EE-234
Experiment No.: 5

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April 13, 2018

1 Aim

To obtain torque speed characteristics (T-N_r) of the squirrel cage induction motor using

- Variable Voltage control
- Variable voltage variable frequency control

2 Equations and Circuit Diagram

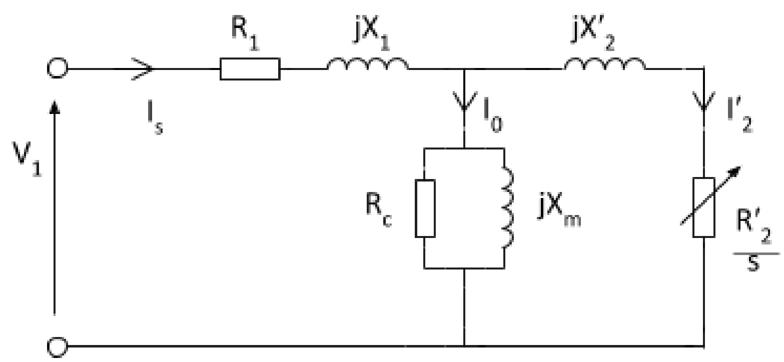

Figure 1: Equivalent circuit of Induction motor

vontrol.png

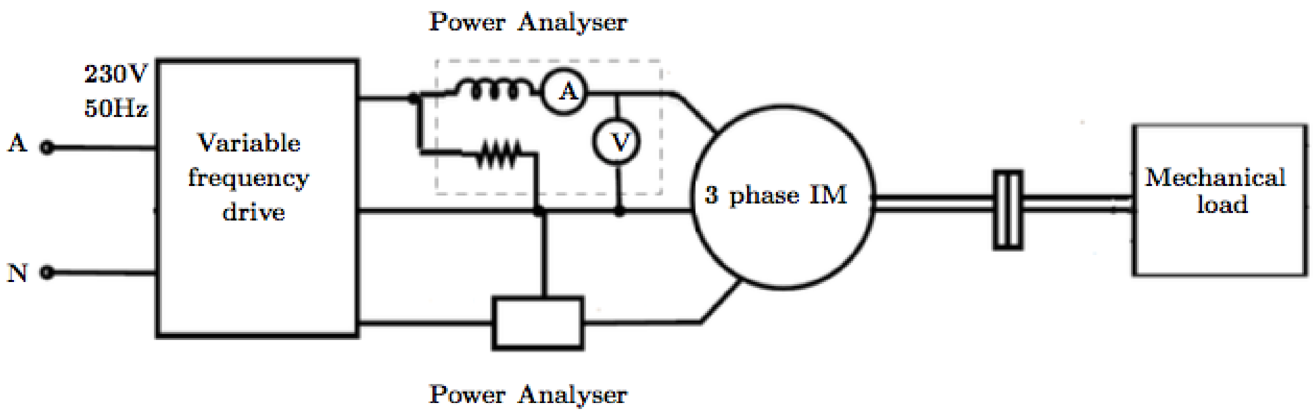

Figure 2: Circuit diagram for VVVF control

vol.png

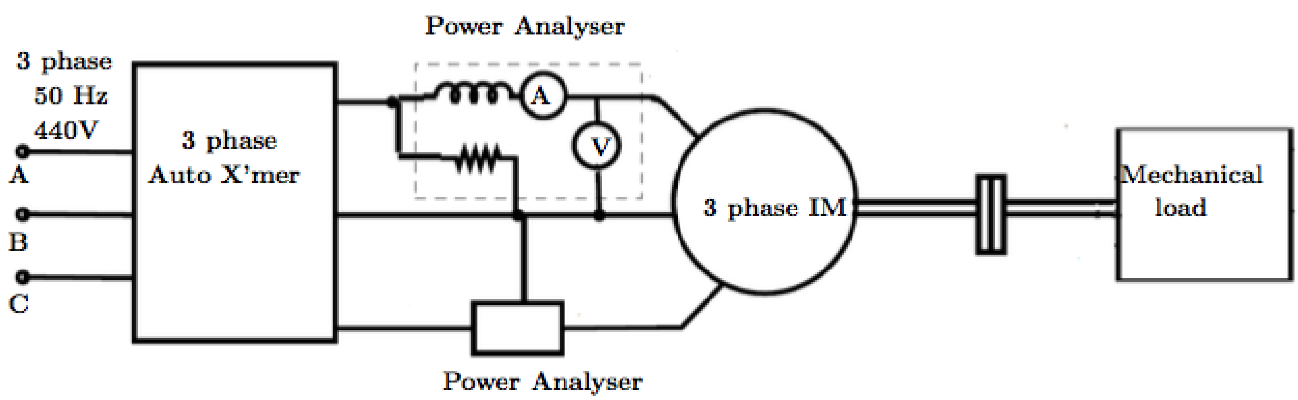

Figure 3: Circuit diagram for variable voltage control

Speed of stator field i.e synchronous speed

$$N_s = \frac{120f}{p}$$

The slip is given by

$$s = \frac{N_s - N_r}{N_s}$$

Torque expression for induction motor:

