THE HASHMITE UNIVERSITY

ELECTRICAL ENGINEERING DEPARTMENT

ELECTRICAL MACHINES LAP

LAP REPORT # 5

Induction Motor II

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Objectives :

The objective of this experiment is star – delta start and plugging , to measure the efficiency at different loads , and to measure the torque characteristics , the torque is a function of the slip (s) .

Theoretical Background :

The induction motor is the most common of all motors , this is because of various advantages is has , such as its simple constriction ,cheaper than other motors and it needs less maintenance than many other motors .

The torque as a function of the slip is:

$$\tau_{\text{ind}} = \frac{3V_{\text{TH}}^2 R_2/s}{\omega_{\text{sync}}[(R_{\text{TH}} + R_2/s)^2 + (X_{\text{TH}} + X_2)^2]}$$

Where :

Vth: is the voltage of the stator

Rth : Thevenin equivalent stator resistance .

Xth : Thevenin equivalent stator inductance ..

R2 : Rotor resistance .

X2 : Rotor Inductance .

ω sync : synchronous angular speed .

s : the slip and is defined as :

$$s = \frac{n_{\text{sync}} - n_m}{n_{\text{sync}}}$$

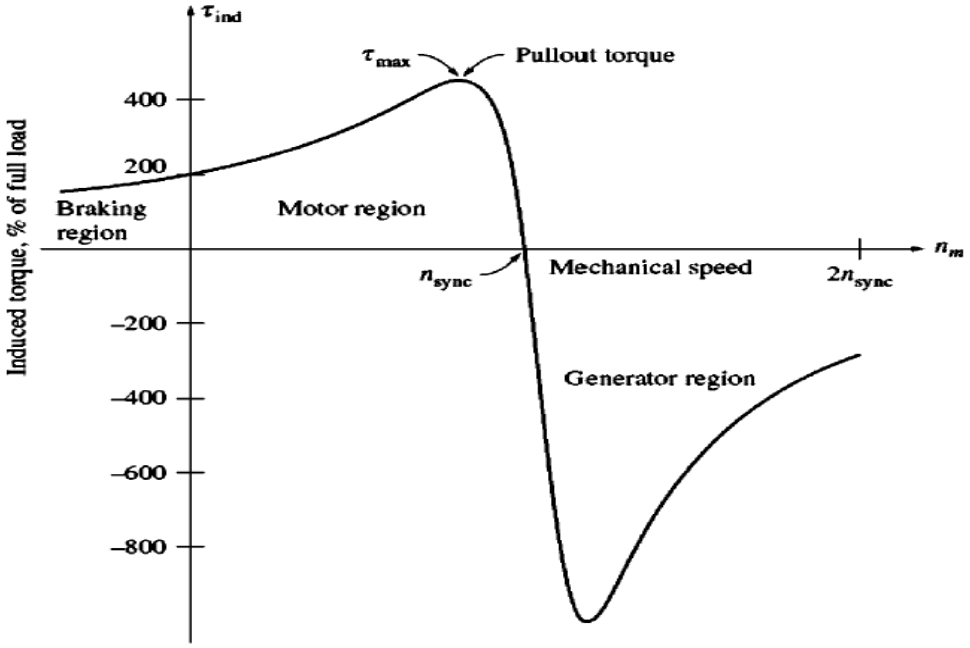
And n sync(nm is defined similarly) is defined as :

$$n_{\text{sync}} = \frac{120 f_e}{P}$$

Where : fe is the frequency of the source and P is the number of poles .

We see from the first equation that the torque is proportional to the square of the stator voltage , which means that it will be very sensitive to the variation of the source voltage .

Atypical plot of the first equation (torque as a function of the mechanical sped) is shown in the figure below :



*Note : nm = (1-s) * n synch , so this curve also represents the torque as a function of the slip with a shift and reflection about the torque axis .*

There are a few critical points in the curve , which are :

1.When the motor is running at synchronous speed (i.e. s = 0) the induced torque is equal to zero .

