

Q2. Determine The Output Voltage For The Network Of Figure 2 If $V = 2 \text{ MV}$ And $R_d = 50 \text{ Kn}$. (5 Marks) Marking

Q2. Determine The Output Voltage For The Network Of Figure 2 If $V = 2 \text{ MV}$ And $R_d = 50 \text{ Kn}$. (5 Marks) Marking in the first paragraph sets the stage for a comprehensive analysis of the problem involving electrical network analysis, specifically focusing on calculating the output voltage in a given circuit configuration. This problem is typical in electrical engineering assessments where understanding the relationship between input voltage, load resistance, and network parameters is essential for designing and analyzing circuits effectively. In this article, we will explore step-by-step methods to determine the output voltage, incorporating relevant formulas, circuit analysis techniques, and practical considerations to ensure clarity and accuracy.

Understanding the Circuit and Given Data

Before we delve into calculations, it is vital to comprehend the circuit configuration (referred to as Figure 2) and the provided data:

- Input Voltage, $V = 2 \text{ MV}$ (MegaVolts)
- Load Resistance, $R_d = 50 \text{ Kn}$ (KiloOhms)

This data indicates a high-voltage input scenario, common in power transmission or specialized high-voltage circuits, where the output voltage depends on the network's internal parameters and the load connected across the output terminals.

Analyzing the Circuit Configuration

Identifying Network Components

In typical analysis, Figure 2 likely depicts a network with various components such as resistors, voltage sources, and possibly other elements like capacitors or inductors. For the purpose of this analysis, assume the network comprises:

- A voltage source V (2 MV)
- A network of resistors configured in a specific pattern (series, parallel, or a combination)
- A load resistor R_d (50 Kn) connected at the output

Understanding how these components are interconnected is critical. Usually, the goal is to find the voltage across the load resistor, which is the output voltage (V_{out}).

Assumed Simplified Network Model

Since the problem references "Figure 2" but does not provide an explicit diagram, we assume a typical scenario where the network can be modeled as a Thevenin equivalent circuit:

- Thevenin equivalent voltage, V_{th}
- Thevenin equivalent resistance, R_{th}

The output voltage V_{out} , across R_d , can be calculated using the voltage divider rule:

$$V_{out} = V_{th} \left(R_d / (R_{th} + R_d) \right)$$

Therefore, the key is to determine V_{th} and R_{th} based on the network's internal parameters.

Calculating Thevenin Equivalent Voltage (V_{th})

Methodology for V_{th} Calculation

To find V_{th} , follow these steps:

1. Remove the load resistor R_d from the circuit.
2. Calculate the open-circuit voltage at the output terminals, considering the internal network and the source V .
3. Use circuit analysis techniques such as voltage division, node voltage method, or superposition, depending on the network complexity.

Given the high voltage of 2 MV, the circuit may involve high-voltage resistors or sources, which should be handled carefully to avoid breakdown or measurement errors.

Superposition Principle Application

If the network contains multiple sources or elements, superposition can be used:

- Consider the effect of the source V alone, with all other sources turned

off.

- Calculate the resulting open-circuit voltage at the output.
- Sum contributions if multiple sources are present.

Assuming only a single source V , the calculation simplifies to analyzing the voltage division based on the network's resistive elements.

Determining Thevenin Resistance (R_{th})

Steps to Calculate R_{th}

To find R_{th} :

1. Turn off all independent voltage sources (replace V with a short circuit).
2. Calculate the equivalent resistance seen from the output terminals, with the network's internal resistors in place.
3. Combine resistors in series and parallel as appropriate to simplify to a single resistance value.

This resistance R_{th} influences how the load resistor R_d interacts with the network, affecting the output voltage.

Calculating Output Voltage (V_{out})

Once V_{th} and R_{th} are known, V_{out} can be computed:

$$V_{out} = V_{th} \left(R_d / (R_{th} + R_d) \right)$$

Given the data:

- $V = 2 \text{ MV}$
- $R_d = 50 \text{ K}\Omega$

the calculation proceeds as follows:

Example Calculation

Suppose the Thevenin equivalent voltage V_{th} is approximately 2 MV (assuming ideal conditions) and R_{th} is calculated to be 100 K Ω . Then:

$$\begin{aligned}
V_{out} &= 2,000,000 \text{ V} \left(50,000 \, \Omega / (100,000 \, \Omega + 50,000 \, \Omega) \right) \\
&= 2,000,000 \text{ V} \left(50,000 / 150,000 \right) \\
&= 2,000,000 \text{ V} \left(1/3 \right) \\
&\approx 666,667 \text{ V}
\end{aligned}$$

This example illustrates that the output voltage is approximately 666.67 kV under these assumptions.

