# ELEC ENG 3PI4
# Laboratory 4
# *Induction Motors*

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**Pre-Lab**

*Equation for calculating induction motor slip:*

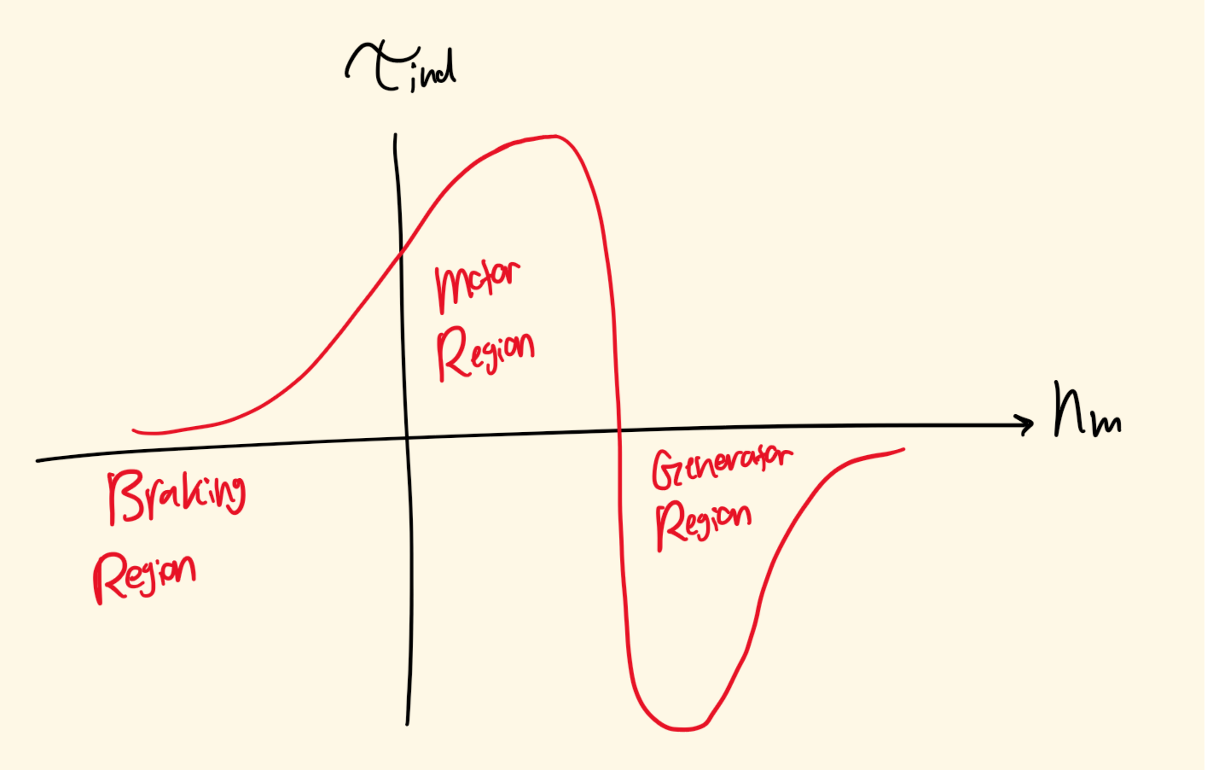
Motor slip speed: $n_{slip} = n_{sync} - n_m$

Motor slip: $s = \left(\frac{n_{slip}}{n_{sync}}\right) * 100\% = \left(\frac{n_{sync} - n_m}{n_{sync}}\right) * 100\% = \left(\frac{\omega_{sync} - \omega_m}{\omega_{sync}}\right) * 100\%$

*Equation for calculating synchronous speed, $n_{sync}$:*

Synchronous speed: $n_{sync} = \frac{120 f_e}{P}$

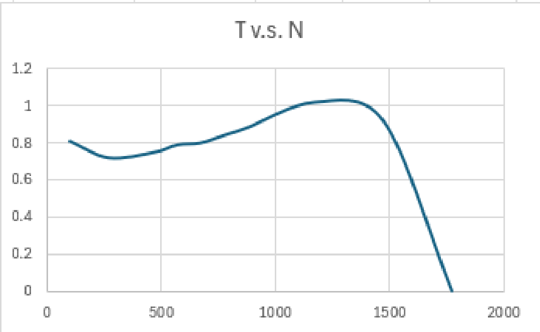
*Torque-Speed characteristic curve of an induction motor:*

