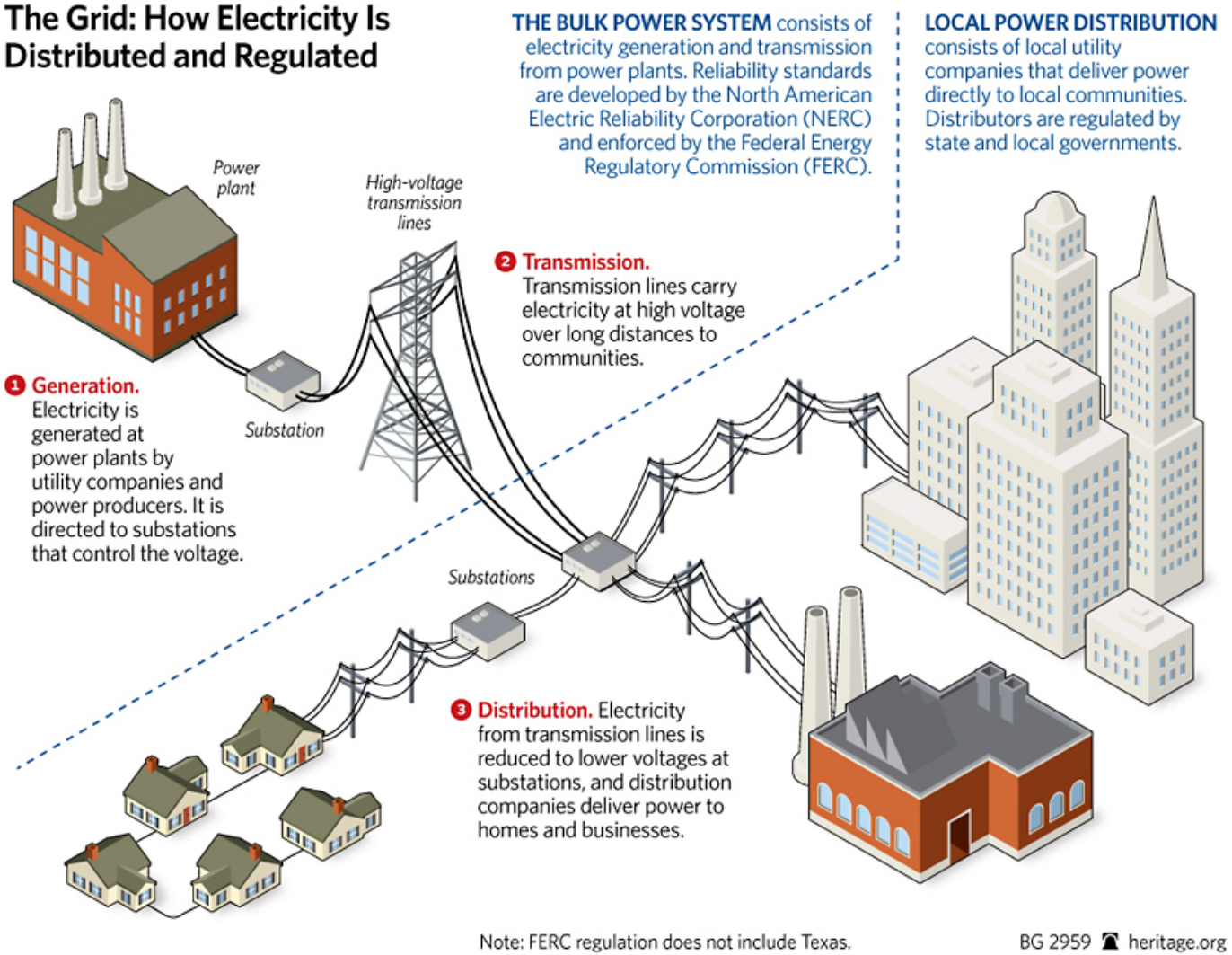
ECE 215 Spring 2025

Objective 1.6: Transformers and Power Transmission

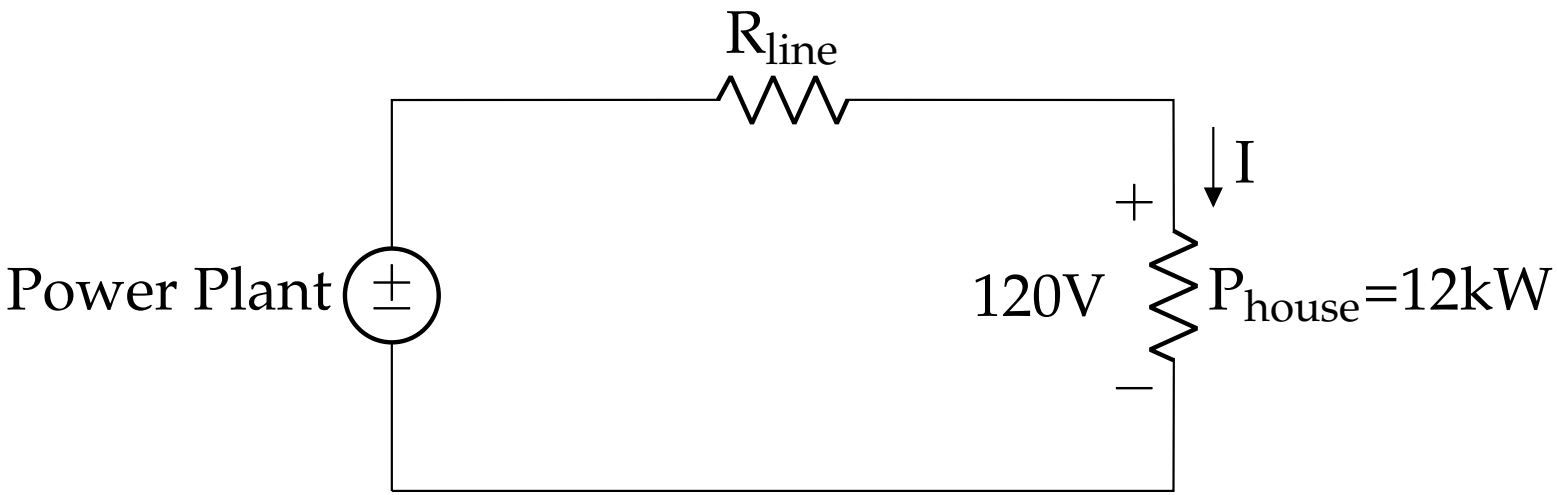
Objective 1.6

I can use a transformer's turns ratio, input voltages and currents, and output voltages and currents to calculate the efficiency, source voltage, and current of a power transmission system with one or more transformers.

