

Operation of a 3 – phase induction motor in star and delta circuit

Object: The first object of this experiment is run the three – phase induction motor first in star and then in delta circuit. The second object is to determine the torque – speed characteristics of a 3 – phase induction motor $M = f(n)$.

Theory: At the instant of starting, the rotor is at stand still. The rotary field in the stator induces the rotor voltage U_r in the rotor. Since the rotor conductors are short – circuited, however, this results in a very high rotor current I_r . The rotor voltage has the same frequency as the stator rotary field. According to the law of "current carrying conductor in a magnetic field" a force acts on the winding through which the rotor current is flowing which affects the circumference of the rotor and thus forms an "inner" torque M which attempts to turn the rotor. If you now release the rotor, it is accelerated by the torque, the motor runs up and the induction effect of the stator rotating field on the rotor is reduced because only the time – related change of the magnetic flux is effective in the rotor.

The speed variation of the magnetic flux depends, however, on the relative speed between the stator rotating field and the rotor movement. Since only the relative movement of the stator rotating field to the rotor is effective, the rotor current and rotor voltage gets smaller with increasing rotor speed n . The inner torque is then also reduced.

For the somewhat ideal case that no external torque has a braking effect on the rotor, this is accelerated up to the synchronous speed on no – load. As a result, however, there would be no more relative movement of the rotor in relation to the stator rotating field which would result in the rotor current, rotor voltage and internal torque being zero. Since torques with a braking effect such as bearing friction or coupled load torques always exist in practice, the rotor speed is lower than the speed of the rotary field. The three - phase induction motor can therefore only form a torque when there is a relative speed or slip between rotor and stator rotating field.

The slip s is defined as the difference between the speed of the rotating field (n_0) and the rotor speed (n). This gives values between ($s = 0$) for slip for the theoretical case that the motor speed corresponds to the synchronous speed and ($s = 1$) for motor at standstill, where:

$$s = (n_0 - n)/n_0$$

where:

n_0 : speed of the rotating field (synchronous speed)

n : rotor speed (motor speed at any load)

The frequency (f_r) of the rotor induced voltage is obtained from the equation:

$$f_r = s \times f_s$$

Star / delta startup of the motor:

Three – phase induction motors above 5.5 kW consume a too high turn – on current during starting which can cause serious mains voltage interruptions. To avoid this the star/delta – startup circuit is used. The turn – on current and the starting torque in star circuit are only a third of the current and the torque in delta circuit. The motor is switched on in star circuit and switches over to delta circuit on reaching the rated speed. The motors must be designed for delta circuit operation, i. e. 400 V must be specified on the rating plate for example for operation on the 400 V three – phase mains supply.

Necessary equipments:

1. Three – phase induction motor (Type 2707).
2. Brake Unit (Type 2719).
3. Control Unit (Type 2730).
4. Universal Power Supply (Type 2740).

Procedure:

Run I:

1. Connect the circuit as shown in Figure (18). Note that the motor stator winding are star connected.
2. Start up the system as already described in experiment 1. The motor must rotate to the right (CW).
3. At no – load, record the speed (n) and the torque ($M \approx 0$) in Table (5) shown below.
4. Slowly increase the load, below the rated value, and record the corresponding speed and torque in the table.
5. Slowly increase the load to obtain the rated speed and then record corresponding torque and the rated speed in the table.
6. Slowly increase the load to obtain a speed above the rated speed and then record the corresponding torque and speed in the table.
7. Increase the load till it reaches the maximum torque. Record the speed and pull – out torque in the table.
8. Increase the load to above the maximum one such that the motor speed is reduced to a minimum available, and record this speed and the corresponding torque in the table.
9. To finish this run, first switch *OFF* the Universal Power Supply and then the Control Unit.

Run II:

1. Connect the circuit as shown in Figure (19). Note that the motor stator winding are delta connected.
2. Repeat steps (2 – 8) listed in the previous run. The results are recorded in Table (6) for delta connection.
3. To finish the experiment, first switch *OFF* the Universal Power Supply and then the Control Unit.

Notes:

- Carry out the measurements without delays if possible. If the motor heats up too much, the measuring results deviate and the motor must cool down.
- Record the characteristic points first on no – load, then for rated speed, then for the pull – out torque and finally for the minimum achievable speed.
- Determine the sub – values in the tables yourself. Make sure that the characteristic points are meaningful.
- Observe the setting of the torque attenuator.

