NAME Treepat Chantaurai

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**Report Sheet for Experiment 8: RLC Circuit**

Abstract

In this experiment, alternating current circuit is investigating its property of phase differences between current, voltage of resistor, voltage of capacitor, voltage of inductor, and the total voltage in RL and RLC circuits. By measuring the signal from the oscilloscope and analyzing/fitting the waves. Both results show that the phase differences between the voltage of inductor and voltage of resistor as well as the voltage of capacitor and voltage of resistor are not totally 90 Degree as suggested by the theory. This may be due to the internal resistance of the coil and the wire; therefore, the reported voltages are the combination between internal resistance and each individual.

Introduction and Theoretical Background

In the alternating current, the input signal of voltage is periodic function, therefore its characteristics are different from direct current. In this type of circuit, the inductor and capacitor become significant.

Given alternating current as , the voltages of resistance, capacitor, and inductance can be described as:

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where XC andXL  capacitive and inductive reactance which can be expressed as and , respectively.

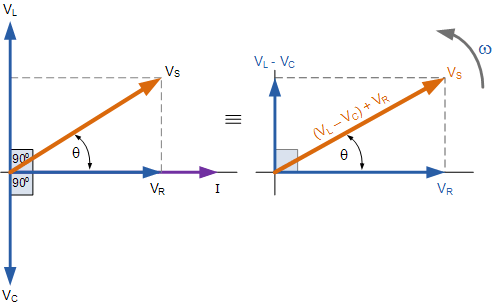


Figure 1 shows the phase difference from voltages

From the phase diagram above, the total voltage can be derived as:

And impedance can be calculated as:

Moreover, the phase difference can be calculated as:

Methods

1. Create R-L circuit with the RLC Circuit board, and connect it to the function generator and Oscilloscope. Record the initial frequency
2. Record the value of R and L.
3. Measure VS, VR, VL with digital multimeter
4. Increase the frequency at the function generator and repeat the step 2-4 again.
5. Change the circuit to R-L-C and repeat step 1-4

Results

**Part 1 – RL Circuit**

Figure 2 shows the VR-VL and V0-I0 for 3 different resistors in RL circuit (voltage vs time)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Result | | Set of experiment (RL Circuit) | | |
| 10 Ω | 33 Ω | 100 Ω |
| Amplitude (Amp, Volt) | I0 | 0.056 | 0.047 | 0.025 |
| V0 | 2.998 | 2.993 | 2.993 |
| VR | 0.562 | 1.548 | 2.559 |
| VL | 2.876 | 2.388 | 1.289 |
| V­tot | 2.930 | 2.846 | 2.865 |
| Phase Difference (rad) | VL - VR | 1.456 | 1.496 | 0.752 |
| Vtot - VR | 1.272 | 0.898 | 0.449 |
| Phase Difference (Degree) | VL - VR | 83.415 | 85.714 | 43.114 |
| Vtot - VR | 72.857 | 51.429 | 25.714 |

Table 1 summarizes the amplitude and phase difference from RL Circuit

According from the theory, the theoretical XL = L = 2fL = 2 x 1000 x 8.2 x 10-3 = 51.52 Ω

and theoretical impedance = sqrt(51.522 + 102) = 52.48 Ω

the results from calculation shown in Table 2 can be demonstrated below:

R (experimental) = VR/I = 0.562/0.056 = 10.04 Ω

XL (experimental) = VL/I = 2.876/0.056

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Set of experiment (RL Circuit) | R | XL | Z | Theoretical XL | Theoretical Z |
| 10 Ω | 10.036 | 51.357 | 52.328 | 51.52 | 52.482 |
| 33 Ω | 32.936 | 0.020 | 60.550 | 51.52 | 61.183 |
| 100 Ω | 102.360 | 51.560 | 114.612 | 51.52 | 112.491 |

Table 2 summarizes the experimental and theoretical values of R, XL, and Z

**Part 2 – RLC Circuit**

Figure 3 shows VR, VL, VC, V0, and I0 for 3 different resistors in RLC circuit (voltage vs time)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Result | | Set of experiment (RLC Circuit) | | |
| 10 Ω | 33 Ω | 100 Ω |
| Amplitude (Amp, Volt) | I0 | 0.189 | 0.077 | 0.028 |
| V0 | 2.998 | 2.998 | 2.998 |
| VC | 1.045 | 0.425 | 0.156 |
| VL | 1.885 | 0.552 | 0.2 |
| VR | 1.362 | 2.544 | 2.832 |
| V­tot | 1.600 | 2.547 | 2.832 |
| Phase Difference (rad) | VC - VR | 1.5259 | 1.4917 | 1.5595 |
| VL - VR | 0.718 | 0 | 0.701 |
| Vtot - VR | 0.0673 | 0.0452 | 0.0452 |
| Phase Difference (Degree) | VC - VR | 87.428 | 85.467 | 89.352 |
| VL - VR | 41.1429 | 42.7338 | 40.143 |
| Vtot - VR | 3.857 | 0 | 2.589 |

