Power Measurements—Lab 13

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See https://mviordache.name/EEGR2051 for more information.

Name___________________________ Date__________ Section_____

EEGR 2051 – Power Measurements

Materials

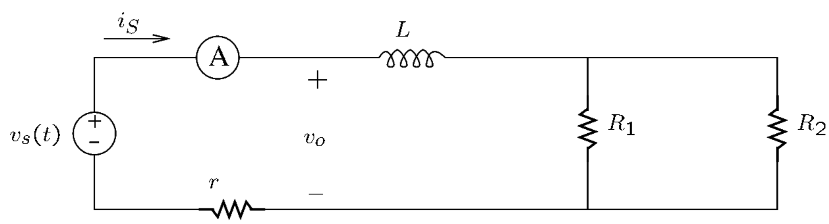
- One 10 Ω resistor, one 220 Ω resistor, and one 180 Ω resistor.
- One 30 mH inductor.
- One capacitor substituter and one resistor substituter.

Procedure

1. Measure the three resistors and indicate their actual value.

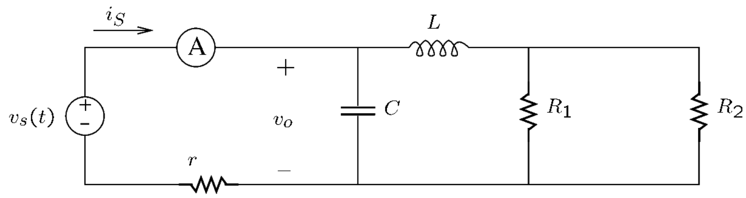
Nominal Value	$r = 10\ \Omega$	$R_1 = 180\ \Omega$	$R_2 = 220\ \Omega$
Actual Value			

2. Set the waveform generator to a sine wave of 600 Hz and 4 V peak-to-peak.
3. Verify the voltage of the generator with the oscilloscope.
4. From now on, let's denote by r, R_1, and R_2 the three resistors, as in the table above.
5. Connect the following circuit.



6. Select manually the range of the ammeter to a value between 20 mA and 500 mA.
7. Note that the $r = 10\ \Omega$ resistor will be used to sense the current.
8. Connect CH1 of the oscilloscope to the waveform generator and CH2 to the sensing resistor.
9. Does the voltage of the source change when you connect the source to the circuit? Explain why.
____
10. Measure the phase angle difference between the source voltage and the source current. Write the answer in degrees. $\Delta\phi =$ ________.
11. Indicate whether the current leads or lags the voltage. _______
12. The power factor is _____________________.
13. Measure the rms value of the load voltage v_o shown in the figure above. $V_o =$ _____________
14. Calculate the apparent power of the load by multiplying V_0 by the rms current. $S =$ __________
15. Measure the rms voltage of the inductor. $V_L =$ _______________
16. The reactive power is $Q =$ ______________
17. Measure the rms voltage on either of R_1 or R_2. $V_R =$ ___________.
18. The average power absorbed by R_1 is $P_1 =$ ____________.
19. The average power absorbed by R_2 is $P_2 =$ ____________.
20. The total average power is $P =$ __________.
21. Find $\sqrt{P^2 + Q^2}$. ____________
22. Is the equality $S = \sqrt{P^2 + Q^2}$ verified? ________________________

23. To correct the power factor, set the capacitor substituter to 100 nF and connect it as in the figure.



24. Increase the value of the capacitor substituter and verify that the phase angle difference changes.
25. When the power factor is corrected, the load current i_S is minimum, and the phase angle difference is zero.
26. Adjust the value of the capacitor substituter until the rms value of the current reaches the minimum value. The value at which the power factor is corrected should be in the range 100 … 3000 nF. $C =$ __________
27. The phase angle difference is $\Delta\phi =$ ________.
28. The following part of the experiment will demonstrate that power factor correction is load dependent, that is, changes in the load require readjusting the value of the capacitor.
29. **Disconnect the resistor R_2 from the circuit.**
30. The phase angle difference is now $\Delta\phi =$ ________.
31. Measure the rms values of the load voltage v_o and the load current i_S. $V_o =$ __________ $I_S =$ ________
32. The apparent power of the load is $S =$ ___________.
33. Measure the rms voltage on R_1. $V_1 =$ ________
34. The average power absorbed by R_1 is $P_1 =$ __________.
35. Should the apparent power S equal P_1? ____
36. Readjust the capacitor substituter until the power factor is corrected. $C =$ __________
37. Measure again the rms voltage on R_1. $V_1 =$ ________
38. The average power absorbed by R_1 is $P_1 =$ __________.
39. By Ohm's law, the rms value of the resistor current is $I_1 =$ __________.
40. Measure the rms value of the inductor voltage. $V_L =$ ____________.
41. The reactive power of the inductor is $Q_L =$ ______________.
42. Measure the rms value of the capacitor current. $I_C =$ __________
43. Measure the rms value of the voltage v_o. $V_o =$ ____________
44. The reactive power of the capacitor is $Q_C =$ ______________.
45. The total reactive power of the load is $Q =$ ____________. Is this correct? ____________________________