The Power Grid

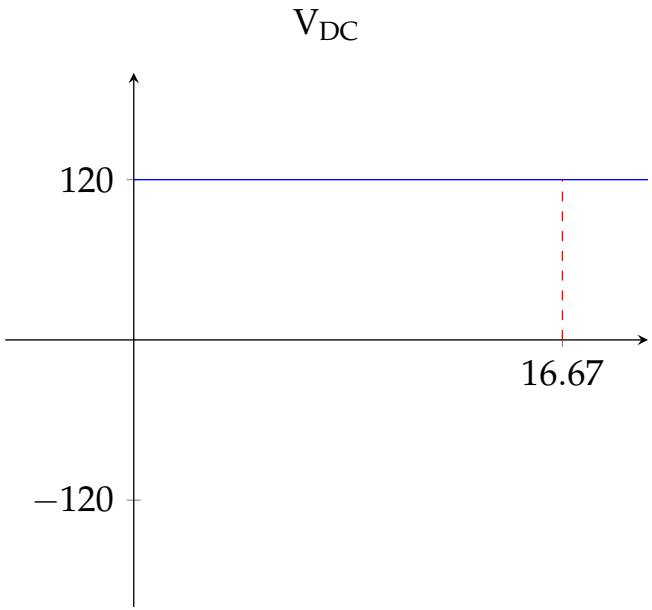


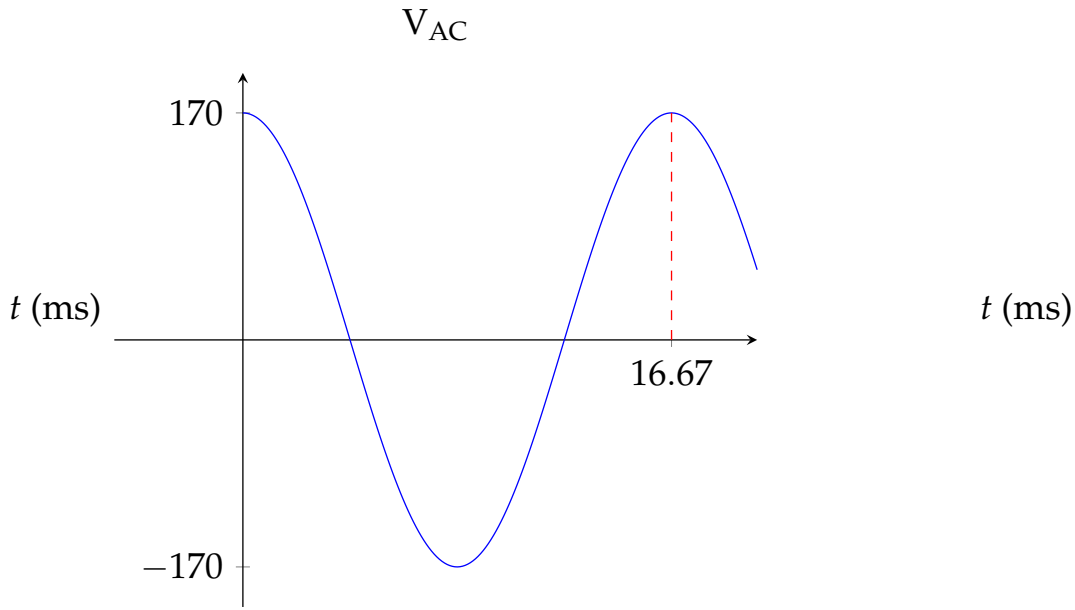
DC Power Transmission



- Assume R=250mΩ /km, what is the efficiency for 20km distance?
- $I = \frac{P_{house}}{V_{house}} =$
- $P_{line} = I^2 R_{line} =$
- $\eta = \frac{P_{useful}}{P_{total}} = \frac{P_{house}}{P_{total}} =$

