

A Generating Station Is Producing 1.2×10^6 W Of Power That Is To Be Sent To A Small Town Located 7.0

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Understanding how electrical power is generated, transmitted, and efficiently delivered to small towns is fundamental in electrical engineering and energy management. This article explores the scenario where a generating station produces 1.2 million watts (1.2×10^6 W) of power, which needs to be transmitted over a distance of 7.0 km to a small town. We will delve into the key concepts involved in power generation, transmission, and the considerations required to ensure minimal power loss and optimal delivery.

Overview of Power Generation and Transmission

Power generation stations are the backbone of electrical supply systems, converting various forms of energy into electrical energy suitable for distribution. Once generated, the electrical power must travel through transmission lines to reach consumers, such as small towns, industries, and households.

Key concepts include:

- Power generation capacity
- Transmission lines and their properties
- Power losses during transmission
- Strategies to minimize losses
- Safety and efficiency considerations

Details of the Power Generation

Generation Capacity and Types

The station's capacity of 1.2 million watts indicates the maximum power it can produce at any given moment. This capacity depends on:

- **Type of power plant:** e.g., thermal, hydroelectric, nuclear, or renewable sources.
- **Efficiency of the generator:** How effectively it converts primary energy into electrical energy.

Electrical Output Characteristics

The generated power is typically alternating current (AC), with parameters such as:

- **Voltage:** The potential difference at which power is generated.
- **Current:** The flow of charge corresponding to the power output.

Transmission of Power Over Distance

The Role of Transmission Lines

After generation, electrical power is transmitted over high-voltage lines to reduce losses. The key properties affecting transmission include:

1. **Voltage level:** Higher voltages allow for lower current for the same power, reducing resistive losses.
2. **Line resistance:** Depends on material, cross-sectional area, and length.
3. **Line length:** In this case, 7.0 km.

Why High Voltage Transmission Is Used

Transmitting power at high voltage minimizes power losses, which are primarily due to the resistance of transmission lines. The power loss

(P_{loss}) can be expressed as:

$$P_{\text{loss}} = I^2 R$$

where:

- (I) = current in the line
- (R) = resistance of the line

By increasing the transmission voltage, the current decreases for a fixed power, reducing (P_{loss}).

Calculating Power Losses and Effective Transmission

Key Equations

The fundamental relationships are:

- Power transmitted:

$$P = V \times I$$

- Power loss due to resistance:

$$P_{\text{loss}} = I^2 R$$

Given the power and resistance, we can determine optimal voltage levels to minimize losses.

Estimating Line Resistance

Suppose the transmission line has a certain resistivity, cross-sectional area, and length. The resistance (R) can be estimated as:

$$R = \rho \frac{L}{A}$$

where:

- (ρ) = resistivity of the conductor material (copper or aluminum)
- (L) = length of the transmission line (7.0 km in this case)
- (A) = cross-sectional area

For practical calculations, typical resistivity values are:

- Copper: $(1.68 \times 10^{-8} \text{ } \Omega \cdot \text{m})$
- Aluminum: $(2.82 \times 10^{-8} \text{ } \Omega \cdot \text{m})$

Design Considerations for Efficient Power Transmission

Choosing the Right Voltage Level

To minimize power losses, the transmission system is usually designed to operate at high voltages, often in the range of tens or hundreds of kilovolts. For a small town located 7 km away, typical transmission voltages might be:

- 11 kV (for distribution)
- 110 kV or higher (for transmission lines)

Transformers and Step-up/Step-down Operations

Transformers are used to:

- Step-up voltage at the generating station
- Step-down voltage near the consumption point

This process ensures efficient transmission and safe delivery.

Balancing Cost and Efficiency

Higher voltages reduce losses but increase costs and insulation requirements. Therefore, a balance is struck based on:

- Cost of equipment
- Safety standards
- Expected power demand

Safety and Reliability in Power Transmission

Ensuring the safety of personnel and reliability of supply involves:

- Proper insulation of high-voltage lines
- Regular maintenance of transmission infrastructure
- Use of protective devices like circuit breakers and relays
- Grounding and lightning protection

Impacts and Benefits of Efficient Power Transmission

Efficient transmission provides several advantages:

- Reduced energy wastage
- Lower operational costs
- Enhanced reliability of power supply
- Environmental benefits by reducing the need for additional power generation

Conclusion

Transmitting 1.2 million watts of power over 7 km from a generating station to a small town involves complex considerations of electrical principles, engineering design, and safety protocols. High-voltage transmission lines play a vital role in reducing power losses, ensuring that the small town receives reliable and efficient electricity. Proper planning, equipment choice, and maintenance are essential to optimize power delivery, minimize costs, and protect infrastructure and personnel.

