ENGR 1181 – Lab 5 – Circuits Lab

Background:

The Circuits Lab introduces students to Ohm's Law and circuit analysis while allowing them to practice writing formulas and doing unit conversions in Excel. Students will review this document before arriving at lab.

Learning Objectives:

1. Accurately measure dimension, voltage, and resistance.
2. Utilize Microsoft Excel to record/calculate Voltage, resistance, current, and power.
3. Calculate properties from measured values.
4. Understand the relationship between structure, property, and function.

Internal Resistance of a Dry-cell battery

Electricity from Chemicals: Mileaf, 7th ed page 6-03, 6-04, 1-42,

The battery is one of the most important power sources in use today because its energy is Self-Contained. This is an advantage that other power sources do not have. Other power sources must first be supplied with outside energy, such as heat, light, or mechanical energy, before they can produce electrical energy. The electrical energy of a battery is produced or supplied by chemical reaction produce by the chemical contained in the battery.

Ordinary batteries rely on chemical reactions to produce an electric current. Chemicals can be combined with certain metals to cause chemical reactions that will transfer electron to produce electric charges. One example of the is the basic Wet Cell, commonly used as car batteries. The battery is used mostly when a portable power source is required, such as flashlights or lanterns or automobile electrical systems. Batteries also provide a reliable source of standby or emergency power in the event of a blackout or loss of 'off-site power'.

Batteries are classified as wet cells or dry cells. The wet cell battery use liquid chemicals for operation, while the dry cell contains a chemical paste. The 'Cell' is the basic unit of the battery, just as the biological cell is the basic unit of Life. The dry cell battery seems to have an obvious advantage in that it is operable regardless of orientation; it can be used when it is upside down, without loss of its chemicals. The advantage of the wet cell is that it can deliver a higher voltage per cell. A Battery often consists of cells connected together to supply a voltage or a current larger than that obtainable from a single cell.

Calculations of currents and other circuit-related parameters in physics or electrical engineering frequently treat batteries as "ideal", meaning they are a source of voltage, but having no resistance. Real batteries have some internal resistance, though it may be relatively small compared to the remainder of the circuit. The purpose of this Experiment is to determine experimentally the internal resistance of a common D-Cell battery.

Transmission Cables

Transmission cables are used to carry electric power from the generation stations to the ultimate users or customers. The users may be industrial, commercial, or residential. Electric power is usually transmitted at very high voltages to reduce lines losses; lost energy due to resistance in the transmission cables. In an ideal electric circuit, all of the electric energy produced by the generating station would be transmitted to and converted by the load into some useful form or purpose, such as heat or light. Most of this lost energy or power loss is in the form of heat produced when the current flows against the resistance of the transmission lines. In practice, it is impossible to build an ideal circuit with no losses. Some of the energy from the generating source is always lost in the transmission lines. This represents wasted energy. This wasted energy is a reality and must be kept to a minimum.

Line loses or energy lost when current flows through a resistor, in this case the transmission line cables, are proportional to the current squared and directly proportional to the resistance. This is usually written as:

$$P = I^2 R \qquad (1)$$

and referred to as the ‘I squared R’ losses; it is the rate at which energy is being lost in the transmission process. By inspection of the equation, the losses can be minimized by decreasing the current or by decreasing the resistance or both. For a given power transmission, current can be decreased by increasing the transmission voltage. Resistance can be decreased by using an excellent conduction material, one with low resistivity, and a large diameter conductor, one with a large cross-sectional area.

The amount of current that a transmission cable can carry depends on the material used and the ability of the cable’s environment to remove thermal heat from the cable. The temperature of the cable cannot be allowed to increase to temperatures that will noticeably increase electrical resistivity of the material and the resulting resistance of the cable.

Estimations of the maximum current density in amps per square millimeter along with the cross sectional area of the cable will be used to calculate the maximum allowable current in the cable.

This experiment will examine the geometry of the transmission cable and will calculate the resistance of a transmission cable. It will also demonstrate the calculation of “ampacity” or the current carrying capacity of a transmission cable. It will calculate line losses and show that the percent of energy lost is lower at higher transmission voltages.