Table 3 summarizes the amplitude and phase difference from RLC Circuit

According from the theory, the theoretical XL = L = 2fL = 2 x 96 x 8.2 x 10-3 = 4.95 Ω

Theoretical XC = 1/C = 1/2fC = 1 / [ 330 x 10-6 x 2 x 96 ] = 5.02 Ω

Theoretical impedance = sqrt[(5.02-4.95)2 + 102) = 10.00 Ω

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Set of experiment  (RLC Circuit) | R | XL | XC | Z | Theoretical XL | Theoretical XC | Theoretical Z |
| 10 Ω | 7.206 | 9.974 | 5.529 | 8.467 | 4.946 | 4.823 | 7.207 |
| 33 Ω | 33.039 | 7.169 | 5.519 | 33.080 | 4.946 | 4.823 | 33.039 |
| 100 Ω | 101.143 | 7.143 | 5.571 | 101.155 | 4.946 | 4.823 | 101.143 |

Table 4 summarizes the experimental and theoretical values of R, XL, XC, and Z

Discussion

In the first part of RL circuit, the phase difference between the voltage of the resistor and that of the inductor are 83.415, 85.714, and 43.114 for 10 Ω, 33 Ω, and 100 Ω experiments respectively. Those values are quite close to the 90 Degree theoretical value. The major cause would be the internal resistance of the coil and slightly from the internal resistance from the wire. With the long length of the coil, the resistance can be multiplied directly up to some large number even the resistivity is still low. That resistance can be quantified as:

* XL,theo = 51.52 = sqrt(XL,exp2+R2) = sqrt(51.3572 + R2) 🡪 Rcoil = 4.09 Ω

On the other hand, the resistance from the wire can be calculated from the difference in resistance between the actual and expected value as:

* Rwire = 0.036 Ω confirming its low contribution to the error of the phase diagram

Finally, the calculated impedance of 52.328 is lower than that expected of 52.482 as well

In the second part of RLC circuit, the phase differences between the voltage of the resistor-inductor and resistor-capacitor are 87.428, 85.467, 89.352; and, 41.142, 42.733, 40.143 respectively. The theory suggests both values to be 90 Degree, however, the error comes from the internal resistance of the wire and/or the coil in some cases. The value of the resistance from coil and wire can be quantified as:

* XL,exp = 9.974 = sqrt(XL,theo2+R2) = sqrt(4.9462 + R2) 🡪 Rcoil+wire = 8.66 Ω

The resistance from the wire can be calculated as:

* XC,exp = 9.974 = sqrt(XC,theo2+R2) = sqrt(4.8232+ R2) 🡪 Rwire = 2.70 Ω

The resistance from the wire connected to the resistor is the difference between the actual and used value of resistance

* Rwire connected to resistor = 2.794Ω

Since there are contribution form the internal resistances, the experimental values of impedance are higher than expected as summarized in Table 4 above.

Finally, the circuit is called resonance when the total voltage of the circuit is in-phase with the voltage of resistance (no phase difference). The results in Table 3 are telling that only the case of 33 Ohm resistor has resonance and the other do not. This is because of the considerable amount of resistance from the coil which subsequently increases the inductive resistance. Comparison of the resonance with its theoretical value can be shown below:

Which is only = -0.78% error accruing to the experimental result.

Conclusion

In conclusion, the RL circuit did not have 90 Degree phase difference between the voltage of resistor and the inductor as the theory suggests because of the internal resistance of the coil itself as a major cause and a minor one form the attached wire. Since the resistance depends not only the material’s resistivity, but also its length, therefore, the long coil’s resistance is calculated to be 4.09 Ohm. Moreover, the resistance from the wire can be calculated from the difference in resistance between the actual and expected value as 0.036 Ohm. In the second part of RLC circuit, two phase differences of resistor-inductor and resistor-capacitor are not 90 Degree as well. The internal resistance of coil connecting to the wire is 8.66 Ohm, the wire connecting to the resistor has internal resistance of 2.70 Ohm, and the wire connecting to the capacitor of 2.70 Ohm. These are error from the same cause as in part 1. Moreover, the circuit has resonance only with the use of 8.2 mH inductor and 96 Hz frequency, resulted an only -0.78% error from the expected theoretical resonant frequency.

Reference

1. Lab manual titled “**Ch8. RLC Circuit”**from Department of Physics on KLMS
2. *Series RLC circuit and RLC series circuit analysis*. Basic Electronics Tutorials. (2019, April 16). Retrieved November 7, 2021, from https://www.electronics-tutorials.ws/accircuits/series-circuit.html.