**ENGR – 2300 Final Project**

**By Andy Nguyen**

**Lecture Session ENGR – 2300.002**

**Problem Statement**

For my final ENGR – 2300 project, I decided to create a project about the “Calculation of DC currents in a linear circuit”. I chose this project because the problem relates to our degree as we are trying to become electrical/computer engineers. Using linear algebra concepts and applying them when doing circuit analysis will increase the efficiency of getting unknown information from that circuit. Using Kirchhoff’s laws is essential when analyzing circuits and depending on the magnitude of a circuit, a lot of variables can be involved. [2] Linear algebra’s solution to dealing with system of equations simplifies a lot of the math when dealing with circuit analysis.

**Find all the individual currents in the circuit below!**

Diagram, schematic

Description automatically generated

To find the currents of the above circuit, we are going to have to utilize Ohm’s law (the voltage drop of a resistor is equal to the current times its resistance) and Kirchhoff’s law that the algebraic sum of all the voltages around any closed loop in a circuit is equal to zero.[3] There are a lot of unknown variables when it comes to circuits like these, but by applying Loop Current analysis, we can determine the unknown individual currents into a system of equations to derive the answers.[4]

**Solution**

Using the above laws and techniques we can create a system of equations to derive our missing currents...

Diagram

Description automatically generated

*Loop 1*

20i1 + 13(i1 – i2) + 1(i1 – i3) + 25i1 = 50 volts

*Loop 2*

13(i2 – i1) + 15i2 + 5(i2 – i3) = 0 volts

*Loop 3*

5(i3 – i2) + 10i3 + 1(i3 – i1) = 0 volts

Then perform distribution and simplify the above system of equations…

*Loop 1*

*59*i1 - 13i2 - i3 = 50

*Loop 2*

*-13*i1 + 33i2­ - 5i3 = 0

*Loop 3*

*-*i1 - 5i2­ + 16i3 = 0

**No Linear Algebra Hand Solution**

Then isolate currents and perform substitution/elimination to gather individual currents…

From *Loop 3*, isolate i1. i1 = -5i2­ + 16i3

- - - - - - - - - - - - -

Substitute *Loop 3* into *Loop 1* and *Loop 2.*

59(-5i2­ + 16i3) - 13i2 - i3 = 50 à -308i2 + 943i3 = 50

-13(-5i2­ + 16i3) + 33i­2 - 5i3 = 0 à 98i2 – 213i3 = 0

- - - - - - - - - - - - -

-308i2 + 943i3 = 50 Eliminate i2. -308i2 + 943i3 = 50 Solve for i3. 273.57143… i3 = 50

98i2 – 213i3 = 0 (22/7) \* (98i2 – 213i3 = 0)

i3 = **0.18276…**

- - - - - - - - - - - - -

98i2 – 213i3 = 0 Substitute i3. 98i2 – 213(**0.18276…**) = 0 Solve for i2.   
i2 **= 0.39722…**

- - - - - - - - - - - - -

59i1 - 13i2 - i3 = 50 Substitute i2 & i3. 59i1 – 13(**0.39722…**) - **0.18276…** = 50 Solve for i1.

i1 = **0.93807…**

- - - - - - - - - - - - -

**Hand Solution Answers**

i1 = **0.93807…**

i2 **= 0.39722…**

i3 = **0.18276…**

**Linear Algebra Hand Solution**

The system of equation above took a bit of calculation and required us to keep track of a lot of variables; linear algebra has streamlined the process of tackling systems of equations using Gaussian Elimination.

**Step 1**:

We first want to take the coefficients and constants from our simplified loop equations and put them into a matrix.

**Step 2**:

[1] Perform Gaussian Elimination by doing row operations which lead to the matrix turning into reduced row echelon form (matrix with diagonal of ones, the last column containing the sought-after values, and the rest of the elements containing 0)

R1 = (1/59) \* R1 à R2 = R2 + 13R1à

R3 = R3 + R1 à

R­2 = (59/1778) \* R2 à

R1 = R1 + (13/59) \* R2 à

R3 = R3 + (308/59) \* R2 à R3 = (127/1915) \* R3 à

R1 = R1 + (7/127) \* R3 à R2 = R2 + (22/127) \* R3 à

We have achieved reduced row echelon form!

