SEMI-LINEAR INDUCTION MOTOR

BRADLEY
University

Electrical and Computer Engineering
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Outline of Presentation

- Introduction
- Prior Work
- Subsystem Level Functional Requirements with Specifications
- Engineering Efforts Completed to Date
- Parts List
- Division of Labor
- Conclusion

Introduction

- Semi-Linear Induction Motor Background
  - Alternating current (AC) motor
  - Powered by a three phase voltage source
  - Force and motion are produced by a semi-linear moving magnetic field
  - Can be used to drive gears and turn wheels

Problem Statement

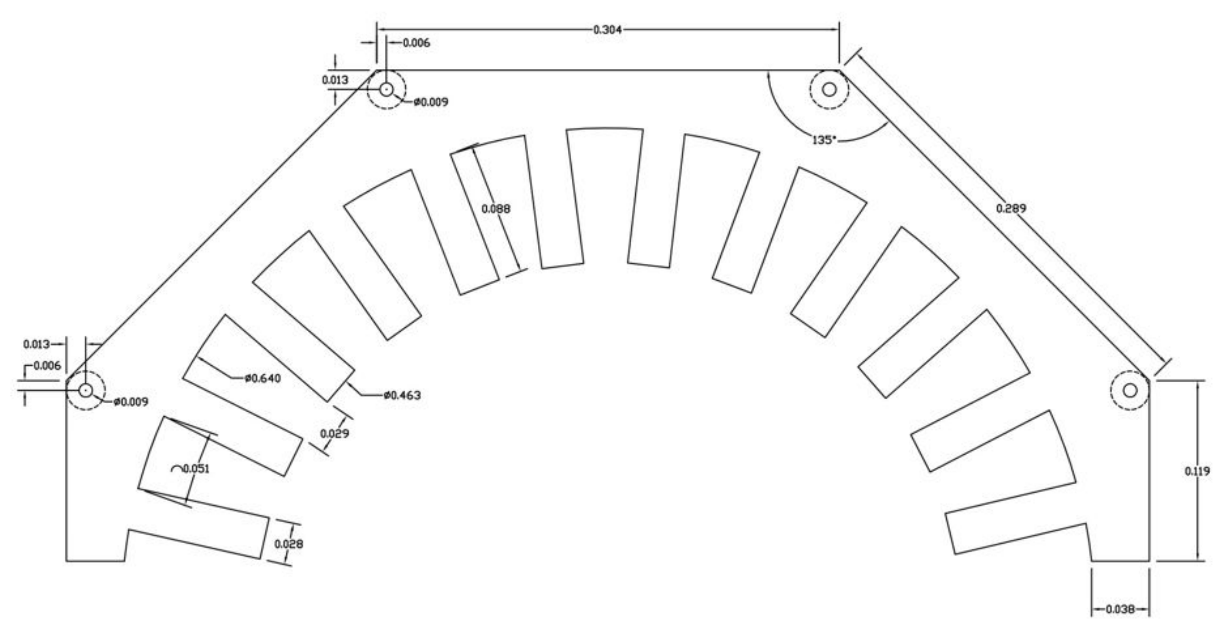
- Troubleshoot previous team’s design to understand the limited functionality
- Thoroughly test the SLIM once reasonable functionality is attained
- Meet all functional requirements
- Redesign the rotor

Prior Work

Prior Work

- Design and build Semi-Linear Induction motor
  - Developed equations for the design of the three phase stator
  - Stator designed to have 12 teeth and 4 poles
  - Wounded the coils and places them on stator teeth
  - Built base and mounted rotor within the stator
  - Wired the SLIM using a Wye Connection

Stator Design



[1]

Had Stator Manufactured by Laser Laminations

[2]

