ECE-311 (ECE, NDSU)
Lab 5 – Experiment
Power 1: ac power calculations and maximum power transfer

1. Objective

The objective of this experiment is to analyze more circuits energized by sinusoidal voltage or current sources. In particular, the concepts of power calculations in sinusoidal steady-state and of maximum power transfer are investigated.

2. Introduction

First, you should refresh your memory on the concepts of phasors (including phasor diagrams), impedance (and its inverse admittance), and power. Phasors and impedance were covered in Circuit Analysis I. For the ac power concept please revisit class notes and read Chapter 11 from textbook. While doing this, solve the following exercise:

An unknown impedance Z is connected across a 380 V, 60 Hz sinusoidal source. This causes a current

of 5A to flow and 1500 W is consumed. Determine the following:

a) Real power (kW)
b) Reactive power (kVAR)
c) Apparent power (kVA)
d) Power factor
e) The impedance Z in polar and rectangular forms

3. Preparation

In preparation for the lab compute the required quantities.

(1) Consider the circuit of Figure 1 and the component values of Table 1. Consider **Vin** as the reference phasor (i.e., assume **Vin** has magnitude 1 and phase zero at all frequencies disregarding **Vs**). Complete the entries of Table 2 corresponding to the theoretical values. Include the calculations on a separate sheet.

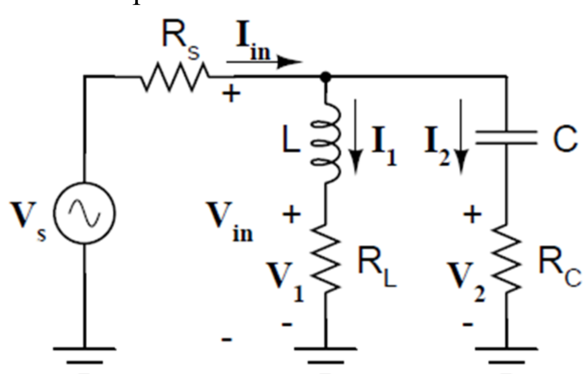

Figure 1: Phasors test circuit

Table 1: Component values for phasor test circuit

Param	Unit	Theor	Exper	Param	Unit	Theor	Exper
Rs	Ohm	50	-	Vs	V	5	-
RL		100		L	mH	1	
RC		100		C	uF	1	

Table 2: Table for phasor test circuit

Frequency (kHz)	Phasor	Theoretical		Experimental	
		Mag (V)	Phase (°)	Mag (V)	Phase (°)
1.8	**Vin**	1	0		0
	V1				
	V2				
18	**Vin**	1	0		0
	V1				
	V2				

(2) Consider the circuit of Figure 2 when the capacitor is connected as indicated by the dashed lines. Derive an expression for the value of the input frequency (in Hertz) as a function of L, C and R such that the impedance of the load is real (i.e., imaginary part is zero).

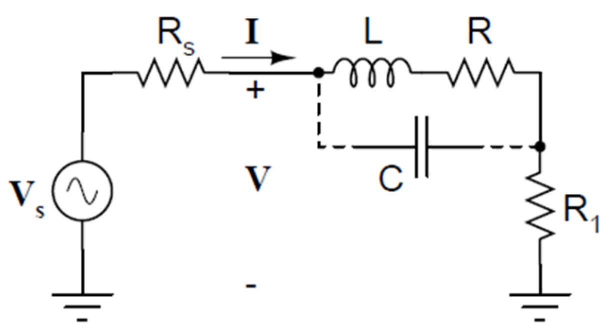

Figure 2: Power calculations test circuit

Table 3: Component values for power calculations test circuit

Param	Vs	Rs	R	R1	L	C
Units	V	Ohm			mH	uF
Theor	10	50	150	5.1	1	0.01
Exper	-	-				

Table 4: Table for power calculations

Param	Unit	With C	Without C
$\|\mathbf{V}\|$	V		
$\|\mathbf{I}\|$	mA		
$\theta_V - \theta_{VR1}$	°		
pf	-		
P	W		
Q	VAR		
S	VA		

(3) Consider the circuit of Figure 3 and the component values of Table 5. Write an expression for the average power *P* delivered to the load in terms of **Vs**, *Rs* and the load resistance *Ri*. Complete the entries of Table 5 corresponding to the theoretical values. Include the calculations on a separate sheet.

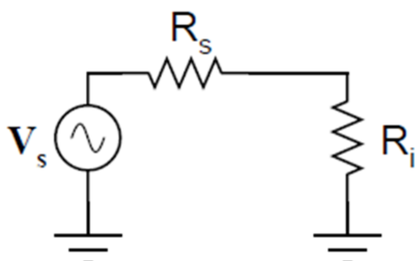

Figure 3: Maximum power transfer test circuit

Table 5: Maximum power transfer calculations

Param	Unit	Theoretical	Experimental	Param	Unit	Theoretical	Experimental
Rs	Ohm	50	-	Vs	V	2	-
R1		24		P1			
R2		51		P2	mW		
R3		100		P3			

4. Procedure

This part of the experiment requires assembling the circuits presented in the previous section and measuring data from all of them. Pay special attention to the procedure to measure the phase angle between two signals and the peak voltage value of a signal.

(1) Assemble the circuit of Figure 1 using the component values of Table 1. Observe **Vin** (the reference phasor) with channel 2 of the oscilloscope at all times, use channel 1 to observe the other signals. Take measurements to complete the entries of Table 2 corresponding to the experimental values. Notice that the magnitude of **Vin** depends on the input frequency and must be measured for both frequencies. Pay attention to the sign of the phase angle.

(2) Assemble the circuit of Figure 2 using the component values of Table 3. Measure the actual values of the components and calculate the frequency at which the load impedance is real using the expression derived in the *Preparation* section. Set the frequency of the signal generator to this value. Take measurements, with and without the capacitor connected to the circuit, to complete the entries of Table 4 corresponding to |**V**| (using channel 2), |**I**| (using channel 1 across *R1*), and the phase between the two of them $\theta_V - \theta_{VR1}$. Notice that the reading from channel 1 is the scaled value of |**I**| by *R1*, *therefore it must be divided by the actual value of R1*. The experimental values of pf, *P, Q*, and *S* in Table 4 will be calculated from these measurements in the *Analysis* section.

(3) Assemble the circuit of Figure 3 using the component values of Table 5. Use a signal frequency of 1 kHz. For each value of *Ri* measure the RMS voltage across the load and calculate the experimental values of Table 5.

5. Analysis

This section is intended for the analysis and comparison of the experimental and theoretical results. Answer all the questions.

(1) Normalize the experimental values of the voltage phasors recorded in Table 1 such that **Vin** appears with magnitude 1 and compare these results with the theoretical values. Find the current phasors **Iin**, **I1**, and **I2** for the frequency of 1.8 kHz. Represent **Iin** as the sum of **I1** and **I2** in a phasor diagram.

(2) Make the necessary calculations to complete the entries of Table 4 corresponding to pf, *P, Q*, and *S*. Explain the effect of the capacitor on the power factor of the circuit and its effect on the reactive power.

(3) From the results of Table 5, determine which of the three resistor values gives the maximum power transfer. Compare this resistor value with the source resistance *Rs*.

(4) What would you change about the procedures of this lab to make it more such that you would be more challenged or would encourage more independent thinking?