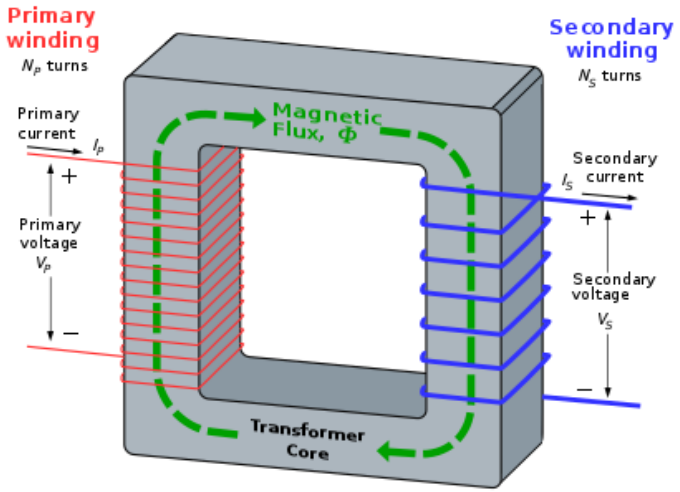
Maxwell's Equations



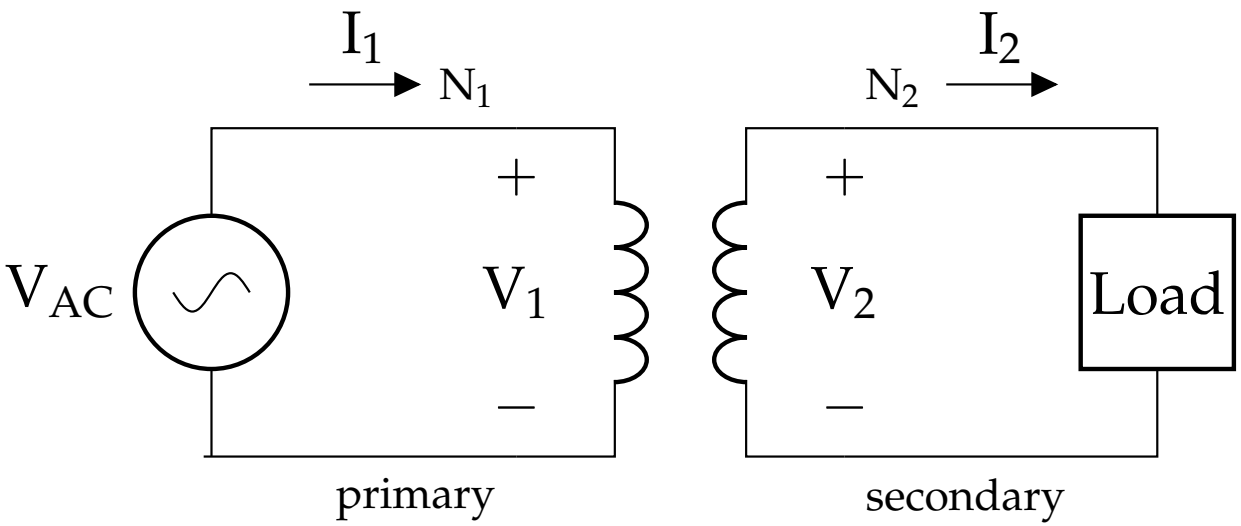


- Ampere says an electric current through a wire produces a circulating magnetic field ($\nabla \times \vec{H} \sim \vec{E}$)
- Farady says a changing magnetic field in a coil produces electric current ($\nabla \times \vec{E} \sim \frac{\partial \vec{H}}{\partial t}$)

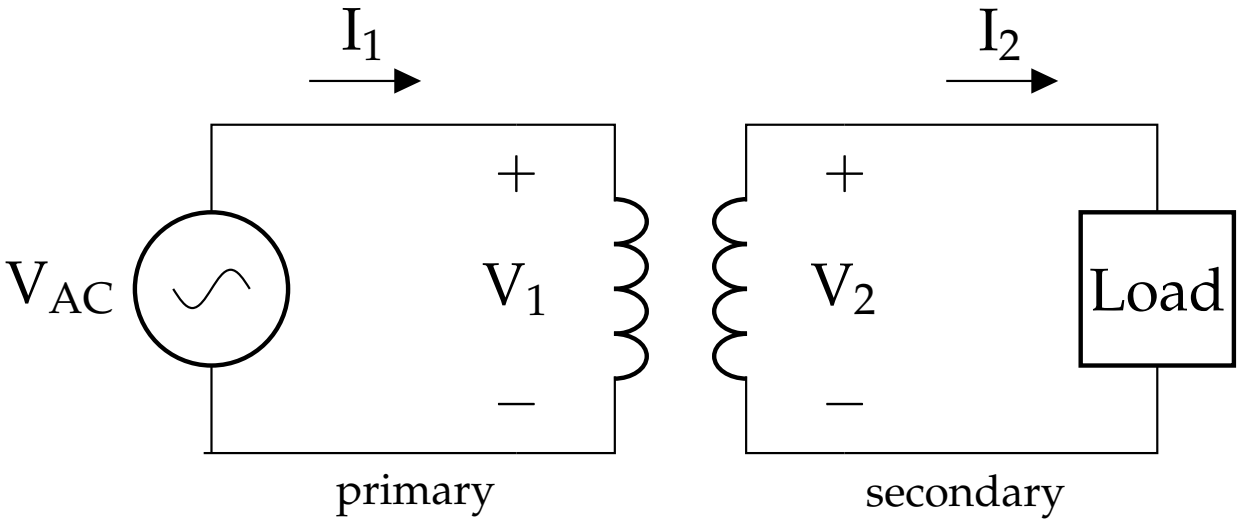
Maxwell Applied



- Changing magnetic flux (ϕ) produces voltage
- $V_{1,2} = N_{1,2}\frac{\partial \phi}{\partial t}$
- Flux on each side is equal