Wound Coils

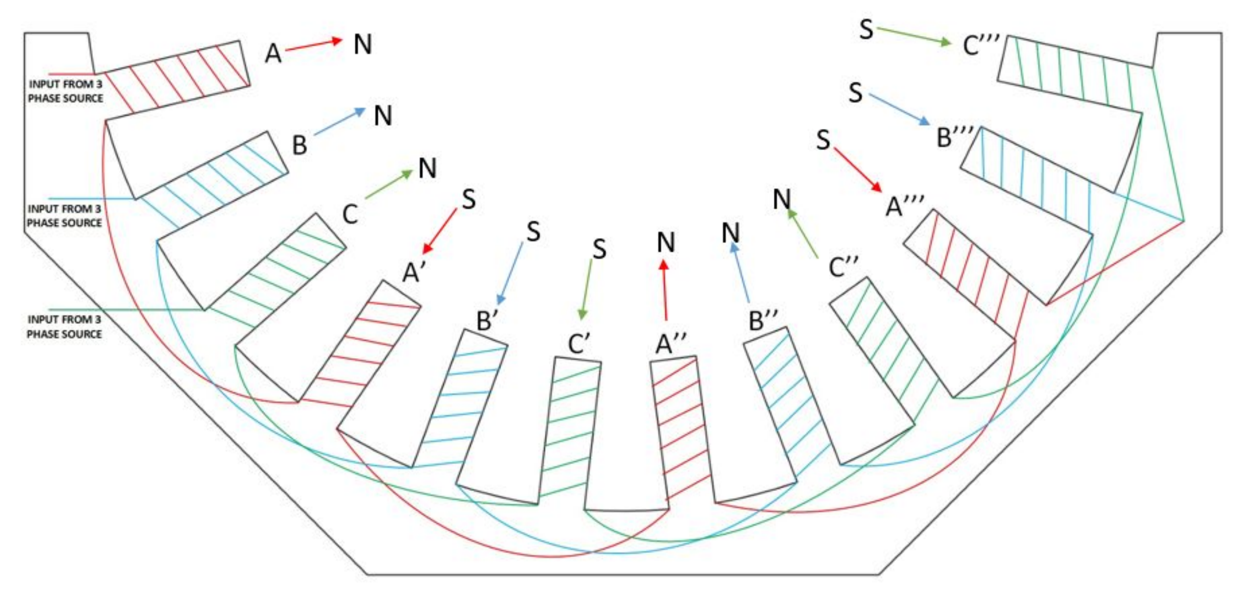
[3]

Mounted and Wired SLIM

[4]

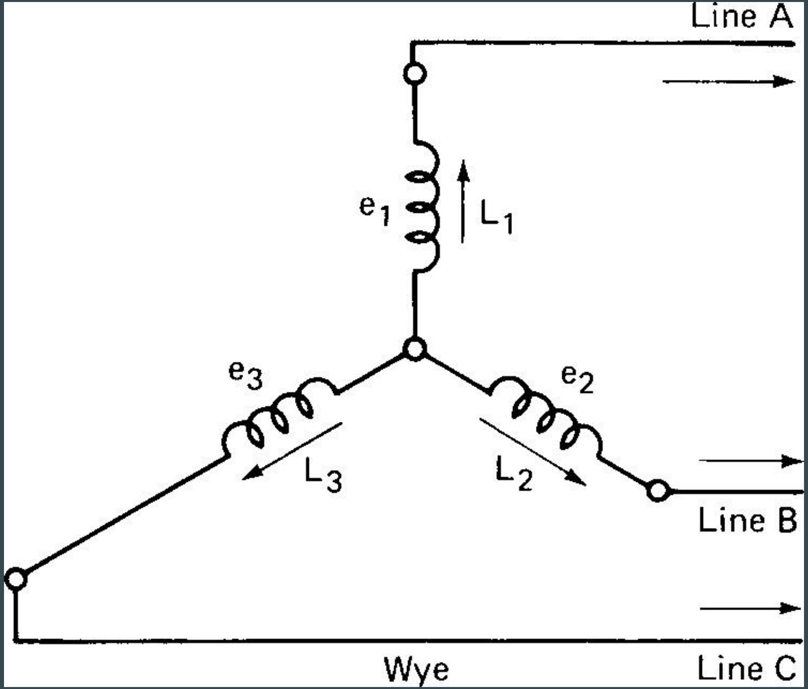
Stator Wiring Diagram

- Figure [5] shows the orientation of the north and south pole at a particular moment in time
- The poles will actually change with the magnetic field as time goes on



[5]

Wye Connection



[6]

Subsystem Level Functional Requirements with Specifications

Subsystem Level Functional Requirements

- VFD will vary the frequency and voltage to produce a moving semi-linear magnetic field that will turn the rotor
- The generated rotation will be measured with a speed sensor that generates a train of pulses via photo-interrupter
- The VFD requires a 0-10 V reference signal that corresponds to a 0-120 Hz frequency range

LCD Subsystem

- Display
    - VFD Output Frequency
    - Rotor speed
    - Desired rotor speed

Tachometer Subsystem

- Main Components
  - Photo-interrupter
  - Transparent disk with notches
- External Interrupt
  - Counts pulses
  - Four pulses per rotation
  - Updates data every 250 ms
- RPM
  - Read speed sensor data
  - Convert pulses to revolutions per minute
  - Convert to string
  - Input string to LCD

[7]

Subsystem to Control Variable Frequency Drive (VFD)

- 0-10 V signal correlates to 0-120 Hz
- A/D Converter
  - Onboard the Atmega128
  - 250 ms interrupt
  - Resolution is 0-5 V
- D/A Converter
  - External Chip
  - Provides 0-10 V reference signal to VFD to control output frequency

[8]

Subsystem Block Diagram

[9]