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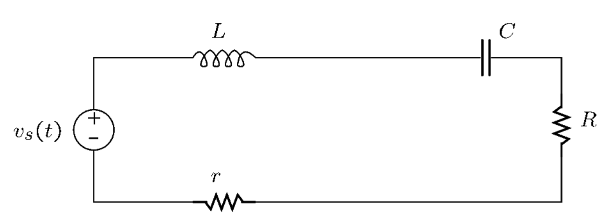
46. Measure the rms value of the load current i_S. $I_S =$ __________
47. The apparent power of the load is $S =$ ___________.
48. Should S equal P_1? ____
49. Many pieces of modern equipment tend to absorb power from the supply in an irregular fashion, as they seek to reduce power consumption. However, this can distort the supply voltage to the point that it no longer resembles a pure sinewave. The following questions evaluate the effect of the distortion on the efficiency of a power system.
50. Note that a zero-average signal $v(t)$ of frequency ω can be decomposed into the sum
$$v(t) = A_1\cos(\omega t + \alpha_1) + A_2\cos(2\omega t + \alpha_2) + A_3\cos(3\omega t + \alpha_3) + \cdots$$
where $A_1\cos(\omega t + \alpha_1)$ is the fundamental and $A_n\cos(n\omega t + \alpha_n)$ is the harmonic of order n.
51. The harmonic distortion of a signal can be calculated with the formula
$$Harmonic\ distortion = \frac{\sqrt{V_{rms}^2 - A_{1,rms}^2}}{A_{1,rms}}$$

where V_{rms} is the rms value of $v(t)$ and $A_{1,rms} = \frac{A_1}{\sqrt{2}}$ is the rms value of the fundamental.

52. For a pure sinusoidal signal of frequency ω, the amplitude of the harmonics is $A_2 = A_3 = A_4 = \cdots =$ _____ Moreover, the harmonic distortion is ______.
53. Set the waveform generator to a triangle wave. Adjust the amplitude of the waveform generator until the rms voltage on R_1 equals the value found at part 37. This step is important in order to ensure that the triangle wave dissipates as much power on the load as the sinusoidal signal.
54. Measure the rms value of the load current i_S. $I_S =$ ______________.
55. Using the oscilloscope, find the rms value of the first harmonic of the source voltage v_S.
    a. Set the time base on 50 ms/div.
    b. Press the MATH button, the Operator soft key, and select FFT.
    c. Set Source 1 to the channel on which you have the source voltage.
    d. If lit, press twice the 1 and 2 buttons to turn off the channels 1 and 2.
    e. Press the MATH button and set Span to 5 kHz and Center to 2.5 kHz.
    f. Press More FFT and then Window; select Rectangle. *Do not press Auto Setup; if you do, you may have to go back to step (a).*
    g. The largest peak on the screen is the fundamental.
    h. Using cursors, measure the value of the fundamental: $A_{1,dB} =$ ____ dB.
    i. Convert dB to rms volts. Note that $A_{1,dB} = 20\log_{10} A_{1,rms}$.
    j. $A_{1,rms} =$ __________.
56. Measure the rms value of the source voltage v_S. $V_{s,rms} =$ ____________
57. Calculate the harmonic distortion: ______________
58. Set the waveform generator to a square wave. Adjust the amplitude of the waveform generator until the rms voltage on R_1 equals the value found at part 37.
59. Measure the rms value of the load current i_S. $I_S =$ ______________.
60. Using the oscilloscope, find the rms value of the first harmonic. $A_{1,rms} =$ __________.
61. Measure the rms value of the source voltage v_S. $V_{s,rms} =$ ____________
62. Calculate the harmonic distortion: ______________
63. Compare the values of the load current I_S found at steps 46, 54, and 59. To reduce the load current, is it better to use a source with high or low harmonic distortion? _________________

Maximum Power Transfer

64. To enhance the efficiency of a power transmission system, it is important to ensure that most power is dissipated on the load and very little power is lost at the source. However, when working with low-power sources, such as the antenna of a receiver, we are not interested in getting the signal as efficiently as possible to the load, but in transferring as much power as possible from the source to the load. It can be proven that we have maximum power transfer when the impedance of the load $\boldsymbol{Z_o}$ is related to the impedance of the source $\boldsymbol{Z_S}$ by the equation $\boldsymbol{Z_o} = \boldsymbol{Z_S^*}$. (Note that $\boldsymbol{Z_S^*}$ denotes the complex conjugate of $\boldsymbol{Z_S}$.) While this implies only 50% efficiency, the load gets the maximum possible amount of power from the source.
65. Connect the following circuit. Using substituters, set $R = 100\ \Omega$, $L = 30$ mH, and $C = 100$ nF.



66. In this circuit, the load will consist of R and C.
67. Set the waveform generator to a sinusoidal signal of 5 V peak-to-peak and 600 Hz.
68. Create a LabVIEW virtual instrument that displays the average power and the graph of the instantaneous power of the load.
    a. To determine instantaneous power, the instrument should measure the voltage on r, to determine the current. It should also measure the voltage on R.
    b. The instrument should divide the voltage on r by r and then multiply the result by the voltage on R. The result of the multiplication is the instantaneous power. This should be averaged to find the average power.
    c. The instrument should acquire data at a rate of 100,000 samples per second for 100 ms. The total number of samples in 100 ms will be _________.
69. Adjust the value of the capacitor until the VI shows maximum power. This value should be between 100 nF and 2 μF. $C =$ ____________
70. Measure the rms value of the capacitor voltage. $V_C =$ _________
71. Measure the rms value of the inductor voltage. $V_L =$ _________
72. Are the inductor and capacitor voltages equal? Should they be equal? ______________________________
73. Adjust the value of the resistor R until the VI reports maximum power. The optimal value should be between 10 Ω and 100 Ω. $R =$ _________
74. Read the output resistance of the waveform generator from its front panel. $R_{out} =$ ______
75. Does R equal $R_{out} + r$? Should they be equal? ____