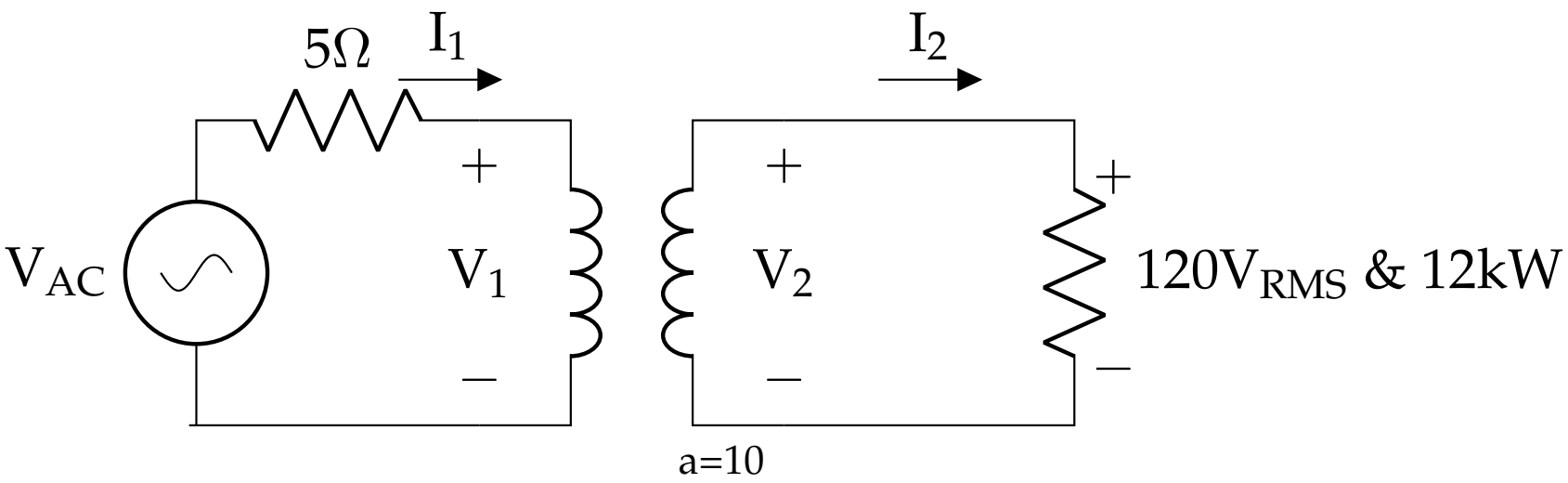


What does a transformer do for us?



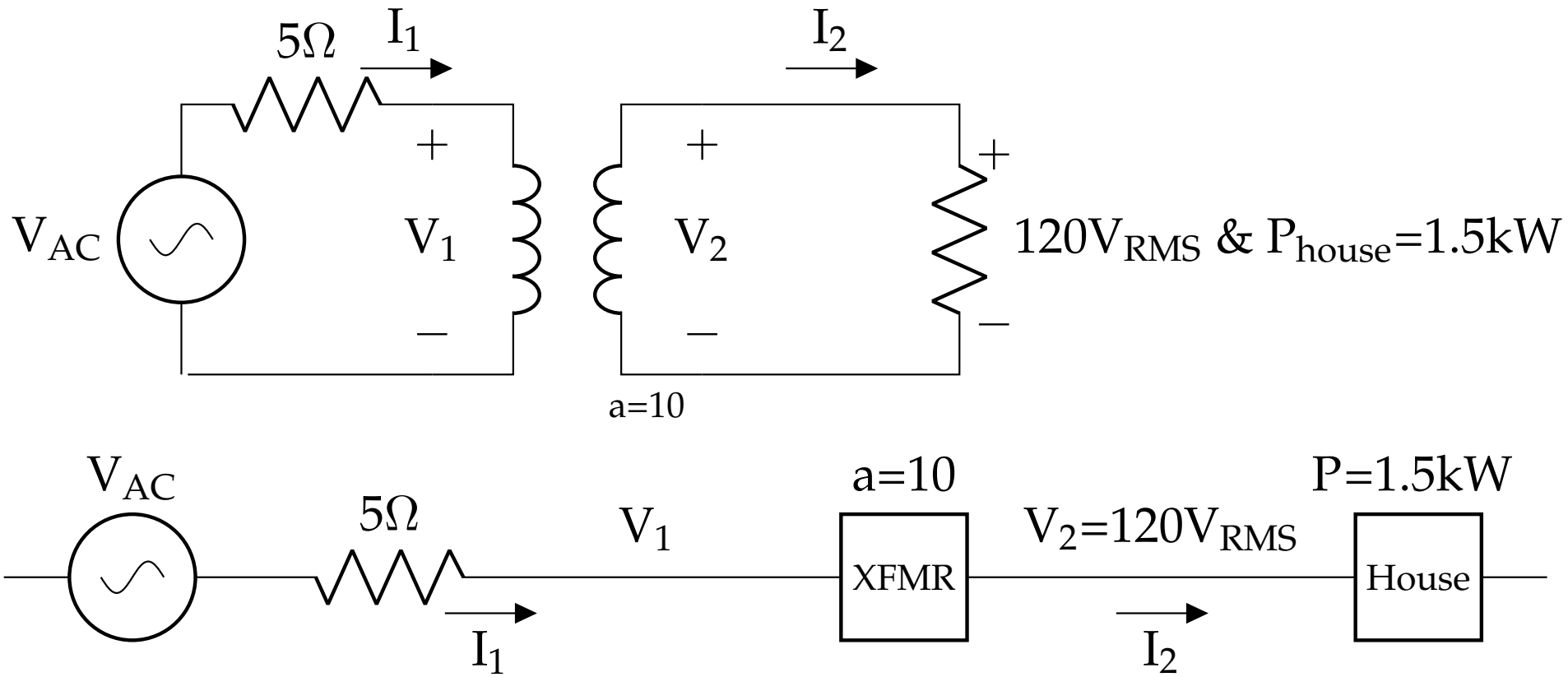
- Power on each side must be conserved
- $P_1 = P_2 \implies V_1 I_1 = V_2 I_2$
- Define the turns relationship as $a = \dfrac{N_1}{N_2} = \dfrac{V_1}{V_2}$
- $(aV_2)I_1 = V_2 I_2$
- $a = \dfrac{N_1}{N_2} = \dfrac{V_1}{V_2} = \dfrac{I_2}{I_1}$
- $a < 1$ is **step up** (why?)
- $a > 1$ is **step down** (why?)