Engineering Efforts Completed to Date

Engineering Efforts

- Reviewed and analyze previous team's design equations
- Determined correct orientation of coils
- Determined if there were any short-circuits in the coils
- Mapped out the magnetic field each phase was producing
- Configured and tested SLIM using a delta connection
- Researched and planned the design of a new rotor

Turns per phase

$$T_{ph} = \frac{P_{out}}{6.66\{pn_{ms}B_{ag}A_{p}k_{w}I_{ph}\eta(PF)\}} \tag{1.1}$$

$P_{out} =$ *Output Power*

$p =$ *Number of Poles*

$n_{ms} =$ *Mechanical Cycles per Second*

$B_{ag} =$ *Average Air – Gap Flux Density per Pole* $= 1.1\ [T]$

$A_{p} =$ *Cross – Sectional Area of Pole Faces* $= 0.0346\ [m]$

$T_{ph} =$ *Number of Turns per Phase*

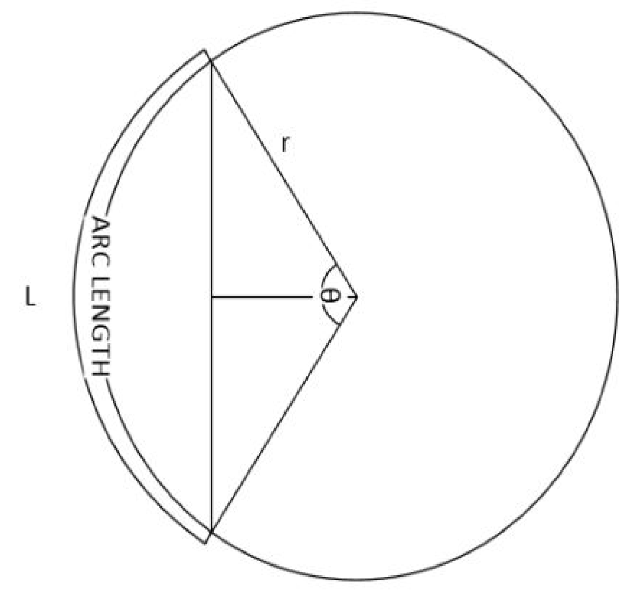
$k_{w} =$ *Coil Winding Factor* $= 0.86$

$I_{ph} =$ *Input Phase Current* $= 3\ [A]$

$\eta =$ *Efficiency* $= 0.6$

$PF =$ *Power Factor* $= 0.7$

Arc Length



[10]

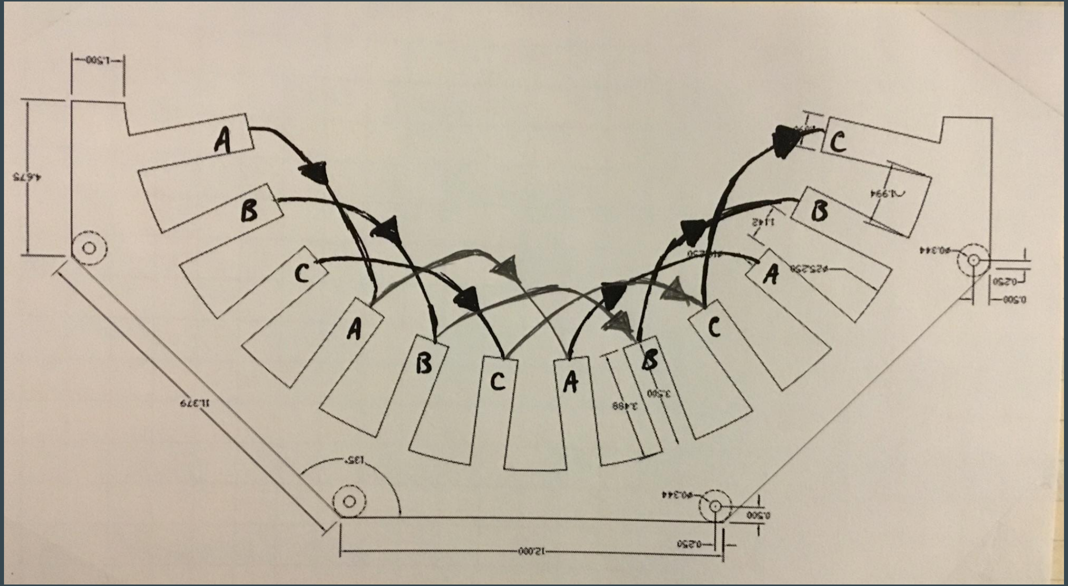
$$L = \Theta * r \qquad (1.2)$$

Coil Orientation

[11]

[12]

