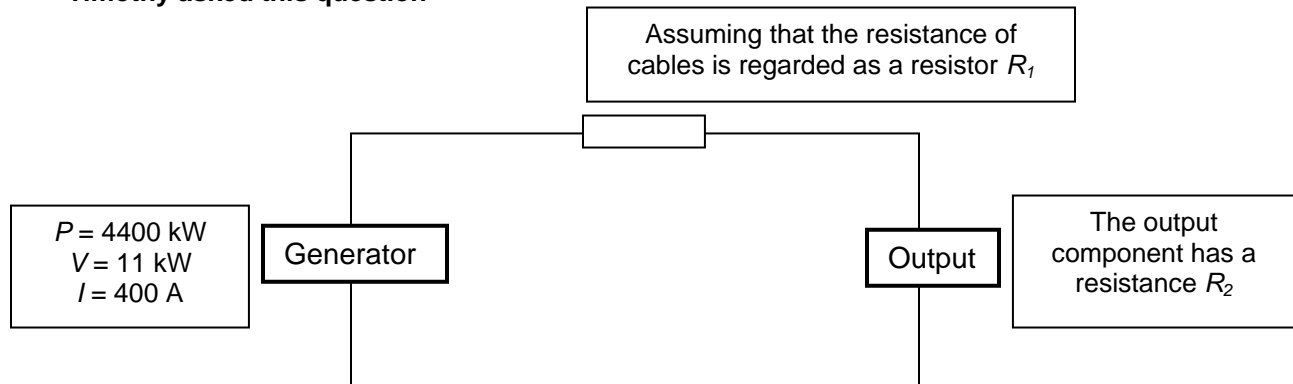


Why do electric cables with higher voltage have less power lost?

Prepared by fRancis Chong

I will be using TYS p263 Q43 Fig. 11 as an example to explain my point.

Timothy asked this question



His reasoning

$$V = IR_1 + IR_2$$

Also,

$$V = V_1 + V_2$$

I mentioned that you can't find the power lost in the R_1 because we do not know V_1 .

But if V_1 is known, we can express power lost = $\frac{V_1^2}{R_1}$ and V_1 can be expressed as $V_1 = \frac{R_1}{R_1 + R_2} V$.

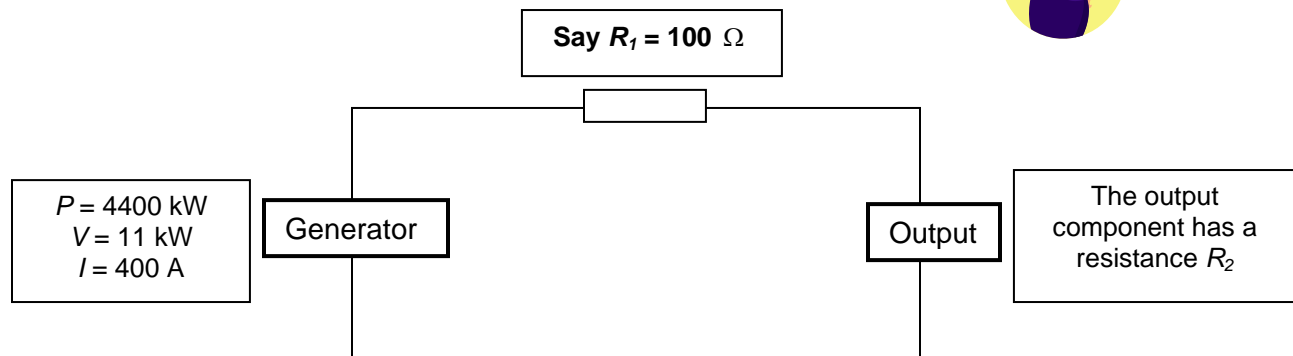
$$\therefore P_{lost} = \frac{\left(\frac{R_1}{R_1 + R_2} V\right)^2}{R_1}$$

This means that if you increase V , P_{lost} will increase!

My Reply

Scenario 1

The best way to find out what's wrong with his reasoning is to use real figures.



