Electrical Circuits LAB #5 - Thevenin/Norton Equivalents, Source Transformation & Energy

Objectives

Understand and apply Thevenin/Norton equivalents, Source Transformation and Energy Concepts

Material

- ➤ Textbook: Electrical Circuits by Nilsson & Lecture material
- ➤ www.EngrCS.com
- ➤ Instruments: Power Supply, Function Generator Multimeter and Oscilloscope
- ➤ Supplies:
    - o Electrical Tool Box
    - o Proto Board
    - o Probes & Connecting Cables
    - o Low Power DC motor
    - o Solar Cell Module
    - o Available Resistors

Experiment 1

Energy Generation, Distribution and Management are major fields of study in Electrical Engineering. In this experiment, we will explore the conversion of light to electrical power using Photovoltaic Cells.

In 1839, Edmond Becquerel noticed that, in addition to heat, the light that is absorbed by certain materials can produce small quantities of electricity. This phenomenon was initially used to measure light levels in photography until the 1950s. Improvements in semiconductor processing and specialized energy requirements have led to the development of photovoltaic cells.

Photovoltaic cells convert light directly into electricity by the interaction of photons and electrons within the semiconductor material. To create a photovoltaic cell, a material such as silicon is doped with atoms from an element with one more or less electrons than occurs in its matching substrate (e.g., silicon). A thin layer of each material is joined to form a junction. Photons striking the cell cause this mismatched electron to be dislodged, creating a current as it moves across the junction. Through a grid of physical connections, the current is gathered. Currents and voltages can be supplied through series and parallel connection arrays of cells.

The DC current produced depends on the material involved and the intensity of the solar radiation incident on the cell. Most widely used today is the single crystal silicon cell, which is also the material, used in this lab. Other alternatives include Gallium arsenide cells (expensive & efficient), thin film process (low cost, flexible). Research into efficiency and cost improvement is underway.

Select a solar module from the lab kit and characterize the module under the most direct in-door lighting available in the lab. The characterization should include the following specification:

a) Module area in square centimeters (cm^2)

b) Total short circuit current (Isc) output by the module and the calculated short circuit current output per cm^2. *Digital Multimeter configured as an Ammeter may be considered a short circuit.*

c) Measure Current Conversion Variability(CCV) across the module.
   Recommended process: Divide the module into 4 equal quadrants. Cover all quadrants except one and perform the process outlined in step b for the uncovered quadrant. Repeat this process for all four quadrant. For this lab, the conversion variability may be calculated as:

$$\text{Current Conversion Variability, CCV} = \frac{Isc\_Max - Isc\_Min}{Average\ Isc}$$

Where:

> *Isc_Max = Maximum of the four Isc measured in this section*
> *Isc_Min = Minimum Isc measured in this section*
> *Average Isc = Average of the four Isc measured in this section*

d) Total open circuit voltage (Voc) output from the module and the calculated open circuit voltage output per cm^2. *Digital Multimeter configured as an Voltmeter may be considered an open circuit.*

e) Measure Voltage Conversion Variability (VCV) across the module.
Recommended process: Divide the module into 4 equal quadrants. Cover all quadrants except one and perform the process outlined in step b for the uncovered quadrant. Repeat this process for all four quadrants. For this lab, the conversion variability may be calculated as:

$$\text{Voltage Conversion Variability, VCV} = \frac{Voc\_Max - Voc\_Min}{Average\ Voc}$$

Where:

> Voc_Max = *Maximum of the four Voc measured in this section*
> Voc_Min = *Minimum Voc measured in this section*
> *Average* Voc = *Average of the four Voc measured in this section*