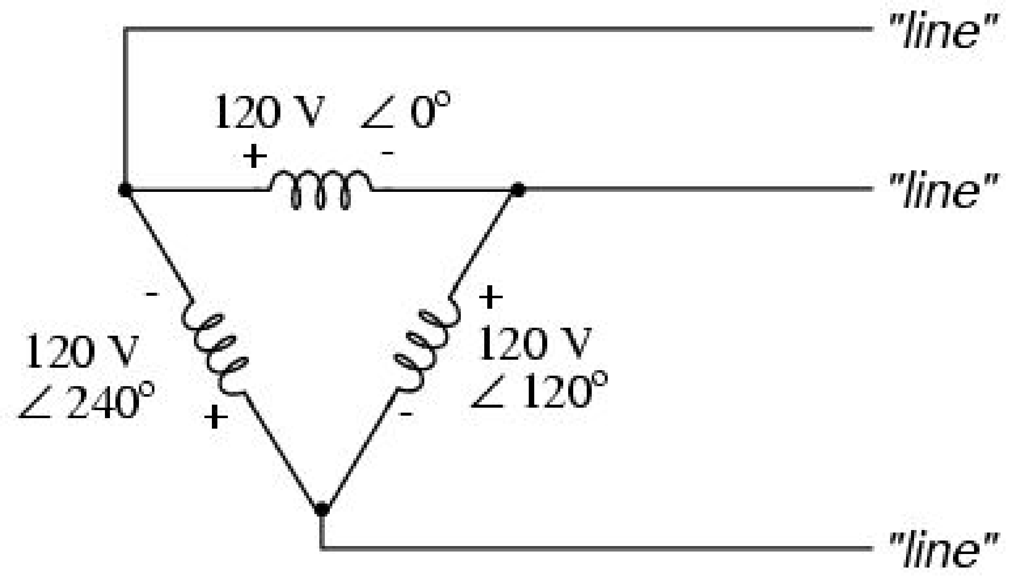
Map of Magnetic Field



[13]

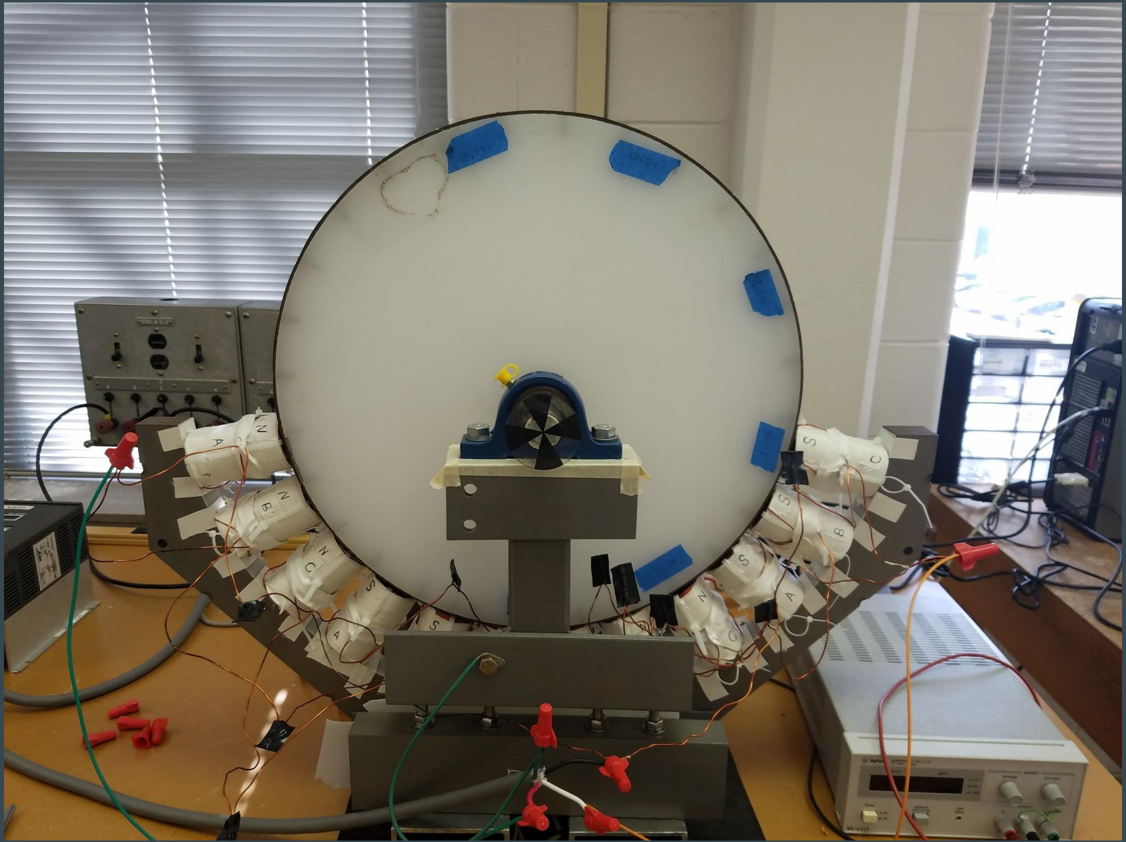
Changed to a Delta Configuration

- The current nearly tripled with this configuration
- Rotation was produced
- After testing the SLIM with delta connection, we can assume the stator was designed to be connected with a Wye connection