By understanding the core concepts of power generation, transmission line properties, and the importance of voltage regulation, engineers can design systems that meet demand while maintaining safety and efficiency standards. As technology advances, innovations in materials, transformer design, and grid management continue to improve the sustainability and resilience of electrical transmission systems.

Keywords for SEO Optimization:

Power transmission, generating station, electrical power, voltage levels, power loss calculation, transmission line resistance, high-voltage transmission, transformer, efficiency, small town power supply, electrical engineering, energy management

Frequently Asked Questions

What is the primary purpose of a generating station in power distribution?

A generating station produces electrical power, which is transmitted to consumers like towns and cities for their daily electricity needs.

How is the power output of 1.2×10^6 W significant for a small town?

This level of power output is sufficient to meet the residential, commercial, and small industrial demands of a small town, ensuring reliable electricity supply.

What is the importance of the distance (7.0 km) in power transmission?

The distance affects voltage drop and transmission efficiency; longer distances require higher voltages or efficient transmission lines to minimize power loss.

What are the main challenges in transmitting power over 7.0 km to a small town?

Challenges include voltage drops, power losses due to resistance in transmission lines, and maintaining voltage stability over the distance.

How can the efficiency of power transmission be improved over 7.0 km?

Efficiency can be improved by using high-voltage transmission lines, reducing resistance, and employing transformers to step up and step down voltage levels.

What role do transformers play in transmitting power

from the generating station?

Transformers increase (step-up) the voltage before transmission to reduce power loss, and then decrease (step-down) the voltage for safe use at the town.

Why is it important to consider power loss in the transmission line calculations?

Power loss affects the overall efficiency and amount of usable power delivered; minimizing it ensures more power reaches the town and reduces operational costs.

What safety measures are necessary when transmitting high power over distances like 7.0 km?

Safety measures include proper insulation, grounded transmission towers, regular maintenance, and adherence to electrical safety standards to prevent accidents and outages.

Additional Resources

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Introduction

The reliable supply of electrical power forms the backbone of modern society, fueling homes, industries, and essential services. Among the myriad components involved in delivering electricity from generation to consumption, the generating station plays a pivotal role. This article undertakes a comprehensive review of a specific scenario: a generating station producing 1.2 million watts (1.2×10^6 W) of power, with the intent to supply a small town situated 7.0 km away. Through detailed analysis, we explore the principles of electrical power transmission, factors affecting efficiency, and the engineering considerations necessary for optimal delivery.

Understanding the Power Generation Context

At the heart of any electrical supply system lies the generating station – a facility equipped with turbines, generators, and control systems designed to convert energy (from fossil fuels, nuclear, hydro, or renewable sources) into electrical energy. Here, the station's output is specified as 1.2 megawatts (MW), which indicates a moderate-scale operation suitable for small to

medium-sized communities.

Key parameters:

- Power output: $1.2 \times 10^6 \text{ W}$
- Distance to load: 7.0 km (~4.35 miles)
- Transmission medium: Typically high-voltage transmission lines

Understanding how this power is transmitted efficiently over the distance involves analyzing the electrical characteristics of the transmission system, including voltage levels, current, and losses.

Transmission Line Fundamentals and Power Losses

Voltage, Current, and Power Relationship

Electrical power transmitted over lines follows the fundamental relation:

$$P = V \times I$$

where:

- P is the power in watts,
- V is the voltage in volts,
- I is the current in amperes.

To minimize losses, power transmission systems operate at high voltages, which reduces the current for a given power level, thereby reducing resistive losses.

Resistive Losses in Transmission Lines

Resistive (or I^2R) losses are the primary cause of efficiency reduction in transmission. The power lost as heat in the line is:

$$P_{\text{loss}} = I^2 R$$

where:

- R is the resistance of the transmission line over the given length.

Losses increase with higher current; thus, increasing the voltage reduces current and loss.