Experiment 2

In the early 1830's, Michael Faraday and Joseph Henry independently discovered the relationship between changing magnetic fields and induced Electro Magnetic Field (EMF) which is known as Faraday's Law. The following diagram shows how Faraday's Law is used to develop DC Electric Motors:
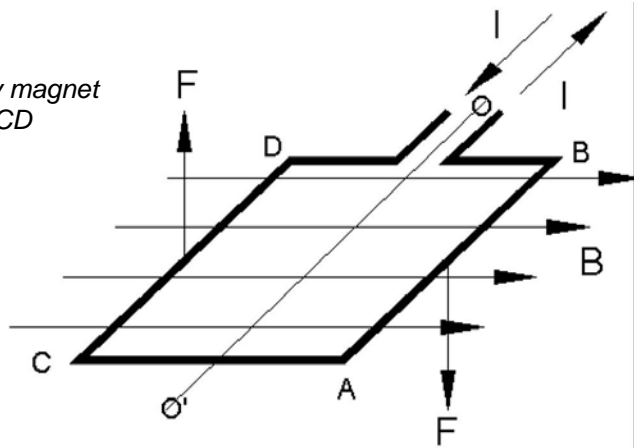
F = **B**L**I** sin A
> *Where:*
>> *B is the magnetic field generated by magnet*
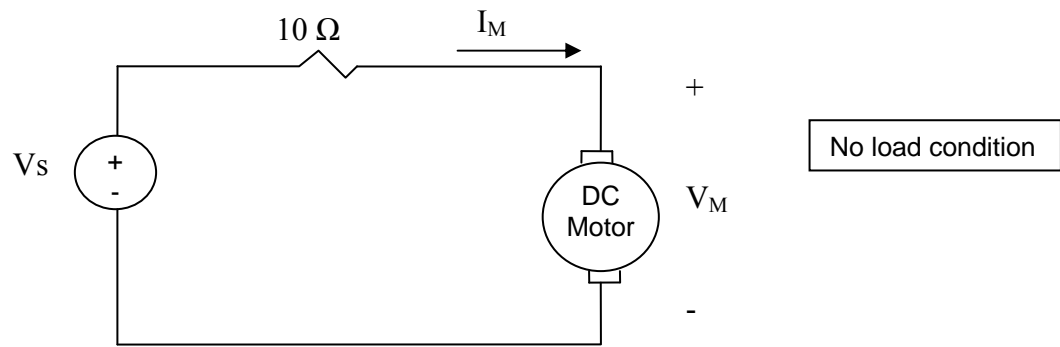>> *L is length of coil Segment AB and CD*
>> *I is the current*
>> *A is the angle between I & B*

Select a low power DC motor from the lab kit and use the following steps to characterize it:

a) Implement the following circuit

$$10 \, \Omega \qquad I_M$$

Vs $\quad \overset{+}{\underset{-}{\bigcirc}}$

DC
Motor $\quad V_M$

$+$

No load condition

$-$

Starting Vs at 0 volts, increase Vs and measure I_M and V_M until the DC motor is rotating continuously. Reverse the process and measure the value of I_M and V_M as you decrease Vs until Vs reaches 0. Note the status of DC motor as you are changing Vs.

b) Plot the I_M (y-axis) vs. V_M (x-axis) and show the status of motor (not rotating, intermittently rotating, and continuously rotating) on your plot.

c) Summarize your observations of IM and VM required to start and run the DC motor continuously.

Experiment 3
Using the information derived earlier in this lab, calculate the number of solar modules required to start the DC motor rotating continuously. Show your work.


Experiment 4
  a) Use the Thevenin equivalent to model the solar module used in the lab.

  b) Use your model from section (a) to show the final circuit (with multiple modules) required to drive the DC motor

Experiment 5
  a) Use the Norton equivalent to model the solar module used in the lab.

  b) Use your model from section (a) to show the final circuit (with multiple modules) required to drive the DC motor

Experiment 6
Maximum power is delivered when the source and load resistance are equal. Use the Solar Cell Module Thevenin equivalent model to calculate the load resistor value that would receive maximum power from the solar module if connected as shown below:
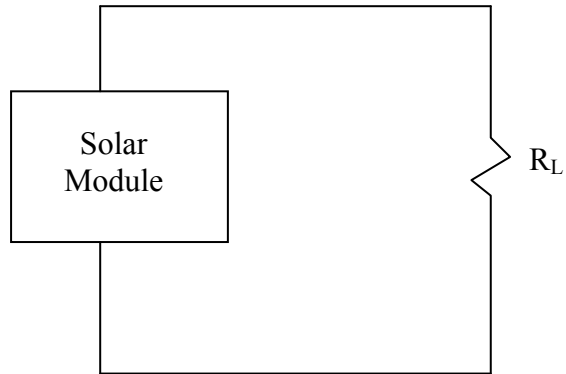
Show the steps used to calculate the value of R_L. Also document the process used to show that the calculated R_L value does or does not receive maximum load power. Explain the reasons for any variances you observe.

NOTE: *Solar Cell and Motor must be returned to the cabinet*.

Report Requirements

Reports must be prepared individually even if the experiments are performed as a team. All reports must be computer printed (formulas and diagrams may be hand drawn) and at minimum:

For each experiment include:
a) Clear problem statement; specify items given and to be found
b) Theory and process used
c) Resulting circuit diagram, tables, graphs, calculations and other results

For the overall report include:
a) Cover sheet with your name, lab, date of completion and team members' names
b) Lessons learned from this lab
c) A new experiment and expected results which provide additional opportunity to practice the concepts in this lab