[14]

Video of Rotor Rotation using a Delta Connection



[15]

Rotor Design Sketches

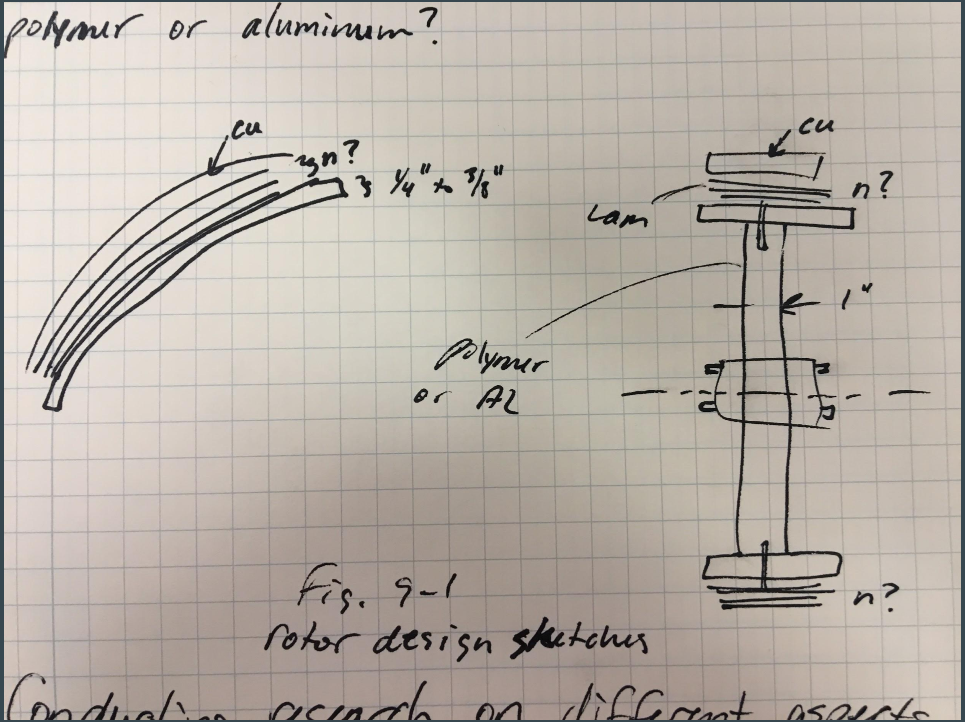


Fig. 9-1
rotor design sketches

[16]

Parts List

Parts List

- The parts list is pending the completion of a new rotor design
  - Will probably include:
    - Rotor Shaft
    - Laminations
      - Laminations will be probably be Aluminum
    - Outside track
    - Some type of bolts and screws

Division of Labor

Division of Labor

- Troubleshooting
  - Review and analyze design equations
    - Edgar and Jacob
  - Determine coil orientation
    - Edgar and Jacob
  - Test for short-circuits
    - Edgar and Jacob
  - Map magnetic field
    - Edgar and Jacob
  - Configure and test delta connection
    - Edgar and Jacob
- Research and design new rotor
  - Edgar and Jacob