2.The maximum torque of the motor is called "Pullout torque" , and the slip at which the torque is maximum is called Smax , and is given by the following formula :

$$s_{max} = \frac{R_2}{\sqrt{R_{TH}^2 + (X_{TH} + X_2)^2}}$$

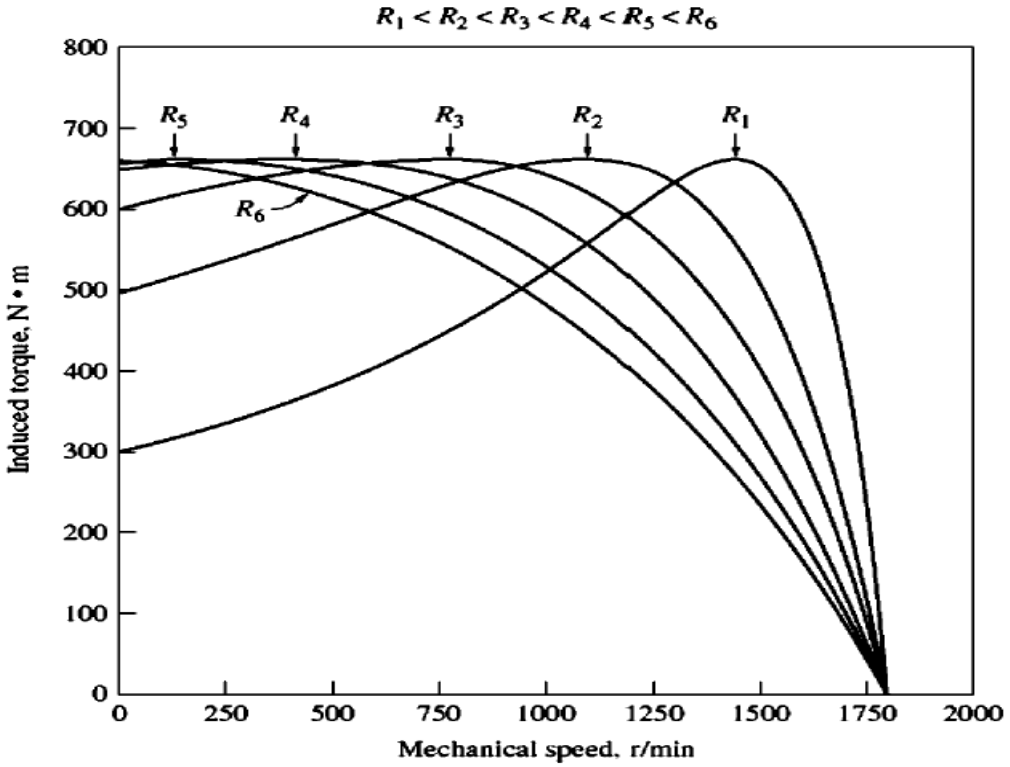
3.When the slip is one (i.e. the mechanical speed is zero) the motor is at starting conditions.

4.If the slip is less than one (i.e. the rotor is running at higher speed than the magnetic field) the motor actually becomes a generator (called regenerative conditions) .

5.If the slip is more than one then it means that the motor is running at opposite direction relative to the magnetic field, which means that it will stop rapidly (called counter-current braking conditions) and this operation is called "Plugging" .

Plugging is done by switching two terminal voltages (phases of the voltage change) causing the magnetic field to switch direction.

We see from the equation of the max slip that it's proportional to the rotor resistance , which means that if we increase the rotor resistance we can start the motor at the pullout torque , this is done by inserting an external resistance in series with the rotor when starting the motor then it's removed, the is operation will cause the characteristics to be shifted as shown in the figure below :



Equipments :

We used the induction motor , a sensitive multimeter , a measurement unit & eddy current brake in this experiment .