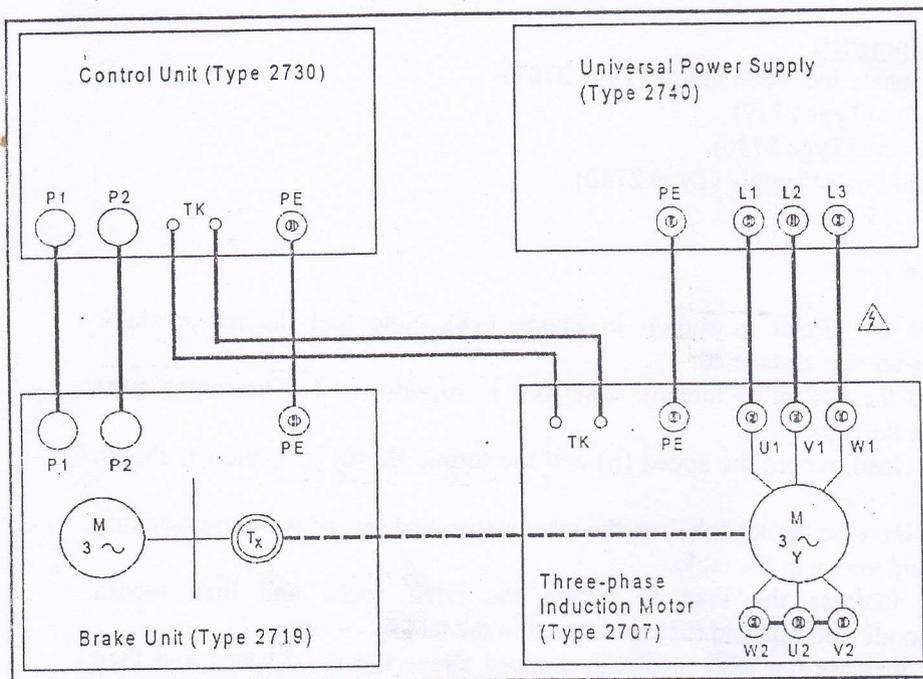


Figure (18)

Star connection circuit diagram of a 3 – phase induction motor

Table (5)

Torque – speed (load) characteristics of a 3 – phase induction motor
With star connected stator windings

Characteristics points	n / rpm	M / Nm
No – load speed		
1st sub - value		
Rated speed		
2nd sub – value		
Pull – out torque		
3rd sub – value		
Minimum speed		

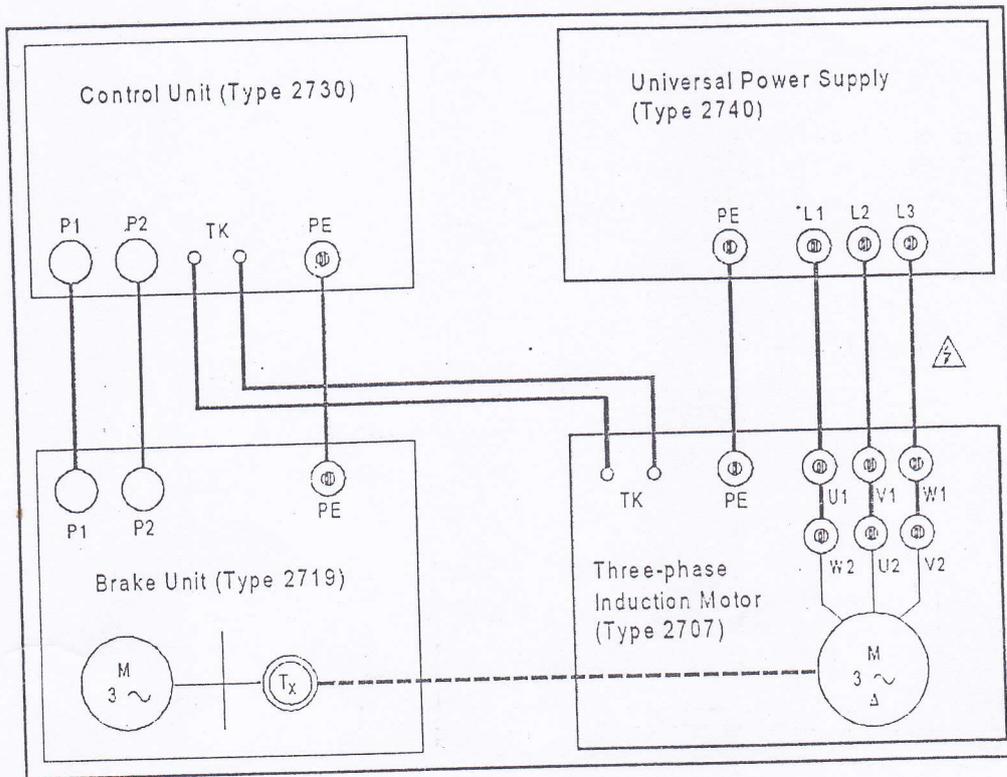


Figure (19)
Delta connection circuit diagram of a 3 – phase induction motor

Table (6)
Torque – speed (load) characteristics of a 3 – phase induction motor
With delta connected stator windings

Characteristics points	n / rpm	M / Nm
No – load speed		
1st sub - value		
Rated speed		
2nd sub – value		
Pull – out torque		
3rd sub – value		
Minimum speed		

Report & Discussion:

1. Draw the load characteristics listed in Table (5) and Table (6). Compare between the two curves. How the torque does behave in both types of connection?
2. The rating plate of a three – phase induction motor carries the specification D/Y 230/400 V. How does the motor behave in delta circuit on the 400 V three – phase mains?
3. When is the star/delta – startup circuit used? Describe the function of the circuit.