Ideal Schedule for Completion

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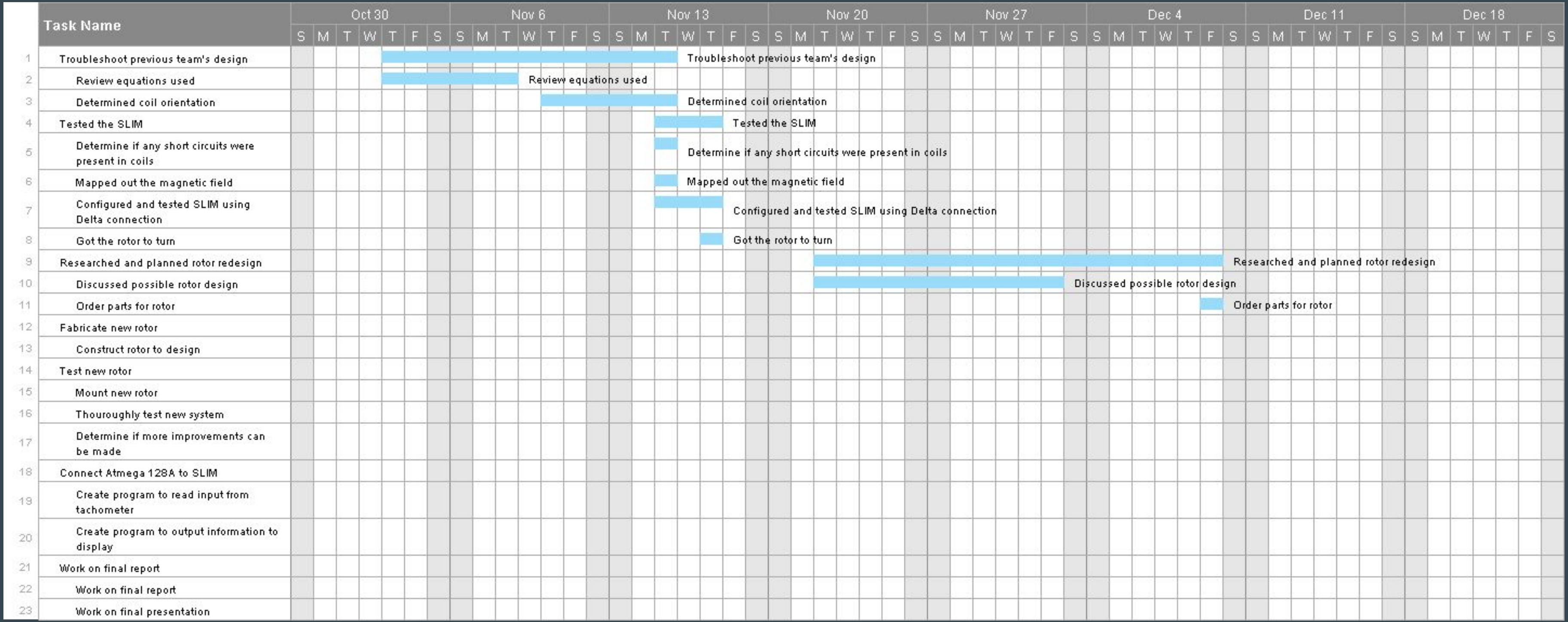
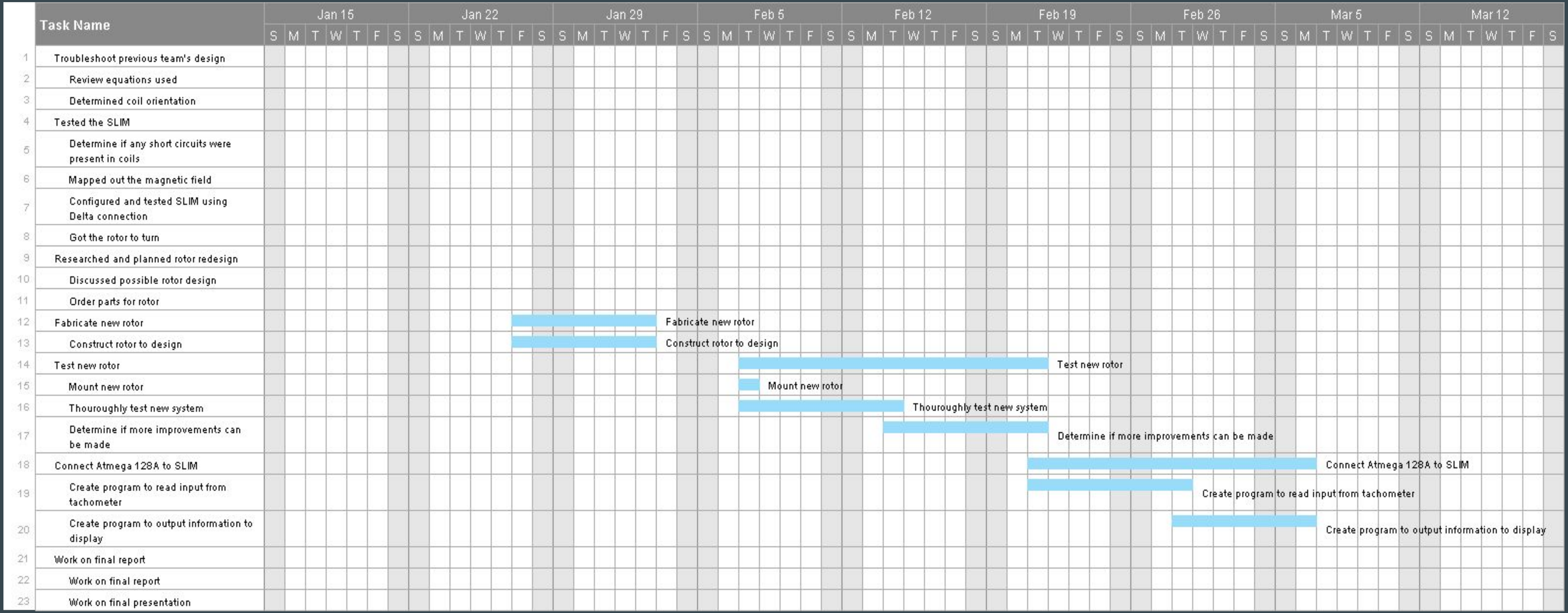


