as a critical factor influencing energy efficiency and operational costs. This article delves into the specifics of an R-l (resistive-inductive) series circuit with a given power factor and apparent power, aiming to determine the true (real) power involved. Such analysis not only enriches our comprehension of electrical behavior but also underscores its practical significance in power system management.

Introduction to Power Factor and Its Significance

What Is Power Factor?

Power factor (PF) is a dimensionless quantity ranging from 0 to 1, representing the efficiency with which electrical power is converted into useful work output. It is defined as the ratio of true power (P, in kilowatts) to apparent power (S, in kilovolt-amperes):

$$\text{Power Factor (pf)} = \frac{P}{S}$$

Expressed as a percentage, a power factor of 73% indicates that 73% of the apparent power is being effectively converted into real work, while the remaining 27% accounts for reactive power that does not perform any net work.

Why Is Power Factor Important?

The significance of power factor extends across multiple facets of electrical engineering and energy management:

- **Energy Efficiency:** A low power factor implies that more apparent power is needed to deliver the same amount of real power, increasing energy losses in transmission lines.
- **Cost Implications:** Many utility companies impose penalties for low power factors because they strain the power grid, necessitating larger capacity infrastructure.

- Equipment Performance: Motors and other inductive loads operate more efficiently and with less heat generation when the power factor is close to unity.
- System Stability: Maintaining a high power factor enhances voltage regulation and reduces the likelihood of system disturbances.

Analyzing the R-l Series Circuit

Components and Their Roles

An R-l series circuit comprises primarily two elements:

- Resistor (R): Converts electrical energy into heat, representing the resistive component that consumes real power.
- Inductor (L): Stores energy in magnetic fields, contributing to reactive power but not dissipating energy as heat.

These elements are connected in series, meaning the same current flows through both, influencing the circuit's overall impedance and power characteristics.

Impedance in R-l Circuits

The total opposition to current flow in an R-l circuit is its impedance (Z), calculated as:

$$Z = \sqrt{R^2 + (X_L)^2}$$

where $(X_L = 2\pi f L)$ is the inductive reactance, dependent on the frequency (f) and inductance (L) .

The phase difference between voltage and current arises due to the inductive reactance, causing the current to lag the voltage—a core reason for reactive power and a lower power factor.

Given Data and Objective

The problem provides:

- Power Factor (pf): 73% or 0.73
- Apparent Power (S): 560 kVA

Objective: Determine the true (real) power (P) consumed by the circuit.

This involves a straightforward application of the fundamental relationships between apparent power, real power, and reactive power.

Calculating the True Power

Step 1: Recall the Power Factor Definition

Using the formula:

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

we can rearrange to find the true power:

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

where:

- P is the true power in kilowatts (kW),
- $\text{pf} = 0.73$,
- $S = 560$, kVA .

Step 2: Perform the Calculation

Substituting the known values:

$$P = 0.73 \times 560 \text{ kVA} = 408.8 \text{ kW}$$

Thus, the true power consumed by the circuit is approximately 408.8 kW.

Step 3: Interpret the Result

This figure indicates the actual amount of power being converted into useful work or heat within the circuit. Given the apparent power and power factor, the circuit's reactive components (primarily due to the inductor) account for the difference between apparent and real power.

Understanding Reactive Power and Its Implications

Reactive Power (Q)

Reactive power represents the energy alternately stored and released by the inductors (and capacitors, if present) in the circuit, measured in kilovolt-amperes reactive (kVAR). It is calculated as:

$$Q = S \sin{\theta}$$

where θ is the phase angle between voltage and current.

Calculating the Reactive Power

First, determine $\sin{\theta}$:

$$\sin{\theta} = \sqrt{1 - \text{pf}^2} = \sqrt{1 - 0.73^2} = \sqrt{1 - 0.5329} = \sqrt{0.4671} \approx 0.6838$$

Now, compute Q :

$$Q = 560 \text{ kVA} \times 0.6838 \approx 383 \text{ kVAR}$$

This reactive power is significant, reflecting the inductive nature of the circuit.

Power Triangle Perspective

The relationship between real power P , reactive power Q , and apparent power S can be visualized through the power triangle:

- Horizontal axis: Real power P
- Vertical axis: Reactive power Q
- Hypotenuse: Apparent power S

The angle θ between P and S embodies the phase difference, with the cosine of this angle equal to the power factor.

Practical Significance and Applications

Energy Efficiency and Cost Savings

Knowing the true power consumption allows consumers and utility providers to optimize energy use. High reactive power can lead to increased losses and higher bills, especially if penalties are imposed for poor power factor.

Design and Maintenance of Power Systems

Electrical engineers can utilize this data to:

- Design appropriate power factor correction systems (e.g., capacitor banks).
- Select suitable equipment rated for the actual power levels.
- Improve system stability and reduce voltage drops.

Equipment Sizing and System Optimization

Accurate knowledge of real power helps in sizing transformers, generators, and other components, ensuring efficient operation and avoiding overcapacity or undercapacity issues.

Conclusion

The analysis of an R-L series circuit with a known power factor and apparent power reveals that the true power—or real power—is approximately 408.8 kilowatts. This figure underscores the importance of understanding power factor dynamics, especially in inductive circuits where reactive power plays a significant role. Maintaining an optimal power factor is crucial for energy efficiency, cost reduction, and system reliability. As electrical systems grow more complex, such fundamental insights become indispensable for engineers, technicians, and utility providers alike, ensuring the seamless and economical delivery of electrical energy.

Additional Considerations

While the calculation provides a clear answer, several real-world factors can influence the actual power consumption and power factor:

- Harmonics: Non-linear loads generate harmonics that can distort power factor calculations.
- Transient Conditions: Sudden load changes may temporarily affect reactive power and phase angles.
- Power Factor Correction Devices: Installing capacitors or synchronous condensers can improve

power factor, reducing reactive power and enhancing efficiency.

Understanding these nuances enables more sophisticated management of electrical systems, fostering sustainable and cost-effective energy use.

In summary, by leveraging the relationship between apparent power, real power, and power factor, it is possible to accurately determine the true power in an R-l series circuit. Such insights are vital for optimizing electrical system performance, reducing losses, and minimizing operational costs—cornerstones of modern electrical engineering practice.

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