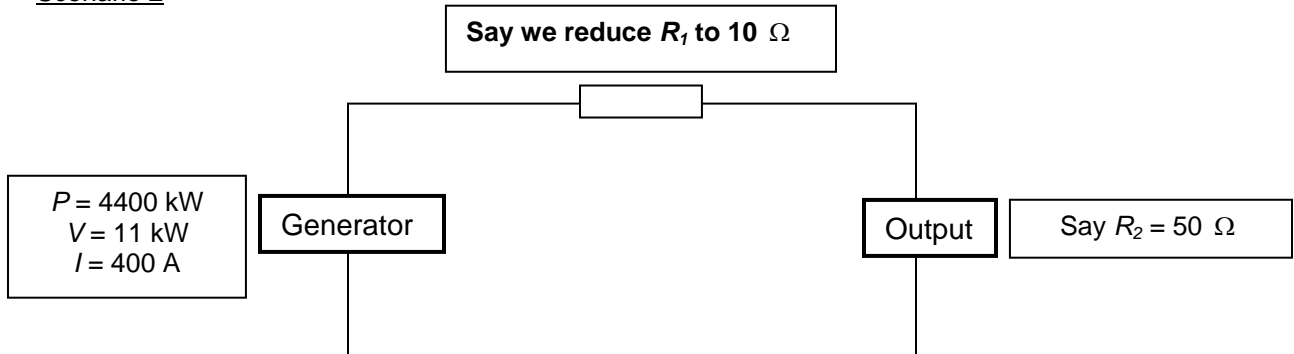
$$\text{Power lost in resistor (cable) } R_1 = I^2 R_1 = (400)^2 100 = 16000 \text{ kW} > 4400 \text{ kW} !!!$$

This means that all the power will be lost in the cables in the form of heat before it even reaches the output!

Conclusion 1

Cables must have as little resistance as possible (by having large cross-sectional area A) and the current flowing through it must not be too large.

Scenario 2



$$P_{lost} = I^2 R_1 = 1600 \text{ kW}$$

$$P_{delivered} = I^2 R_2 = 8000 \text{ kW}$$

$$\text{Total power in } R_1 \text{ and } R_2 = 1600 + 8000 = 9600 \text{ kW} > 4400 \text{ kW!!!}$$

Conclusion 2

For a particular power to be delivered, R_2 has to be specifically calculated such that $P = I^2 R_1 + I^2 R_2$ and R_2 has to be 17.5Ω in this case.

Using Potential divider, V_1 and V_2 and hence their power can be found

$$V_1 = 4 \text{ kV} ; P_1 = \frac{(4 \times 10^3)^2}{10} = 1600 \text{ kW}$$

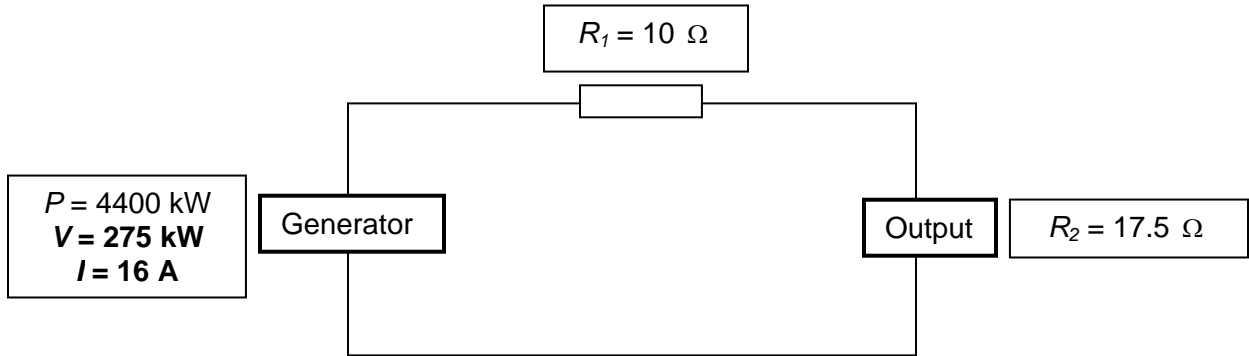
$$V_2 = 7 \text{ kV} ; P_2 = \frac{(7 \times 10^3)^2}{17.5} = 2800 \text{ kW}$$