$$T = \frac{3V_s^2 R_2/s}{\omega_s((R_1 + R_2/s)^2 + (X_1 + X_2)^2)}$$

from this, we can get the T-N_r relation

2.1 Variable Voltage control

If we vary only the voltage applied to the stator then Torque will vary proportional to V_s^2. The value of slip at which torque is maximum is given by:

$$s = \frac{R_2}{\sqrt{R_1^2 + (X_1 + X_2)^2}}$$

Hence we see that it is independent of V_s. Thus we can expect the graph of T-N_r to look something like this:

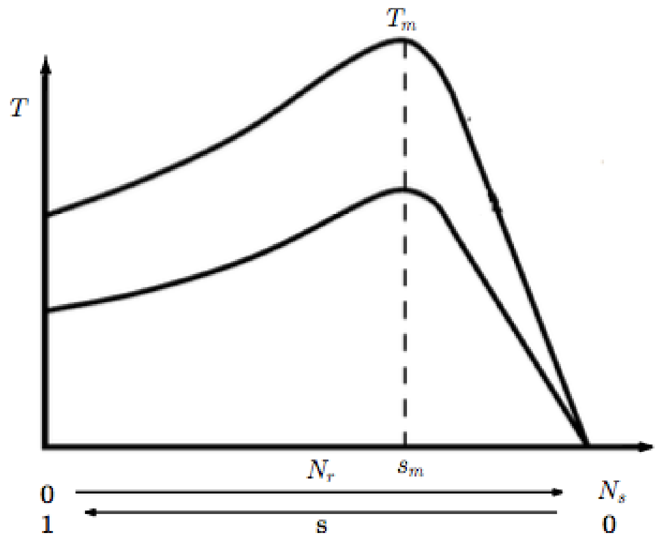

Figure 4: Variable voltage control

2.2 Variable Voltage variable frequency control

In VVVF control, we vary Voltage and frequency of stator voltage such that V/f is constant. This is done to keep the operating flux constant as

$$\phi \propto \frac{V}{f}$$

If $V_s = KV_{rated}$ and $f = Kf_{rated}$ then torque is given by:

$$T = \frac{3V_s^2 R_2/sK}{\omega_s((R_2/sK)^2 + X_2^2)}$$

and max torque is given by :

$$T_m = \frac{3V_s^2}{2\omega_s X_2}$$

which is independent of K. Hence max torque remains constant. Thus we can expect a characteristics as follows:

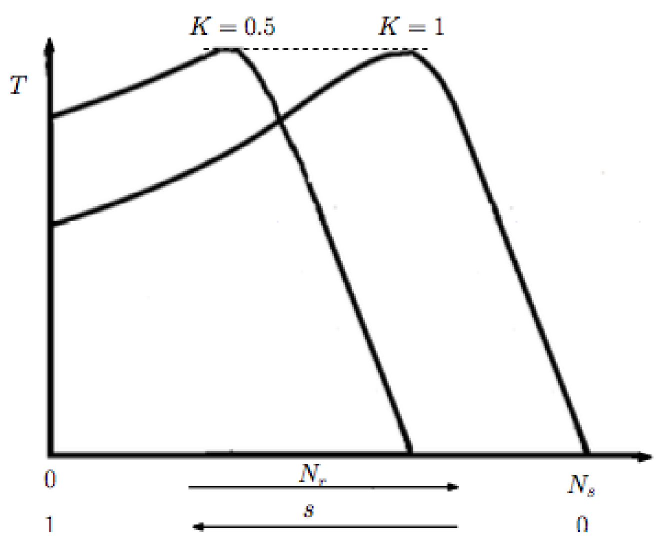

Figure 5: VVVF control

3 Observations

3.1 Variable Voltage control

Vs=110V				
Load	Ir(A)	Vr(V)	Nr(rpm)	Torque(Nm)
0	0	160.3	1463	0
2	0.4	154.2	1437	0.4713678425
4	0.8	149.3	1405	0.9335677153
5	1.2	145.5	1386	1.383417812
6	1.5	141.9	1352	1.728897781
7	1.7	136.2	1308	1.943974837
8	2.1	129.3	1245	2.395084401