	Task Name
1	Troubleshoot previous team's design
2	Review equations used
3	Determined coil orientation
4	Tested the SLIM
5	Determine if any short circuits were present in coils
6	Mapped out the magnetic field
7	Configured and tested SLIM using Delta connection
8	Got the rotor to turn
9	Researched and planned rotor redesign
10	Discussed possible rotor design
11	Order parts for rotor
12	Fabricate new rotor
13	Construct rotor to design
14	Test new rotor
15	Mount new rotor
16	Thouroughly test new system
17	Determine if more improvements can be made
18	Connect Atmega 128A to SLIM
19	Create program to read input from tachometer
20	Create program to output information to display
21	Work on final report
22	Work on final report
23	Work on final presentation

[17]

Ideal Schedule for Completion



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[18]

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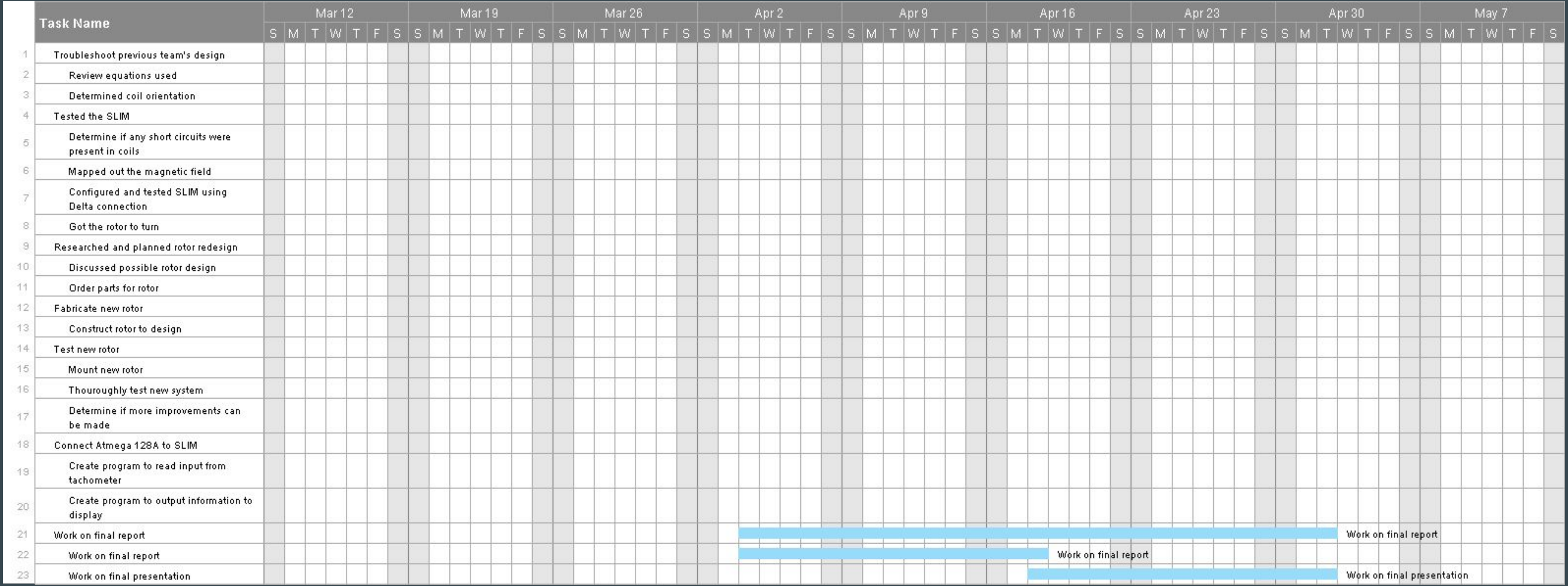

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[19]

Conclusion

Conclusion

- Future Directions
    - Design a new rotor
        - Increased efficiency
        - May possibly be able to use water jet in Morgan hall to cut out laminations for rotor
- Delta Configuration resulted in significantly larger currents than Wye Configuration
    - May want to return to Wye Connection
    - If we can increase efficiency with new rotor design then the smaller currents will be fine

Questions?