Procedure :

1.Measuring the efficiency characteristics and toque characteristics :

We used the practical diagram to connect the induction motor and the eddy current brake , we used the eddy current brake to take measurements of speed and to control torque , then we started adjusting the ac voltage until 220 V and held this value constant , we set the connection to wye (using X switch) and started the motor by switching the switch Z to forward , the motor started accelerating , when the speed became constant we switched X to delta connection , we set the load of the motor to minimum using eddy current brake and started taking measurements by varying brake force by steps of 1 NM , the results of the measurements is shown in the following table :

Measured Values			
I_1 (A)	P_{in} (w)	$M_{(NM)}$	$n_{(rpm)}$
2.7	260	0	
2.8	405	1	1500
3.03	700	2	1490
4.25	1460	3	1440
4.44	1500	4	1430
4.74	1580	5	1420

To calculate the output power we used the relation : $P_{out} = M*2*\pi*N/ 60$, and to calculate the efficiency we used the ratio between the output power and the input power , the power factor can be calculated using the input current , voltage , and power using the relation :

$$Cos\,(\theta) = \frac{Pin}{\sqrt{3}\,Vt\;\;Iin}$$

The slip is calculated using the relation :

$$S = \frac{n1 - n2}{n1}$$

Where n1 is fixed and equal 1500 rpm , calculated using the following relation with 4 poles and frequency of 50 HZ :

$$n_{sync} = \frac{120 f_e}{P}$$

A summary of calculated Values is shown next (corresponding to measured values) :

Calculated Values			
$P_{out\ (w)}$	η %	$Cos\ (\theta)$	S %
0	0	.2527	
157.08	38.78	.514	0
213.06	30.4	.606	.666
452.4	31	.901	4
599	40	.886	4.66
743.51	47.05	.874	5.33

2. Starting current:

We set the connection using the X switch to delta connection , and used the Z switch to start the motor , we made sure that the eddy current brake is set to maximum , and the rotor isn't rotating , we started to adjust the voltage in away such that the stator current is increased by steps of 1 , we repeated the same procedure for wye connection , the following table shows the results for this test :

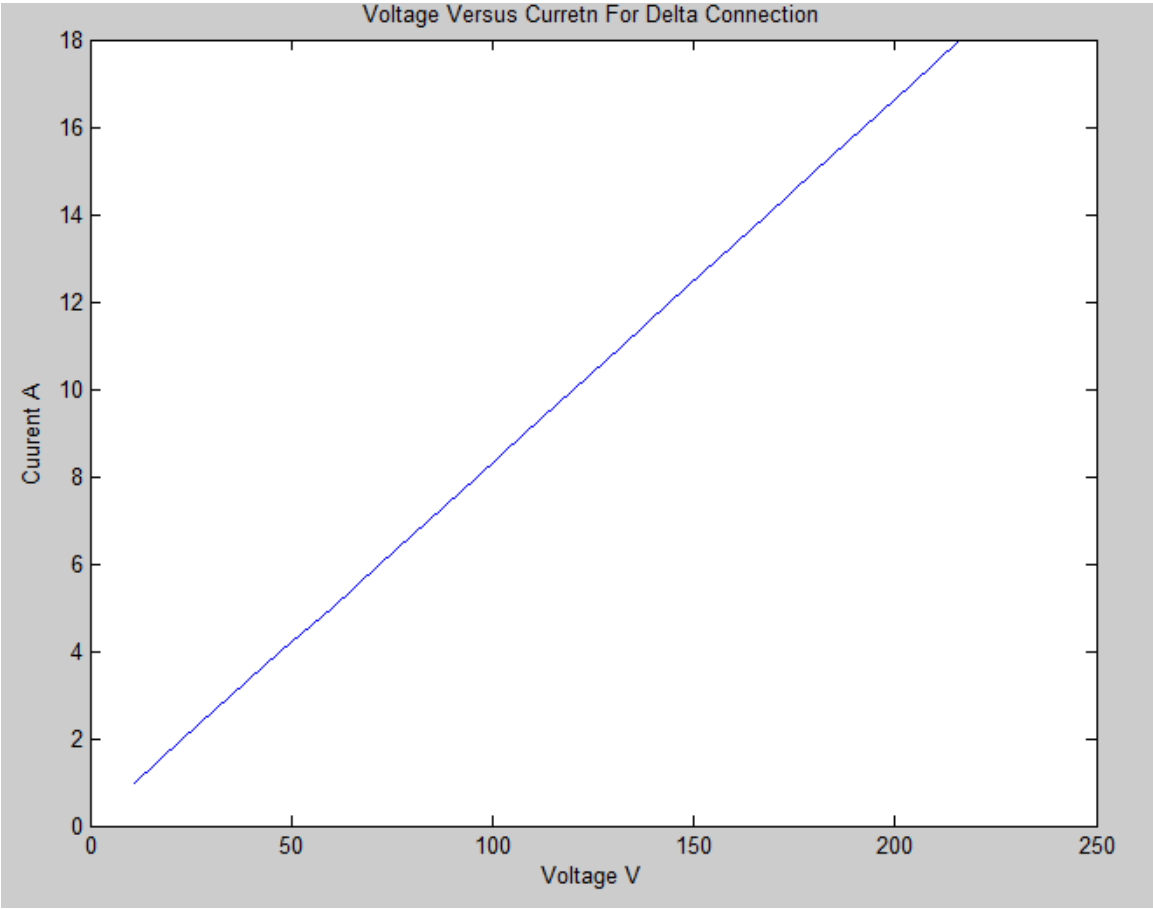
	Delta rated Current					Wye rated Current		
U(v)	11	23	35	47	60	35	72	107
I_1(A)	1	2	3	4	5	1	2	3