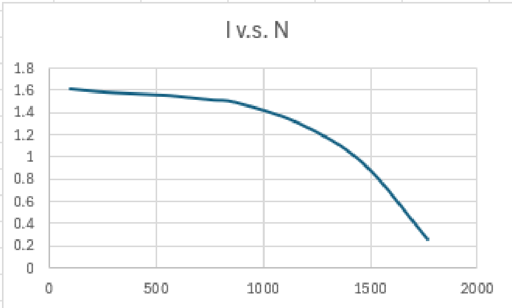


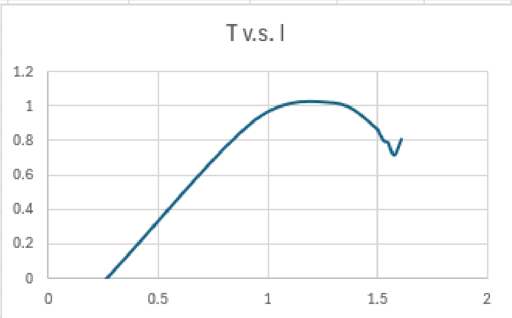
## A. Load Characteristics - Star Connection

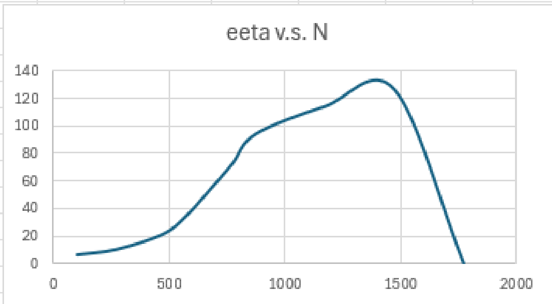
| N(rpm) | 1770 | 1470 | 1170 | 870 | 770 | 670 | 570 | 470 | 270 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|
| T(Nm) | 0 | 0.92 | 1.02 | 0.88 | 0.84 | 0.8 | 0.79 | 0.75 | 0.72 | 0.81 |
| $I_{Line}$(A) | 0.26 | 0.94 | 1.3 | 1.49 | 1.51 | 1.53 | 1.55 | 1.56 | 1.58 | 1.61 |
| cosθ | 0.497 | 0.831 | 0.775 | 0.73 | 0.726 | 0.718 | 0.715 | 0.712 | 0.703 | 0.698 |
| $P_{apparent}$ (W) | 15.3 | -93.5 | 120.5 | 130.1 | 131.5 | 132.1 | 133.1 | 133.4 | 132.8 | 134.4 |
| $P_{mech,out}$ (W) | 0 | 118.38 | 137.74 | 122.52 | 95.48 | 70.16 | 46.08 | 28.67 | 13.89 | 8.9 |
| (%) | 0 | 126.609626 | 114.307 | 94.1737 | 72.6084 | 53.1113 | 34.6206 | 21.4918 | 10.4593 | 6.62202 |

**Plots:**



**Questions:**

*1. Calculate the slip at the rated load for the experimental three-phase induction motor.*

Ns = (120)(fs)/P = (120)(60)/4

S = {(Ns - N)/Ns}*100 = {(1800-1650)/1800}*100 = 8.3

*2. Explain the torque-speed characteristic curves for the three-phase squirrel-cage induction motor.*

Here, we see a linear slope between the full-load and no-load operating regions

*3. How can you control the speed of the squirrel-cage induction motor? (Four methods)*

There are various methods, including… voltage control, resistance control, frequency control, pole changing

*4.How to operate the three-phase induction machine in generating mode?*

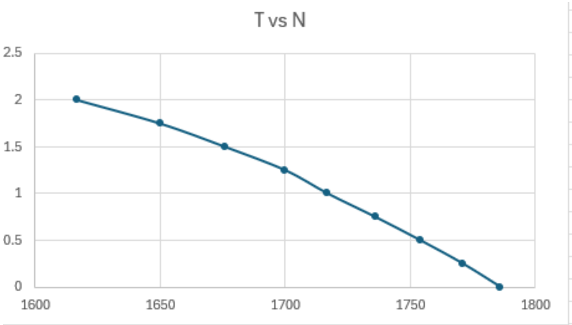
To do this, we make Rotor speed > n_sync. In this case, S is negative and the direction of the air gap power is in the opposite direction, thus we operate the induction machine in generator mode.