FIND I_2, a, P_{LINE}, AND η



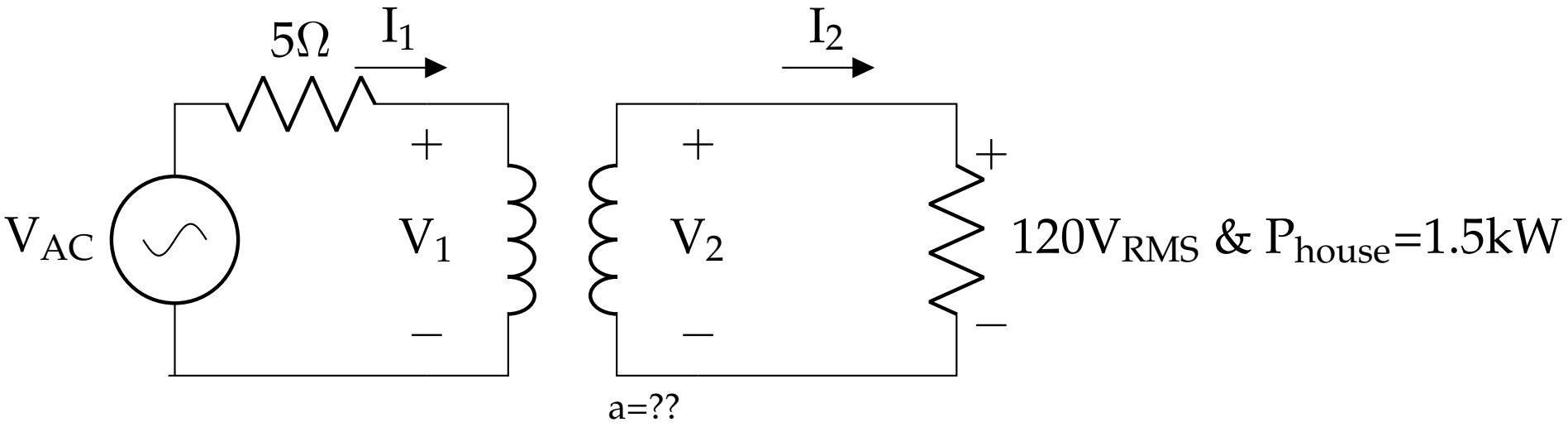
EXAMPLE 1

What is the efficiency of this circuit?