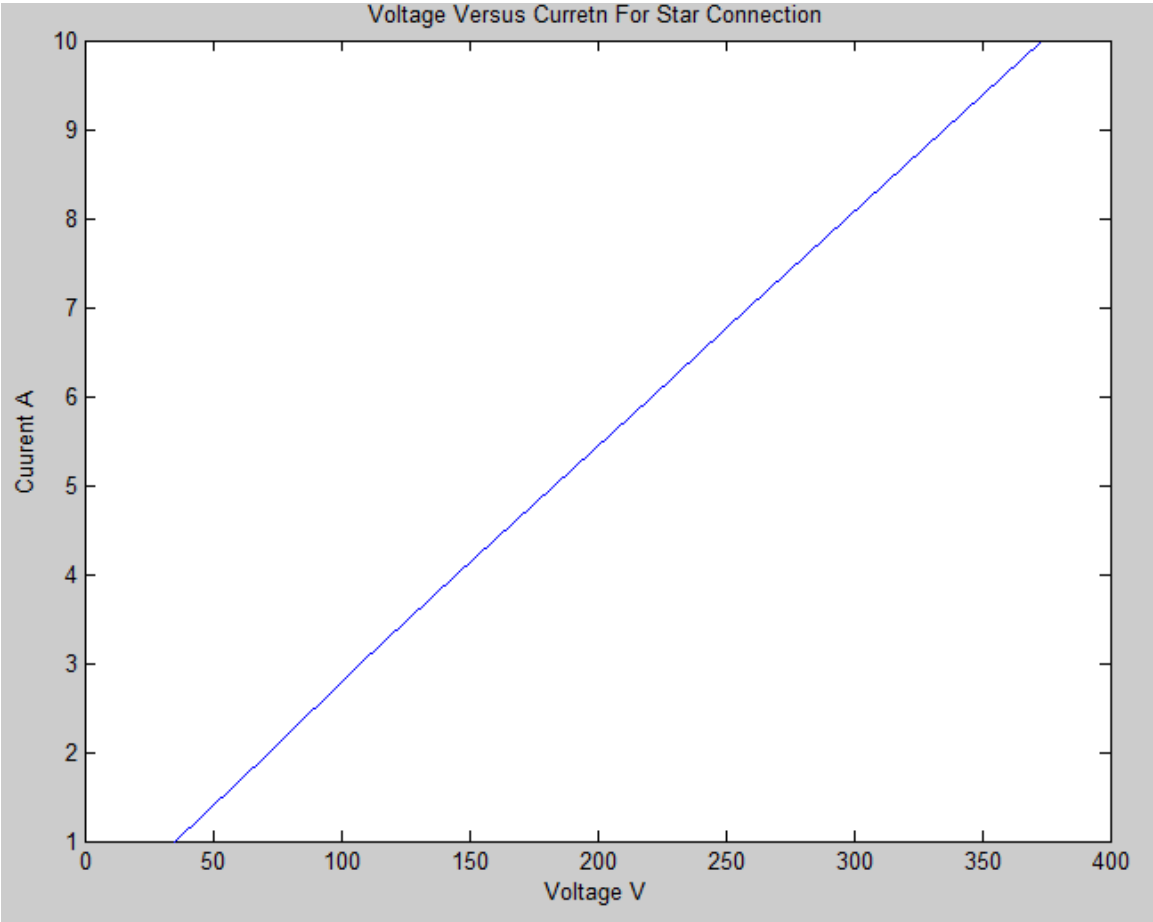
3. Plugging:

We Used the X switch to set a wye connection , the set the voltage to 220 volts , and started the motor using the Z switch set to forward , the motor started to accelerate , when it stopped accelerating we changed the connection to delta connection , then we changed the direction of the magnetic field using the Z switch set to "Reverse" , the motor started to slow down much faster than the normal turn off .

Problems:

1.Using the results, draw the graph $I_1 = F(U)$, the starting current as a function of the stator voltage . The U axis must run to 220 V, Extend the curve and read the starting current at rated voltage.

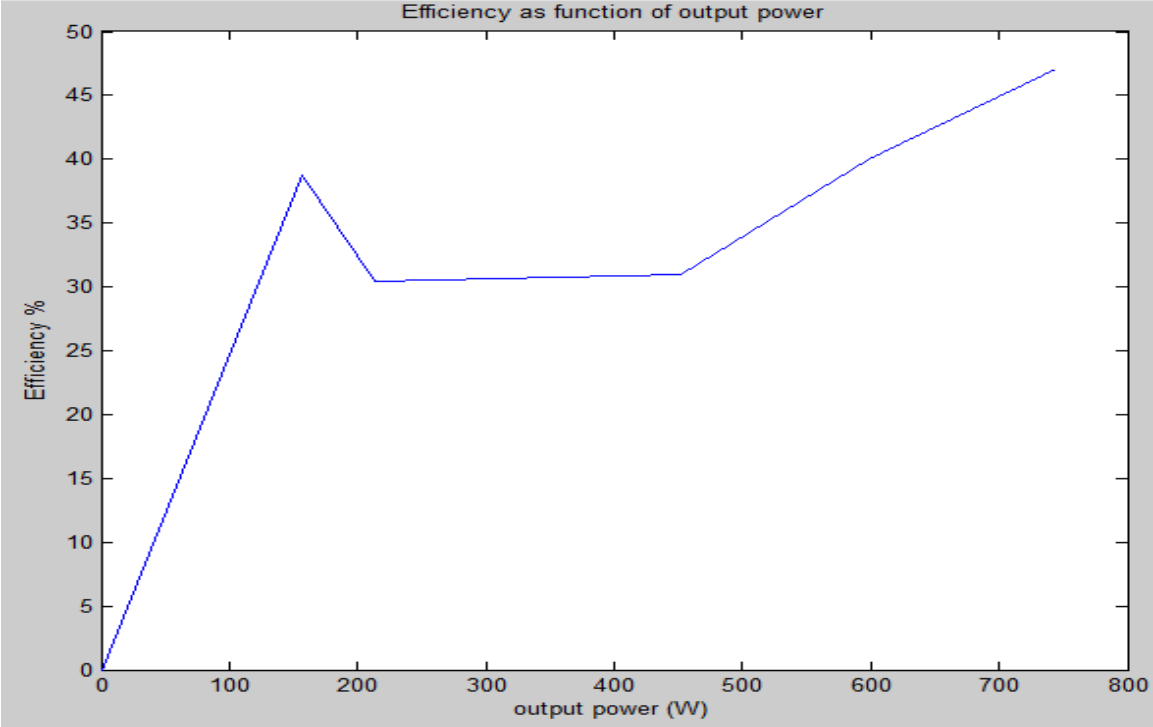


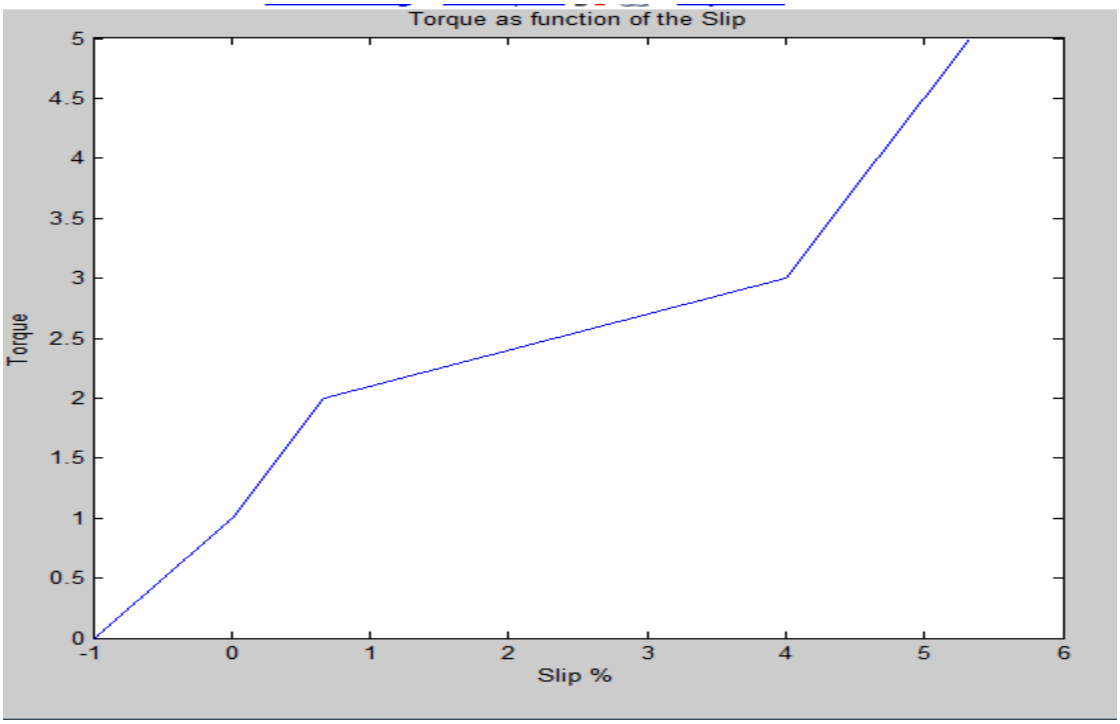


2. Calculate the ratio between starting current for delta and star connection. What is the theoretical value?

The ratio is almost 18.3/10.4 = 1.76 , The theoretical value is $\sqrt{3}$ *= 1.732*

3. Draw the graphs (η = f(P_{out})) for measurements in the table , and the graph for M = f(s) , Extrapolate graphs to M = 0 . What should be the slip for M =0 ? Explain the difference .





The difference is due to friction with air , so when the torque is zero , we the motor will rotate at faster speed (to overcome the friction of air) than the synchronous speed and the motor becomes a generator .

4. Calculate the percentage of no load current in the relation to the rated current .

No load current is 2.7 and rated current is 4.8 , the ratio is .5625 .

Conclusions :

1. In this experiment we saw how the motor is started and how the loads are connected , and how different measurements are taken , measurements of speed , torque , current , and voltage .

2. we learned how to make a delta connection in the induction motor , how to switch to a star connection using a switch , how motor is accelerated , and how different calculations are made .

3.We saw how plugging the motor is used to turn it off in a very short time.