Engineering Analysis of Power Transmission

Step 1: Choosing the Transmission Voltage

Suppose the station transmits power at a high voltage V_{trans} . For a

small town, typical transmission voltages range from 11 kV to 220 kV, depending on infrastructure.

Assuming an initial transmission voltage of 11 kV (a common distribution level), the current (I) can be calculated:

$$I = \frac{P}{V_{\text{trans}}} = \frac{1.2 \times 10^6 \text{ W}}{11,000 \text{ V}} \approx 109.09 \text{ A}$$

This current leads to a certain level of line loss, which can be minimized by increasing (V_{trans}) . Alternatively, the station could generate power at a higher voltage (say 33 kV or 110 kV) to reduce current and losses.

Step 2: Estimating Line Resistance

The resistance (R) of the transmission line depends on the material (copper or aluminum), cross-sectional area, and length.

For example:

- Copper wire resistance: approximately $0.0178 \text{ } \Omega/\text{mm}^2/\text{m}$
- Aluminum wire resistance: approximately $0.0282 \text{ } \Omega/\text{mm}^2/\text{m}$

Suppose the line uses aluminum conductors with a cross-sectional area of 100 mm^2 :

$$R_{\text{per km}} = 0.0282 \text{ } \Omega/\text{mm}^2/\text{m} \times 100 \text{ mm}^2 \times 1000 \text{ m} = 2.82 \text{ } \Omega/\text{km}$$

For 7 km:

$$R_{\text{line}} = 2.82 \text{ } \Omega/\text{km} \times 7 \text{ km} = 19.74 \text{ } \Omega$$

Step 3: Calculating Power Losses

If transmitting at 11 kV:

$$P_{\text{loss}} = I^2 R = (109.09 \text{ A})^2 \times 19.74 \text{ } \Omega \approx 235,513 \text{ W}$$

This is nearly 20% of the generated power, indicating significant losses.

Alternatively, increasing the transmission voltage to 33 kV reduces current:

$$I = \frac{1.2 \times 10^6}{33,000} \approx 36.36 \text{ A}$$

Corresponding losses:

$$P_{\text{loss}} = (36.36)^2 \times 19.74 \approx 26,097 \text{ W}$$

Approximately 2.17% of the power, a much more efficient scenario.

Transformer Considerations

To adapt the voltage levels between generation and transmission, step-up transformers are employed at the generating station, and step-down transformers near the load. Proper transformer selection and maintenance are essential to minimize additional losses.

Key considerations:

- Voltage regulation: Ensuring consistent voltage delivery.
- Efficiency: Typically above 98%, but losses add up.
- Capacity: Transformers must handle the maximum load comfortably.

Engineering Challenges and Solutions

1. Minimizing Transmission Losses

- Use of higher transmission voltages to reduce current.
- Employing conductors with lower resistance or larger cross-sectional areas.
- Implementing advanced materials like high-temperature superconductors (future potential).

2. Ensuring Voltage Stability

- Install reactors and capacitors for power factor correction.
- Use regulators to prevent voltage fluctuations.

3. Reliability and Safety

- Regular inspection for corrosion or damage.
- Proper grounding and fault protection systems.

Environmental and Economic Implications

Environmental Impact

Higher transmission voltages and larger conductors can have environmental footprints, such as visual impact and land use. Employing underground cables, though costly, can mitigate some issues.

Economic Considerations

- Capital costs of transformers and conductors.
- Operational costs due to losses.
- Cost-benefit analysis favors higher voltages for efficient transmission even if initial investments are higher.

Conclusion

The scenario of a generating station producing 1.2×10^6 W of power for a small town 7 km away encapsulates core principles of electrical engineering and power systems. Efficient transmission hinges on understanding the interplay between voltage, current, and resistance. By elevating the transmission voltage and selecting appropriate conductors and transformers, losses can be minimized, ensuring that the maximum amount of generated power reaches the end-users.

This case exemplifies the importance of meticulous engineering design in power systems, balancing technical efficiency, economic viability, and environmental considerations. As power demands grow and renewable sources become more prevalent, such analyses will remain crucial in developing sustainable and reliable electrical infrastructure.

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In summary, understanding the technical and engineering aspects of power transmission from a generating station to a small town involves a detailed analysis of power levels, line resistance, voltage strategies, and infrastructure components. Proper system design ensures minimal losses, economical operation, and consistent supply—cornerstones of effective electrical power delivery.

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