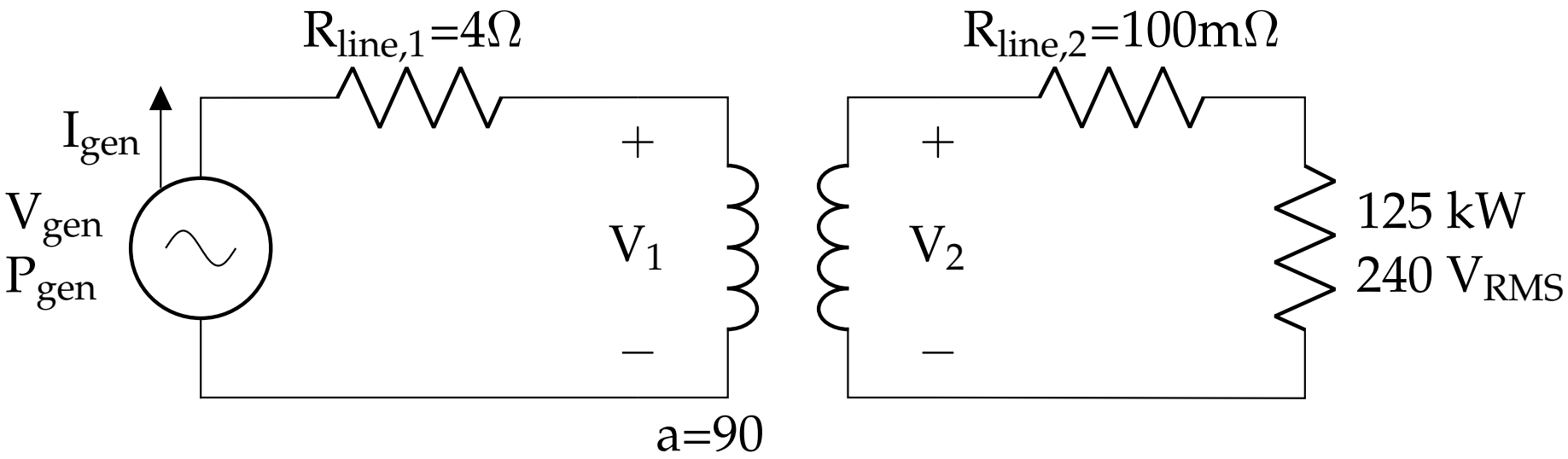


EXAMPLE 2

If we desired a transmission efficiency of 99%, what is the required turns ratio (a) and new source voltage?



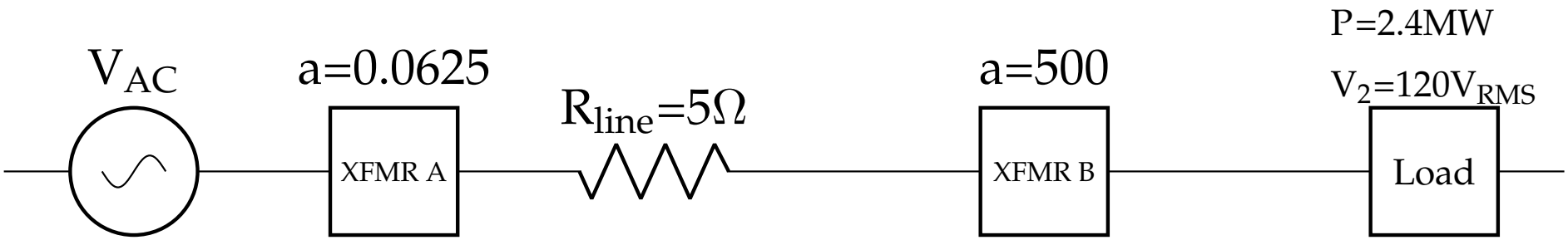
EXAMPLE 3



- What is the current provided by the generator?
- How much power is provided by the source?
- What is the voltage of the generator?
- What is the efficiency of the system?

Example 4

Find the source voltage and system efficiency.



Steps:

- Find the load current
- Reflect XFMR B current and voltage
- Find R_{line} losses and voltage drop V_{line}
- Find voltage V_{A2} of secondary of XFMR A
- Reflect XFMR A current and voltage
- Find power produced at plant
- Find system efficiency