Problem 22C

RMS CURRENTS AND POTENTIAL DIFFERENCES

PROBLEM

In 1945, turbo-electric trains in the United States were capable of speeds exceeding 160 km/h. Steam turbines powered the electric generators, which in turn powered the driving wheels. Each generator produced enough power to supply an rms potential difference of 6.0×10^3 V across an 18 Ω resistor. What was the maximum potential difference across the resistor? What was the maximum current in the resistor? What was the rms current in the resistor? What was the generator's power output?

SOLUTION

1. DEFINE

Given: $\Delta V_{rms} = 6.0 \times 10^3$ V $\quad R = 18\ \Omega$

Unknown: $\Delta V_{max} = ?$ $\quad I_{max} = ?$ $\quad I_{rms} = ?$ $\quad P = ?$

2. PLAN

Choose the equation(s) or situation: Use the equation relating maximum and rms potential differences to calculate the maximum potential difference. Use the definition of resistance to calculate the maximum current, then use the equation relating maximum and rms currents to calculate rms current. Power can be calculated from the product of rms current and rms potential difference.

$$\Delta V_{max} = \sqrt{2}(\Delta V_{rms})$$

$$I_{max} = \frac{\Delta V_{max}}{R}$$

$$I_{rms} = \frac{I_{max}}{\sqrt{2}}$$

$$P = \Delta V_{rms} I_{rms}$$

3. CALCULATE

Substitute values into the equation(s) and solve:

$$\Delta V_{max} = (1.41)(6.0 \times 10^3\ \text{V}) = \boxed{8.5 \times 10^3\ \text{V}}$$

$$I_{max} = \frac{(8.5 \times 10^3\ \text{V})}{(18\ \Omega)} = \boxed{4.7 \times 10^2\ \text{A}}$$

$$I_{rms} = (0.707)(4.7 \times 10^2\ \text{A}) = \boxed{3.3 \times 10^2\ \text{A}}$$

$$P = (6.0 \times 10^3\ \text{V})(3.3 \times 10^2\ \text{A}) = \boxed{2.0 \times 10^6\ \text{W}}$$

4. EVALUATE

To determine whether severe rounding errors occurred through the various calculations, obtain the product of the maximum current and maximum potential difference. The product of ΔV_{max} and I_{max} should equal $2P$, which for this problem equals 4.0×10^6 W.

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ADDITIONAL PRACTICE

1. In 1963, the longest single-span "rope way" for cable cars opened in California. The rope way stretched about 4 km from the Coachella Valley to Mount San Jacinto. Suppose the rope way, which is actually a steel cable, becomes icy. To de-ice the cable, you can connect its two ends to a 120 V (rms) generator. If the resistance of the cable is $6.0 \times 10^{-2}\ \Omega$,

a. what will the rms current in the cable be?
b. what will the maximum current in the cable be?
c. what power will be dissipated by the cable, thus melting the ice?

2. In 1970, a powerful sound system was set up on the Ontario Motor Speedway in California to make announcements to more than 200 000 people over the noise of 50 racing cars. The *acoustic* power of that system was 30.8 kW. If the system was driven by a generator that provided an rms potential difference of 120.0 V and only 10.0 percent of the supplied power was transformed into acoustic power, what was the maximum current in the sound system?

3. Modern power plants typically have outputs of over 10×10^6 kW. But in 1905, the Ontario Power Station, built on the Niagara River, produced only 1.325×10^5 kW. Consider a single generator producing this power when it is connected to a single load (resistor). If the generated rms potential difference is 5.4×10^4 V, what is the maximum current and the value of the resistor?

4. Stability of potential difference is a major concern for all high-emf sources. In 1996, James Cross of the University of Waterloo in Canada, constructed a compact power supply that produces a *stable* potential difference of 1.024×10^6 V. It can provide 2.9×10^{-2} A at this potential difference. If these values are the rms quantities for an alternating current source, what are the maximum potential difference and current?

5. Certain species of catfish found in Africa have "power plants" similar to those of electric eels. Though the electricity generated is not as powerful as that of some eels, the electric catfish can discharge 0.80 A with a potential difference of 320 V. Consider an ac generator in a circuit with a load. If its maximum values for potential difference and current are the same as the potential difference and current for the catfish, what are the rms values for the potential difference and current? What is the resistance of the load?

6. A wind generator installed on the island of Oahu, Hawaii, has a rotor that is about 100 m in diameter. When the wind is strong enough, the generator can produce a maximum current of 75 A in a 480 Ω load. Find the rms potential difference across the load.

7. The world's first commercial tidal power plant, built in France, has a power output of only 6.2×10^4 kW, produced by 24 generators. Find the power produced by each generator. If one of these generators is connected to a 120 kΩ resistor, find the rms and maximum currents in it.

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