References #1-6

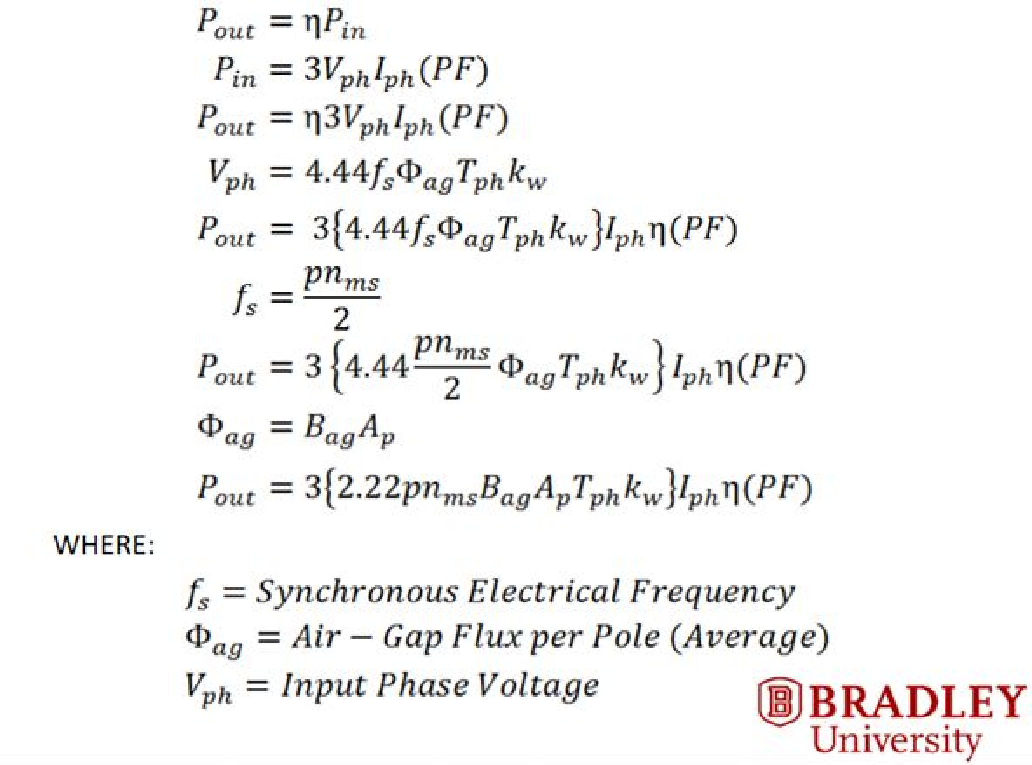
[1] Stator Design. [Diagram]. Retrieved from 2016 LIM Senior Electrical Engineering Project Final Report.
[2] Stator. [Photograph]. Retrieved from 2016 LIM Senior Electrical Engineering Project Final Report.
[3] Wound Coils. [Photograph]. Retrieved from 2016 LIM Senior Electrical Engineering Project Final Report.
[4] Mounted and Wired SLIM. [Photograph]. Retrieved from 2016 LIM Senior Electrical Engineering Project Final Report.
[5] Stator Wiring Diagram. [Diagram]. Retrieved from 2016 LIM Senior Electrical Engineering Project Final Report.
[6] Wye Connection. [Diagram].

References #7-14

[7] Tachometer. [Photograph]. Retrieved from 2016 LIM Senior Electrical Engineering Project Final Report.
[8] Variable Frequency Drive. [Photograph]. Retrieved from 2016 LIM Senior Electrical Engineering Project Final Report.
[9] Subsystem Block Diagram. [Drawing].
[10] Arc Length. [Drawing]. Retrieved from 2016 LIM Senior Electrical Engineering Project Final Report.
[11] Compass. [Photograph].
[12] Coil Orientation. [Photograph].
[13] Map of Magnetic Field. [Photograph].
[14] Delta Configuration. [Drawing].

References #15-19

[15] Rotor Rotation using a Delta Connection. [Video].
[16] Rough Rotor Design. [Photograph].
[17] Ideal Schedule for Completion #1. [Photograph].
[18] Ideal Schedule for Completion #2. [Photograph].
[19] Ideal Schedule for Completion #3. [Photograph].



$$P_{out} = \eta P_{in}$$

$$P_{in} = 3V_{ph}I_{ph}(PF)$$

$$P_{out} = \eta 3V_{ph}I_{ph}(PF)$$

$$V_{ph} = 4.44 f_s \Phi_{ag} T_{ph} k_w$$

$$P_{out} = 3\{4.44 f_s \Phi_{ag} T_{ph} k_w\} I_{ph} \eta (PF)$$

$$f_s = \frac{p n_{ms}}{2}$$

$$P_{out} = 3\left\{4.44 \frac{p n_{ms}}{2} \Phi_{ag} T_{ph} k_w\right\} I_{ph} \eta (PF)$$

$$\Phi_{ag} = B_{ag} A_p$$

$$P_{out} = 3\{2.22 p n_{ms} B_{ag} A_p T_{ph} k_w\} I_{ph} \eta (PF)$$

WHERE:

$f_s = Synchronous\ Electrical\ Frequency$

$\Phi_{ag} = Air - Gap\ Flux\ per\ Pole\ (Average)$

$V_{ph} = Input\ Phase\ Voltage$

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