- - - - - - - - - - - - -

**Linear Algebra Answers**

i1 = **0.93807…**

i2 **= 0.39722…**

i3 = **0.18276…**

**MatLab Solution**

Using MatLab, we can find the missing currents even faster by using the automated processes stored in the software.

We once again first want to take the coefficients and constants from our simplified loop equations and put them into a matrix.

In MatLab, for format of creating a matrix should be like…

‘A’ is just a name in which we can call our matrix to use again within the program.

A = [ 59 -13 -1 50; -13 33 -5 0; -1 -5 16 0]

To solve for the missing currents of the circuit, we can perform elementary matrix operations to reduced row echelon form.

R1 = (1/59) \* R1 à = E1 R2 = R2 + 13R1à = E2

R3 = R3 + R1 à= E3 R­2 = (59/1778) \* R2 à= E4

R1 = R1 + (13/59) \* R2 à= E5 R3 = R3 + (308/59) \* R2 à= E6

R3 = (127/1915) \* R3 à= E7 R1 = R1 + (7/127) \* R3 à= E8

R2 = R2 + (22/127) \* R3 à= E9

E9 \* E8 \* E7 \* E6 \* E5 \* E5 \* E4 \* E3 \* E2 \* E1 \* A =

***Alternatively, rather than performing row operations manually, we can use the rref(\*matrix variable name\*) to see the reduced row echelon form almost instantaneously.***

reduced\_ref\_A = rref(A) =

- - - - - - - - - - - - -

**Conclusion**

I learned from this project that linear algebra has the amazing capability of increasing the efficiency at which we process linear systems of equations. Also when we use linear algebra concepts in addition with software like MatLab, we see that efficiency of processing problems that are at a large scale can be solved in a matter of seconds. Linear algebra does not only the above electrical circuit, but can solve any missing values of electrical circuits has long as a system of equations can be produced. An AC circuit with resistors, capacitors, and inductors can be solved for there missing values because it the circuit is a system of differential equations.[5] When analyzing a circuit using Loop Current Analysis, we see that we can apply the system of equation to makes a matrix to find the unknown values of a current. The scale of a problem no longer becomes an issue when applying linear algebra.

**References**

1. Larson, R., Elementary Linear Algebra, 8th edition  
2. Website:

<https://linearalgebraapplications19.wordpress.com/2019/03/30/matrices-applied-to-electrical-circuits/>

3. Website:

<https://www.electronics-tutorials.ws/dccircuits/kirchhoffs-voltage-law.html>

4. Website: <https://www.maplesoft.com/content/EngineeringFundamentals/15/MapleDocument_15/Nodal%20and%20Loop%20Analysis.pdf>

5. Website:

<http://faculty.salina.k-state.edu/tim/DAT/linAlg/linSysApp.html>

**Sharing with Partner**

1. Shared with Alan Tran
2. We met once on Discord the week before the last week of classes and we met another time after May 4th (our 3rd exam for linear algebra)
3. We brainstormed ideas such as creating a complicated current analysis circuit and really big temperature heat maps to perform Gaussian elimination on. We discussed and tried to modify an image files, but we were not exactly sure how to implement images on MatLab.
4. Alan decided to do the temperature distribution project and my project is similar to his in that we both use the linear algebra concept of Gaussian elimination to find our missing values. The missing average temperatures on the heat distribution map can essentially create a system of equation, in which he then takes the coefficients and constants of the SOE and puts it into matrix; proceed to put the matrix into reduced row echelon form and you will have you missing temperatures.
5. I was able to explain the principles of operation for the technology because both are projects were similar in that we are assembling a system of equations and trying to find the unknown values of something.
6. The most interesting aspect of our exchange was the utility linear algebra concepts provided for doing these projects. We talked a lot about linear algebra’s effective process at increasing the efficiency of getting/doing something. We realized that MatLab’s linear algebra functions created an efficient/robust way of processing numbers.