Practical Considerations and Limitations

High Voltage Handling

Working with 2 MV inputs requires specialized equipment and safety protocols. High-voltage resistors must withstand the voltage, and measurement devices should be rated accordingly.

Circuit Tolerances and Non-Idealities

Real-world components have tolerances and parasitic elements, which can affect the accuracy of the calculation. Simulation tools like SPICE can help model complex networks more precisely.

Impact of Load Resistance

The value of R_d significantly influences the output voltage. A higher R_d results in a voltage closer to V_{th} , while a lower R_d causes voltage drops across R_{th} , reducing V_{out} .

Conclusion

Determining the output voltage for a network with a high input voltage and load resistance involves understanding the circuit's Thevenin equivalent, calculating the open-circuit voltage (V_{th}), and the equivalent resistance (R_{th}). Applying the voltage divider rule provides an effective way to find the voltage across the load resistor R_d . In the context of the given data ($V = 2 \text{ MV}$ and $R_d = 50 \text{ k}\Omega$), the output voltage can be approximated once the network's internal parameters are known. This process underscores the importance of circuit analysis techniques, such as superposition and Thevenin's theorem, in solving complex electrical networks.

By mastering these principles, electrical engineers can accurately predict circuit behavior, optimize designs, and ensure safety in high-voltage applications. Whether in power transmission, high-voltage testing, or specialized electronic systems, understanding how to determine output voltage is essential for effective circuit analysis and design.

Frequently Asked Questions

What is the primary goal when determining the output voltage in the given network with $V = 2\text{ MV}$ and $R_d = 50\text{ k}\Omega$?

The main objective is to calculate the voltage across the load resistor R_d by analyzing the circuit to find the output voltage based on the given source voltage and resistor values.

Which circuit analysis method is most suitable for calculating the output voltage in this network?

The Thevenin equivalent method or voltage division technique are most suitable for simplifying the circuit and determining the output voltage accurately.

How does the value of R_d ($50\text{ k}\Omega$) influence the output voltage in the network?

The load resistor R_d affects the voltage division across the circuit; a higher R_d tends to increase the output voltage, approaching the open-circuit voltage, while a lower R_d results in a voltage drop and a lower output voltage.

What assumptions are typically made in calculating the output voltage in this scenario?

Assumptions often include ideal circuit components, no parasitic elements, linear behavior, and that the source voltage remains constant at 2 MV during analysis.

If the circuit involves reactive components, what additional factors must be considered in determining the output voltage?

If reactive components are present, impedance, phase differences, and frequency-dependent behaviors must be considered, typically requiring AC analysis and complex impedance calculations.

What is the significance of the 5-mark marking scheme in solving this problem?

The 5-mark scheme indicates that a detailed, step-by-step solution including circuit analysis, calculations, and clear explanations are expected to achieve full marks.

Additional Resources

Determine The Output Voltage For The Network Of Figure 2 If $V = 2 \text{ MV}$ And $R_d = 50 \text{ k}\Omega$

Introduction

In the realm of electrical engineering, understanding the behavior of complex networks is fundamental for designing reliable and efficient systems. The process of determining the output voltage across a network, especially under specified conditions, is a critical step in circuit analysis, influencing everything from power distribution to signal processing. This article delves into the detailed methodology for calculating the output voltage of a particular network, referred to as "Figure 2," given an input voltage $(V = 2 \text{ MV})$ and a load resistance $(R_d = 50 \text{ k}\Omega)$.

While the schematic of Figure 2 is not provided here, the analysis will be based on typical network configurations involving resistors, voltage sources, and load elements. The goal is to establish a comprehensive approach that can be generalized to similar networks, ensuring clarity and depth for engineers and researchers seeking to understand the intricate relationships within such circuits.

Fundamental Concepts in Circuit Analysis

Before diving into the specifics of the calculation, it is essential to revisit core principles that underpin circuit analysis:

- Ohm's Law: Relates voltage (V) , current (I) , and resistance (R) via $(V = IR)$.
- Voltage Division: In series resistor networks, the output voltage can be determined by proportional division of the input voltage.
- Thevenin's Theorem: Simplify complex networks to an equivalent single voltage source and resistor to facilitate analysis.
- Loading Effect: The impact of the load resistance (R_d) on the network's output voltage, which can cause voltage drops and influence the overall transfer function.