Procedure:

Task 1: Internal Resistance of a Dry-Cell Battery

Equipment:

- Two Dry cell size D Batteries, nominal 1.50 volts.
- Electronics Kit, Miscellaneous connecting wires,
- One Multimeter
- One Resistor (approximately 100 ohms)

Procedure:

1. Measure and record the Open-Circuit emf voltage (E), the voltage across the battery with no load using the multimeter and two probes.

2. Place the battery in the circuit with the smallest resistor and measure the 'Loaded-Circuit' voltage (V_T) of the battery. Place the probes at the battery terminals while the battery is in series with the resistor.

3. To prevent the flow of current, remove the wires that connect the battery to the resistor. With no current flowing, measure the resistance of the external 100 ohm resistor.

4. Repeat the process with one other battery, and record the voltages in the data sheet provided. Use the 100 ohm resistor for both batteries.

5. Calculate and record the internal resistance of the battery using the equation below:

$$r = R \times \left(\frac{E}{V_T} - 1\right) \qquad (2)$$

6. Calculate and record the current in the circuit using the equation below. Watch the units. Data sheet asks for mA.

$$I = \frac{V_T}{R} \qquad (3)$$

7. Answer all questions at the bottom of the sheet

Task 2: Transmission Cables

Equipment:

- Two samples of transmission cables selected from the collection offered. Some Copper and some Aluminum.
- Ruler and Caliper for measuring cable length and diameter and diameter of individual wire strands.
- Scale for measuring mass of cable sample

Procedure:

1. Each Team will be provided with two cables, one copper and one aluminum.

2. Record the 'name tag' attached to each cable. Observe and record the material of which the cable is made.

3. Count and record the number of strands of wire that constitute the transmission cable.

4. Measure the diameter of the cable.

5. Calculate the diameter of the individual strands by dividing the cable diameter (reduced for insulation if any) by the number of strands across the cable. Note that this is not the total number of strands that were counted previously, but the number of strands side by side going across the diameter of the cable. For example, if there were seven total strands counted in the cable, the number of strands going across the diameter side-by-side would be three. Nineteen total strands wound by five, and so on.

6. Using the diameter of a <u>single strand</u> along with the total number of strands, calculate the area of the transmission cable.

7. Calculate the resistance of a one-mile length of single strand using the resistivity of the material provided.

$$R = \frac{\rho L}{A} = \frac{4\rho L}{\pi d^2} \qquad (4)$$

In this equation, ρ = resistivity, A = Area of a single strand of wire, L = one mile converted to meters, d = diameter of a single strand of wire.

The Resistivity of Copper is 1.72 E-08 ohm-m and for Aluminum is 2.75E-08 ohm-m.

8. Calculate the resistance of a one-mile length of the cable. Hint: treat the total number of strands as so many parallel resistors. The resistance of the cable should be much less than the resistance of a single strand.

9. Calculate the maximum allowable current for the cable using the allowable current density for the material and the total area of the cable.

$$I = J \times A \qquad (5)$$

In this equation, J = maximum allowable safe current density (amps/mm^2), A = Area of entire cable.

The current density limit for Copper is 3.5 A/mm^2 and for Aluminum is 2.2 A/mm^2

10. Measure the length and mass of the cable. Calculate the mass or weight per km and per mile of the cable.

11. Fill in the table by calculating values of Power, Line Losses per mile, percent line loss compared to total power, voltage drop of loss per mile, and percent voltage drop compared to the given line voltages. Calculating Power use:

$$P = V \times I_{max} \qquad (6)$$

In this equation, V = the voltages listed, I = the maximum current you calculated above.

Calculating Power Loss use:

$$\Delta P = I_{max}^2 \times R \qquad (7)$$

In this equation, I = the maximum current you calculated above, R = resistance you calculated for the one mile cable. Note: you cannot use V^2 / R because you do not yet have ΔV (voltage drop)

Calculating Percent Power Loss use:

$$Percent\ power\ loss = \frac{I_{max}^2 \times R}{P} \times 100 \qquad (8)$$

Calculating Voltage Drop use:

$$\Delta V = I_{max} \times R \qquad (9)$$

Calculating Percent Voltage Drop use:

$$Percent\ voltage\ drop = \frac{\Delta V}{V} \times 100 \qquad (10)$$

Use formulas in Excel to do all calculations. The units are already provided on the data sheet.

12. Make sure to complete all calculations in the provided Excel workbook. Answer all questions in the Reflection questions sheet. Each student will turn in their own completed Excel workbook on Blackboard.