$$V_1 + V_2 = 11 \text{ kV} = V ; P_1 + P_2 = 4400 \text{ kW} = P$$

You can clearly see that you can either use $I^2 R_1$ or $\frac{V_1^2}{R_1}$ to find power lost in cable and you can get the same answer and you will always satisfy $P = P_{lost} + P_{delivered}$ (Conservation of Energy) for the particular set of calculated resistance of resistors.

Scenario 3

Now we increase the voltage to 275 kV and we use the same R_1 and R_2 that we calculated earlier.



Using I^2R to find power

$$P_1 = (16)^2 10 = 2560 \text{ kW}$$

$$P_2 = (16)^2 17.5 = 4480 \text{ kW}$$

$$P_1 + P_2 = 7040 \text{ kW} \neq P!!!$$

Using V^2/R to find power

$$V_1 = 100 \text{ kV} ; P_1 = \frac{(100 \times 10^3)^2}{10} = 1000000 \text{ kW}$$

$$V_2 = 175 \text{ kV} ; P_2 = \frac{(175 \times 10^3)^2}{17.5} = 1750000 \text{ kW}$$

$$V_1 + V_2 = 11 \text{ kV} = V$$

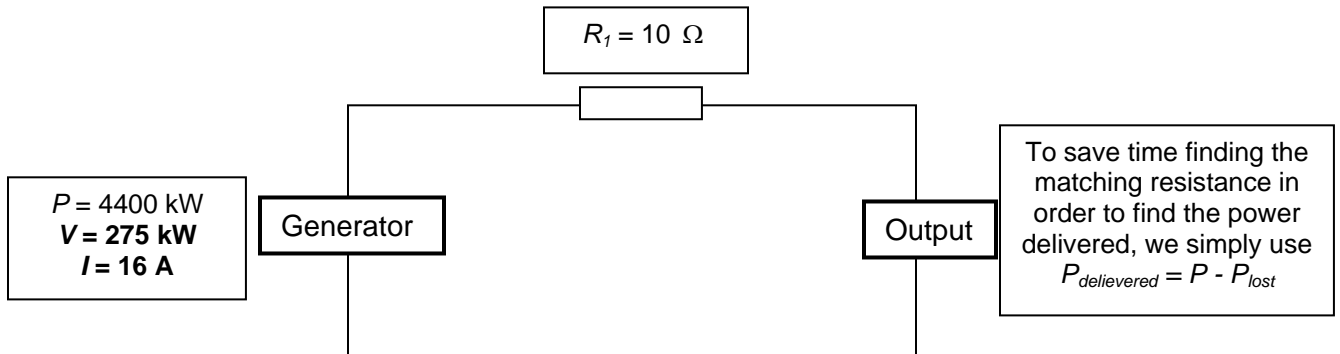
$$P_1 + P_2 = 2750000 \text{ kW} \gg 4400 \text{ kW}!!!$$

Conclusion 3

Both ways of finding power as shown above do not give you the input power!

This clearly shows that when we increase the input voltage, we have to change the combination of resistors in the circuit. It cannot remain the same.

Since the length of cables are fixed and hence their resistance is fixed, we can only change the resistance of the output component. To find the matching resistance, it must satisfy $P = I^2 R_1 + I^2 R_2$ as mentioned earlier. To simplify matters, you always see such circuit in TYS questions.



Therefore, Tim's reasoning $\left[P_{lost} = \frac{\left(\frac{R_1}{R_1 + R_2} V \right)^2}{R_1} \right]$ will only be correct if he finds the matching resistance.

And in the event, he will find that when V is increased, P_{lost} will certainly drop due to the corresponding change in R_2 .