34.20 **(8) $15,000 cfm$ computer room air conditioning units are provided to cool a data center in a "N+2" redundant configuration such that (6) units are normally running and (2) units are normally in standby. Each unit has a $7.5 bhp$ fan with variable speed control which delivers its full design volume at $60 Hz$. The data center operates 24/7 and the average cost of electricity is $\$0.16/kWh$. What is the annual savings associated with running all units at a reduced speed providing the same total volume of air? Assume all fan motors have an efficiency of 90%.**

A. $10,600

B. $13,100

C. $18,500

D. $22,900

In the initial configuration, Scenario 1, (6) units are running at 100% speed to produce their maximum airflow and (2) units are on standby i.e. not running. Calculate the total voume flow rate of air required to satisfy the room.

$$Q_{total} = 6Q_1$$

$$Q_{total} = (15,000 cfm) = 90,000 cfm$$

In Scenario 2 when all units are run, the volume required from each unit is reduced. Calulate the required cfm per unit.

$$Q_2 = \frac{Q_{total}}{8} = \frac{90,000 cfm}{8} = 11,250 cfm$$

Use the Fan Laws (1b) to determine the power per unit for Scenario 2. (For clarity, this solution uses bhp rather than W, as the motor efficiency will be used later to find the electrical power input, $\dot{W}_{in}$. There is no change in diameter or density. Fan speed, rpm, is linearly proportional to volume flow rate, Q.

$$\frac{bhp_2}{bhp_1} = \left(\frac{N_2}{N_1}\right)^3 = \left(\frac{Q_2}{Q_1}\right)^3$$

$$bhp_2 = bhp_1 \left(\frac{Q_2}{Q_1}\right)^3 = (7.5hp)\left(\frac{11,250 cfm}{15,000 cfm}\right)^3 = 3.16 bhp\,(per\ unit)$$

Find the total bhp for both scenarios. Note Scenario 1 uses only (6) units and Scenario 2 uses all (8) units.

$$bhp_{2,total} = (8)(3.16 bhp) = 25.31 hp$$

$$bhp_{1,total} = (6)\,(7.5bhp) = 45hp$$

Calculate the total reduction in bhp.

$$bhp_{1,total} - bhp_{2,total} = 45hp - 25.31hp = 19.69hp$$

Apply the motor efficiency to determine the input electrical power and convert units to KW.

$$\dot{W}_{in} = \frac{bhp}{\eta_{motor}} = \left(\frac{19.69hp}{0.9}\right)\left(\frac{0.7457KW}{hp}\right) = 16.31KW$$

Determine the annual savings for this reduction in demand.

$$Savings = (16.31KW)\left(\frac{24hr}{day}\right)(365days)\left(\frac{\$0.16}{kWh}\right) = \$22,863$$

Answer D