



AC Power Analysis and Design

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Purpose:

Practice AC circuit power analysis and maximum power transfer design.

Equipment Required:

- 1 - HP 34401A Digital Multimeter
- 1 - HP 33120A Waveform Generator
- 1 - HP 54600B Oscilloscope
- 1 - Protoboard
- 1 - HP 4263B RCL Meter (shared)
- 1 - 820- Ω Resistor
- 1 - 10- Ω Resistor
- 1 - 1-mH Inductor
- 1 - 100-mH Inductor

Prelab:

Review Sect. 14-1 through 14-5 in the text*. The circuit of Fig. 1 represents a model of a power system. Use phasor analysis methods to find V_L and I_L . Find the total complex power S_{tot} provided by the source V_s and the complex power absorbed by the “transmission lines” S_{TR} and the “load” S_L . Remember to use rms values for these calculations. All phase angles should be referenced to V_s .

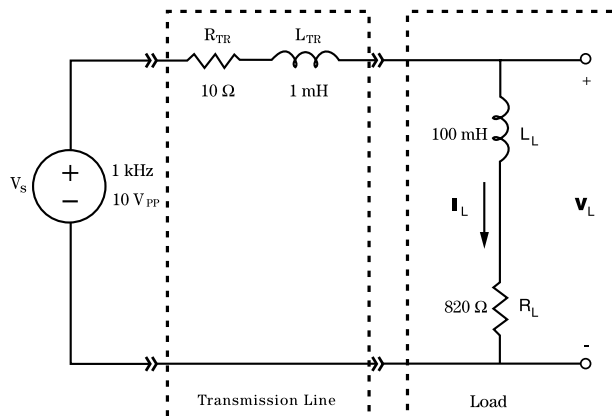


Figure 1

Procedure:

1. Build the circuit
 - a. Measure and record the actual values of the inductors with an RCL meter and the resistors with the DMM. In your journal draw a schematic like that of Fig. 1, labeling each element with its measured value. Recalculate the complex powers and V_L using the actual element values. Construct the circuit of Fig. 1 on a protoboard.



- b. Set the function generator to produce a 1-kHz sine wave with an amplitude V_A of 5 V ($V_{pp} = 10$ V).

2. AC Power Analysis

Make two sets of measurements, each including the amplitude and phase of the signal.

- a. For the first measurement, connect the channel one scope probe (CH1) to the source/transmission line interface, and CH2 to the transmission line/load interface. Measure the amplitude of both V_s and V_L . Before proceeding, verify that the voltage predicted by your phasor analysis of this circuit agrees with the actual value at this interface. If it does not, check your calculations and the circuit to ensure there are no errors. Configure the scope in X-Y mode to measure the phase angle of V_L . (Instructions for using a Lissajous pattern to measure the phase angle can be found in the experiment "Sinusoidal Steady State." This measured phase angle should agree with the computed phase angle. Be sure to compare these measured results to the theoretical values calculated using the actual element values.
- b. Perform the same set of measurements, that is amplitude and phase, across the 820 k Ω resistor in the "load". From this measurement, calculate the amplitude and phase angle of the current I_L in this series circuit.

3. Power factor correction

- a. Find the parallel capacitance needed to correct the load power factor to unity.
- b. Connect the required amount of capacitance to the circuit of Fig. 1. Determine the new V_L by measuring the voltage across the load, and the phase angle referenced to V_s .

4. Maximum power transfer

- a. Add the last digit of your student number to that of your partner. Determine your design problem from Table 1 below.
- b. Design a load circuit that will extract maximum power P from the load circuit. Your design should minimize the number of parts, and must be within 5% of transferring maximum power to the load.
- c. Build the circuit and make appropriate measurements to verify that your load circuit maximizes power transfer. Have an instructor sign off in your journal, verifying system compliance with the design criteria.
- d. Calculate the complex power that is delivered to the load.

Conclusion:

1. AC Power Analysis

Use the V_L and I_L data collected in Procedure 2 to compute the complex power S_{TOT} and S_L . Compare these results with the complex power calculated in Procedure 1. From your measurements, determine the average power P and the reactive power Q delivered to the load. Use the values of P and Q computed from the measurements to compute the power factor from $pf = P/|S|$. Indicate whether the load power factor is leading or lagging.



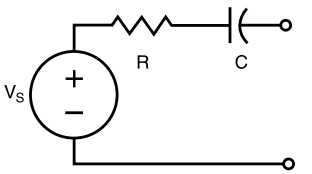
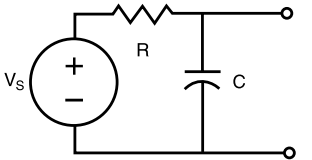
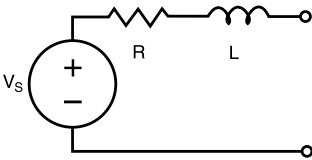
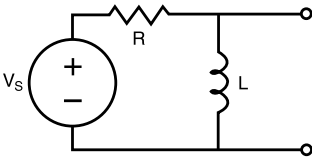
2. Power factor correction

Use the value of V_L measured in Procedure 3 to compute S_L and the new power factor pf. From this calculation, does it appear the power factor correction improved the power factor?

3. Compute the power savings

The “efficiency” of the power system can be evaluated by comparing the amount of average power dissipated in the load P_L , with the amount of average power produced by the source P_S . Compute the efficiency of the circuit before and after the power factor correction was made.

Table 1

Design Number	Source Circuit	Source specifications
1, 4, 8		$f = 5 \text{ kHz}$ $V_s = 5\angle 0$ $R = 470 \, \Omega$ $C = 0.15 \, \mu\text{F}$
2, 5, 9		$f = 10 \text{ kHz}$ $V_s = 5\angle 0$ $R = 10 \text{ k}\Omega$ $C = 0.015 \, \mu\text{F}$
3, 6		$f = 2.5 \text{ kHz}$ $V_s = 5\angle 0$ $R = 10 \text{ k}\Omega$ $L = 10 \text{ mH}$
4, 0		$f = 5 \text{ kHz}$ $V_s = 5\angle 0$ $R = 1 \text{ k}\Omega$ $L = 10 \text{ mH}$

* Roland E. Thomas and Albert J. Rosa, The Analysis and Design of Linear Circuits, Prentice Hall, (New Jersey, 1994)