Figure 6:

Vs=220V				
Load	Ir(A)	Vr(V)	Nr(rpm)	Torque(Nm)
2	0.4	159.9	1482	0.4737098125
4	0.8	157.4	1475	0.9370328666
6	1.5	154.9	1469	1.736093098
8	2.1	152.3	1464	2.397895489
10	2.75	149.9	1453	3.114016015
12	3.54	147.5	1447	3.960763222

Figure 7:

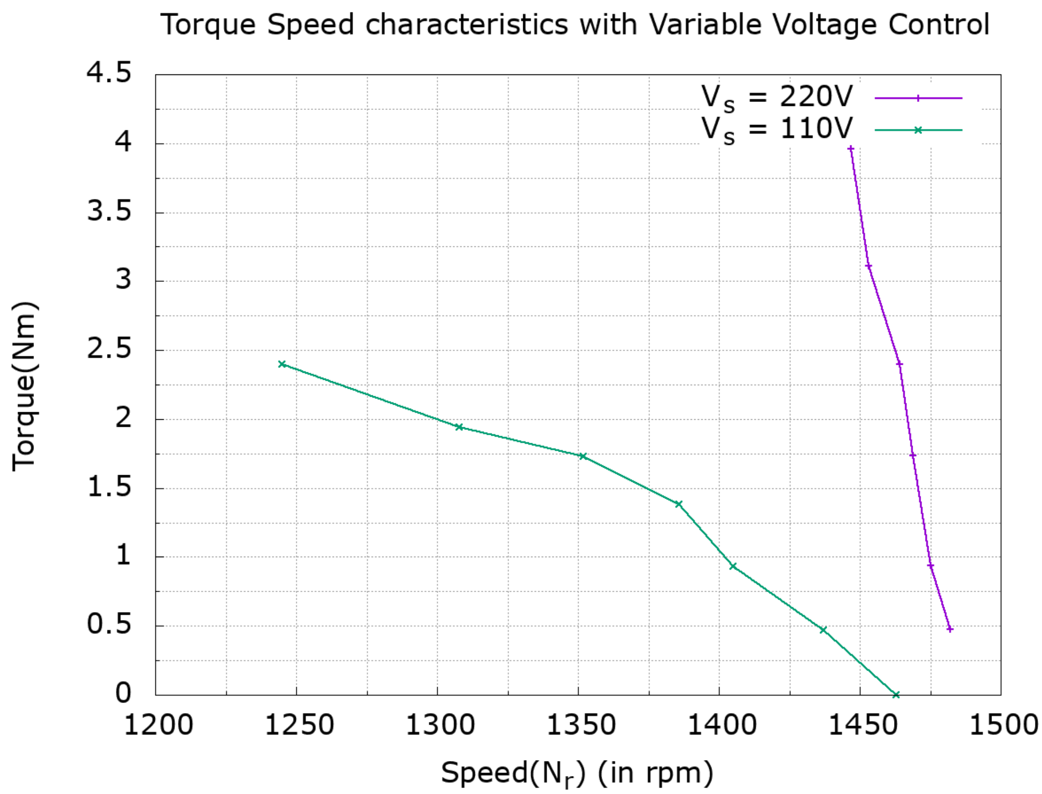

Figure 8:

3.2 V/f Control

Ns = 800 rpm				
Load	**Ir(A)**	**Vr(V)**	**Nr(rpm)**	**Torque(Nm)**
0	0	86.5	791.9	0
2	0.3	83.3	787.9	0.3483112563
4	0.6	81.6	783.9	0.6858878326
6	1	80.1	779.2	1.128901178
8	1.5	78.9	774.2	1.678755503
10	1.9	76.6	769.2	2.077856011
12	2.4	75	764.4	2.585974159

Figure 9:

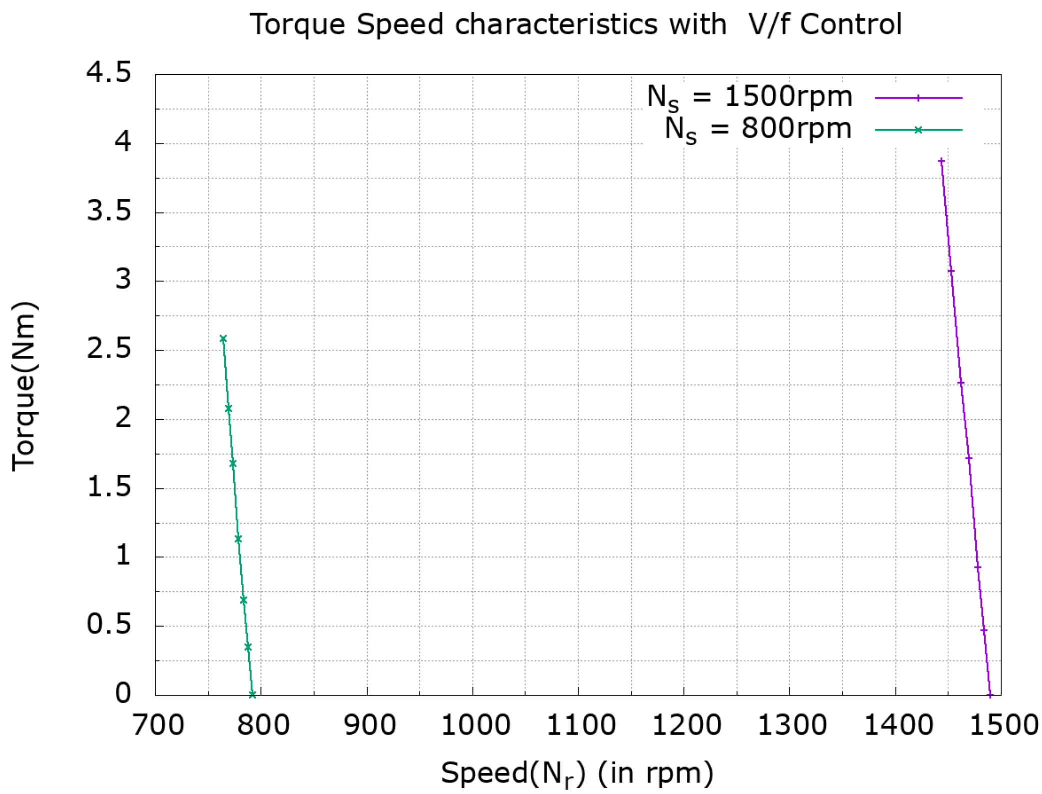

Figure 10:

Ns = 1500 rpm				
Load	**Ir(A)**	**Vr(V)**	**Nr(rpm)**	**Torque(Nm)**
0	0	161.3	1490	0
2	0.4	158	1484	0.467687251
4	0.8	155.5	1478	0.9243113806
5	1.5	153.2	1470	1.716742045
6	2	150.6	1462	2.262454995
7	2.75	147.9	1453	3.074026503
8	3.5	145.3	1444	3.867575669

Figure 11:

4 Inference

In the first part of the experiment we vary the torque keeping the supply frequency constant(frequency(f) control). As the torque is dependent on the magnetic field strength, it in turn is proportional to the field flux and correspondingly to the applied stator voltage.Thus, the maximum torque is dependent on the applied stator voltage.However, the slip at which the torque is maximum is constant. Thus, This method gives a speed control only below the

normal rated speed as the operation of the voltages if higher than the rated voltage is not admissible. This method is suitable where the intermittent operation of the drive is required and also for the fan and pump drives.However it is not suitable for constant load operation and also produces less starting torque.
In the second part we explored the $\frac{V}{f}$ control, which we keep the flux to be constant and vary the stator voltage and frequency accordingly. Here we observe that the maximum torque remain constant but the slip at which torque is maximum varies.This enables us to reach rated voltage and frequency values at base speed.This control can prove to be advantageous for several applications.In general, we can achieve wider range of speed and the starting current requirement is also low.

5 Demo experiment

In the demo, we were shown the polyphase AC systems.The demo expeiment consisted of a demonstration of a 3 phase distributed under the following conditions-

- **Application of DC current** When a DC current is applied to any one of the 3 windings, there is a sinusoidal distribution of flux in space. The flux produced due to each phase is phase shifted by 120 degree electrical angle with respect to each other, which is due to the fact that the windings are 120 degree apart in space. We verified this by putting the compass at the centre of the winding and observing its direction of deflection.
- **Application of 3 ϕ AC current** When a 3 phase AC supply is connected to the winding, the distribution of the flux generated wrt time for each winding becomes sinusoidal. Due to this a rotating magnetic field is generated. This was demonstrated through the MATLAB(octave) simulation of the same. Additionally, a 3 ϕ AC supply was applied to the winding. We then checked the direction of the field by placing a compass which we then observed was rotating which confirms the presence of rotaing magnetic field.
  Additoinally we observed that at the centre of the winding(the axis of rotation of the magnetic field) the compass needle does not rotate. This is because the magnetic field at the centre is zero, as the 3 symmetrically placed windings with a current at a phase difference of 120 degree to one another cancel each other out completely.