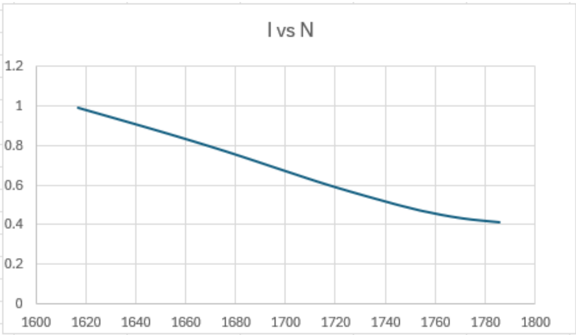
## B. Load Characteristics - Delta Connection

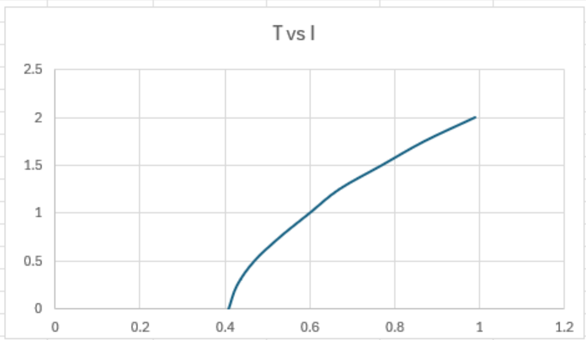
| **N(rpm)** | 1789 | 1776 | 1765 | 1751 | 1738 | 1723 | 1706 | 1688 | 1674 | 1652 | 1627 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **T(Nm)** | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 | 1.2 | 1.4 | 1.6 | 1.8 | 2 |
| **$I_{Line}$(A)** | 0.42 | 0.44 | 0.46 | 0.50 | 0.55 | 0.60 | 0.67 | 0.74 | 0.80 | 0.89 | 0.98 |
| **cosθ** | -0.238 | -0.371 | -0.488 | -0.580 | -0.655 | -0.712 | -0.755 | -0.789 | -0.808 | -0.825 | -0.839 |
| **$P_{apparent}$** | - | -34.0 | -47.3 | -60.8 | -75.0 | -89.9 | -105.2 | -121.7 | -135.1 | -153.0 | -172.2 |

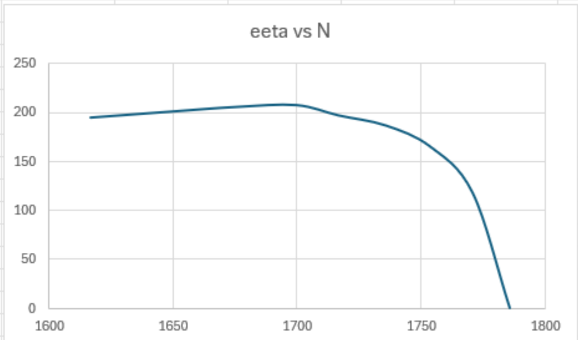
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **(W)** | 20.9 | | | | | | | | | | |
| **$P_{mech,out}$ (W)** | 0 | 46.4 | 91.9 | 136.4 | 179.85 | 223.58 | 263.41 | 303.4 | 338.3 | 0 | 47.06 |
| **$\eta$(%)** | 0 | 136.47 | 194.29 | 224.34 | 239.8 | 248.7 | 250.38 | 249.52 | 250.4 | 0 | 27.32 |
| **Voltage** | 209.0 | 209.2 | 208.7 | 208.9 | 209.0 | 208.8 | 208.8 | 208.4 | 209.0 | 209.2 | 209.1 |

**Plots:**




**Questions:**

*1. Compare load characteristics of the three-phase induction motors with star and delta connections through Figures.*

1.) Comparing T v.s. N, we see the same general trend. In part A we have a larger range of speed, and thus we can see more of the curve shape.

2.) Comparing I v.s. N, we see the same trend in the negative slope. We also have a limited range here and thus cannot see the full shape in part B

3.) Comparing T v.s. I, we see they both follow a positive trend, and have a parabolic shape.

4.) Comparing eeta v.s. N, we see a similar trend, but not the exact same. In part A, our graph peaks and then begin decreasing, whereas in part B we have limited range and thus we only see a steady value, and then a decrease

*2. Power factor and efficiency affect the economical use of a motor. Calculate the product of power factor and efficiency, for each speed (delta connection) and compare it through Figures. What can be said of the results of the calculations?*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **cos** | -0.276 | -0.438 | -0.567 | -0.663 | -0.731 | -0.772 | -0.808 | -0.833 | -0.848 |
| **%** | 0 | 117.67 | 164.59 | 186.27 | 196.51 | 207.05 | 205.2 | 200.52 | 194.3 |
| **product** | 0 | -51.53946 | -93.32253 | -123.49701 | -143.64881 | -159.8426 | -165.8016 | -167.03316 | -164.7664 |

We see that the product of power factor and efficiency decreases as we increase torque. We expect this because power factor and efficiency are inversely proportional, therefore as torque increases, so does the required power. This ultimately leads to a decrease in power factor.