Assumed Network Configuration and Parameters

Given the lack of a visual schematic, we will consider a common and representative network configuration for such a problem:

- A voltage source $(V = 2 \text{ MV})$ (which equals $(2 \times 10^6 \text{ V})$)
- A series resistor (R_s) connected to the voltage source
- A network of resistors (possibly a voltage divider or more complex topology)
- A load resistor $(R_d = 50 \text{ k}\Omega)$ connected at the output node where the voltage is to be determined

This setup typifies many practical applications, such as high-voltage transmission or signal measurement circuits, where the load resistor's value

significantly affects the voltage at the output node.

Step-by-Step Approach to Determine the Output Voltage

1. Establish the Equivalent Circuit

The first step involves simplifying the network by combining series and parallel resistances, applying Thevenin's theorem if necessary.

- Identify the portion of the network that feeds the load (R_d) .
- Calculate the Thevenin equivalent voltage (V_{th}) and resistance (R_{th}) seen by the load.

2. Determine Thevenin Voltage (V_{th})

- If the network includes voltage dividers, use the voltage division rule:

$$V_{th} = V \times \frac{R_{series}}{R_{total}}$$

where (R_{series}) is the resistance in series with the node of interest, and (R_{total}) includes the resistances in the network.

- For more complex networks, analyze node voltages or mesh currents as appropriate.

3. Calculate Thevenin Resistance (R_{th})

- Turn off the independent voltage source (V) by replacing it with a short circuit.
- Replace all independent sources with their internal resistances (voltage sources replaced by short circuits).
- Calculate the equivalent resistance seen from the load node.

Incorporating the Load Resistance (R_d)

Once the Thevenin equivalent is established, the output voltage across (R_d) can be computed:

$$V_{out} = V_{th} \times \frac{R_d}{R_{th} + R_d}$$

This formula accounts for the voltage division between the Thevenin resistance and the load resistance, illustrating the loading effect.

Numerical Calculation Based on Assumed Values

Suppose, for illustration, the following parameters are derived from the network:

- $(V_{th} = 1.8 \text{ MV})$

- $(R_{th} = 10\text{ k}\Omega)$

Applying the formula:

```
\[
V_{out} = 1.8 \times 10^6 \times \frac{50 \times 10^3}{10 \times 10^3 + 50 \times 10^3} = 1.8 \times 10^6 \times \frac{50}{60} = 1.8 \times 10^6 \times 0.8333 \approx 1.5\text{ MV}
\]
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This hypothetical calculation demonstrates how the load resistor influences the final output voltage, reducing it from the open-circuit Thevenin voltage due to the voltage divider effect.

Factors Affecting the Output Voltage

Several factors can influence the accuracy and reliability of the calculated output voltage:

- Network Topology: Complexity of the resistor network can introduce non-linearities or additional voltage drops.
- Component Tolerances: Real-world resistors and sources have tolerances that can alter voltage levels.
- Parasitic Elements: Capacitances and inductances, especially in high-voltage systems, can affect the network's behavior.
- Temperature Effects: Resistance values can vary with temperature, impacting the voltage division.

Practical Considerations and Applications

Understanding how to determine the output voltage in such networks is vital in various applications:

- High-Voltage Transmission: Ensuring safe and efficient voltage levels at different points in the network.
- Sensor Signal Conditioning: Designing circuits where signals are derived from high-voltage sources.
- Measurement Systems: Calibration of voltmeters and other instrumentation that rely on accurate voltage division and loading effects.

Furthermore, engineers must consider safety protocols when dealing with high voltages like 2 MV, ensuring proper insulation, grounding, and protective equipment.

Conclusion

Determining the output voltage of a network such as the one depicted in Figure 2, with a known input voltage and load resistance, involves a systematic approach rooted in fundamental circuit analysis principles. By simplifying the network via Thevenin's theorem and applying voltage division, engineers can accurately predict the voltage across the load. This process not only aids in the design and analysis of high-voltage systems but also enhances understanding of how load effects influence circuit behavior.

While the specific numerical result depends on the precise network configuration, the methodology outlined provides a robust framework applicable to a wide range of circuit analysis scenarios. Mastery of these techniques is essential for electrical engineers working in power systems, instrumentation, and high-voltage engineering, ensuring safe, efficient, and reliable circuit operation.

References

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- Alexander, C. K., & Sadiku, M. N. O. (2012). Fundamentals of Electric Circuits. McGraw-Hill Education.
- Hayt, W. H., Kemmerly, J. E., & Durbin, S. M. (2012). Engineering Circuit Analysis. McGraw-Hill Education.

This comprehensive analysis underscores the importance of systematic circuit evaluation and reinforces foundational principles vital for electrical engineering practice.

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