OBTAINING THE CIRCUIT PARAMETERS OF A THREE-PHASE ASYNCHRONOUS MOTOR

1. Purpose of Experiment

Calculation of losses of Three Phase Asynchronous motor through idle and short circuit experiments and deriving equivalent parameter values.

2. Materials

- One three-phase asynchronous motor
- NE7010 Machine experiment set
- One three-phase auto transformer
- Three avometers

3. Preparation Questions

1)Why are asynchronous machines also called induction machines?

2) Draw the complete and approximate electrical equivalent circuit of the asynchronous machine and explain the elements in the circuit.

3)What do you understand about idle operation and short circuit losses of asynchronous motor?

4) Why do idle-operated asynchronous motors draw more magnetizing current than idle-operated transformers? Explain.

5) Explain with the formula why the induced voltage in the rotor windings is low when asynchronous motors operate at idle.

6)Why is the short circuit test not performed at rated voltage?

7)Draw the M = f(n) graph of the asynchronous motor and state the important points.

8) Draw the electrical equivalent circuit of a direct current parallel excitation machine.

9) The stator winding resistance of a 220 V, 50 Hz, 6-pole, star-connected, 1410 rpm and 4.5 kW power asynchronous motor was measured as 0.8125 Ω using a multimeter. In the empty study experiment; U0=220V, I0=9.8A, P0=540W and in the short circuit experiment; Measured as UK=60V, IK=20.2A, PK=1080W.

a.Calculate and draw the equivalent circuit parameters of this asynchronous motor?

b.Find the rated moment of the machine and the slip at this moment.

4.Three Phase Asynchronous Motor Experiments

4.1. Entrance

Every electrical machine is a device that transforms energy, and electrical energy is seen at least once in this transformation. Generators convert mechanical energy into electrical energy, and motors convert electrical energy into mechanical energy. There are always losses in energy conversions, and these losses appear as heat. One of the main advantages of electrical machines is that losses are small and therefore their efficiency is very high.

Electric machines are used with increasing importance as generators in power plants and as engines in industry, transportation, offices, homes and drive mechanisms because they work with electrical energy, which is the highest quality among all types of energy, and are suitable for all kinds of control and control. Electric motors run almost all work machines wherever there is electrical energy. While they provide the necessary mechanical power, they also allow operations to be carried out in the best and most economical way. Industrialization, increasing production and productivity, shortening working time and improving working conditions could be achieved with the widespread use of electric motors in industry.

4.2. Structure and Operation of Asynchronous Motors

An asynchronous motor consists of two basic elements, one stationary (stator) and the other rotating (rotor). In the stator, three-phase rotating field windings with a 120o electrical angle between their axes are placed in the slots. The rotor usually has shorting bars (squirrel cage ASM). However, the rotor may also have three-phase windings. In motors with wound rotors, the winding ends are often brought out with the help of bracelets and brushes (bracelet ASM). Rotating field windings create a field rotating at synchronous speed (ns) in the air gap between the rotor and stator.

$$n_s = \frac{60 * f_s}{p}$$

Here, fs: Stator windings supply frequency. p: Number of pole pairs. If the rotation speed of the rotor is nr, the relative speed of the rotating field with respect to the rotor will be ns-nr. In this case, the rotating field is in the rotor windings.

$$f_2 = (n_s - n) * p$$

It induces a frequency voltage. Ratio of rotor and stator frequencies,

$$\frac{f_r}{f_s} = \frac{n_s - n_r}{n_s} = s$$

It is defined as slippage. Voltages with frequency fr induced in the rotor conductors, the force acting on the rotor conductors with current Ir.' flowing through the rotor conductors, cause the rotor to rotate.

Examine the operating conditions of the machine according to the rotor speed, synchronous speed and slip conditions below.

$$\mathbf{n_r < 0, s > 1}$$

The rotor rotates in the opposite direction to the rotating field. This mode of operation is called “BRAKING”.

$$\mathbf{0 < n_r < n_s, 0 < s < 1}$$

The electrical power received from the network is converted into mechanical power on the motor shaft. The machine works as “ENGINE”.

$$\mathbf{n_r > n_s, s < 0}$$

It means that the rotor rotates at a speed above synchronous speed. In this case, the direction of energy flow is from the rotor to the stator. In these conditions, the machine works as a "GENERATOR".

$$\mathbf{n_r = 0, s = 1}$$

As can be understood from the fact that the speed is zero, the engine is "STOPPING".

$$\mathbf{n_r = n_s, s = 0}$$

It means that the rotor rotates at synchronous speed, in which case no voltage is induced in the rotor conductors since the rotor is stationary relative to the rotating field. Therefore, the force that causes the rotor to rotate disappears and the engine slows down. This operating point is a theoretical point for an asynchronous machine.

4.3.1. Idle Operation Experiment of Three Phase Asynchronous Motor

Asynchronous motors operated at idle draw power from the network. This absorbed power gives the sum of stator iron losses, friction and ventilation losses. Since the speed of the idle engine is close to the rotating field speed, the iron and copper losses of the rotor are negligible. Currents flowing through the stator windings of an asynchronous motor operating idle under normal mains voltage cause copper losses in these windings. If this loss is calculated and subtracted from the power drawn by the motor from the network, the remaining power gives the sum of the stator iron losses, friction and ventilation (wind) losses.

$$P_0 = P_{Fe} + P_{Cu0} + P_{s+v}$$

$$P_{Cu0} = I_{10}{}^2 . R_s$$

This value is the power lost over the resistance of the stator windings and is called the copper loss in idle operation. If we substitute equation 5 into equation 4, we can find the total of iron and friction losses.

In these formulas;

P_0: Free operating power drawn from the network (watts)

P_{Fe}: Stator iron loss (watts)

P_{Cu0}: Stator copper loss in idle operation (watts)

P_{s+v}: Shows friction and ventilation (wind) losses.

I_{10}: A phase current (ampere) passing through the stator windings.

R_s: Stator one phase winding a.c. It shows the ohmic resistance (Ω).

In the experiment, the voltage is reduced to approximately 25% of the nominal voltage, where the number of revolutions remains almost constant. It is seen that the engine speed decreases more at voltages lower than this value. The power up to the point where the constancy of the rpm is broken is equal to the friction and wind losses and can be considered constant.

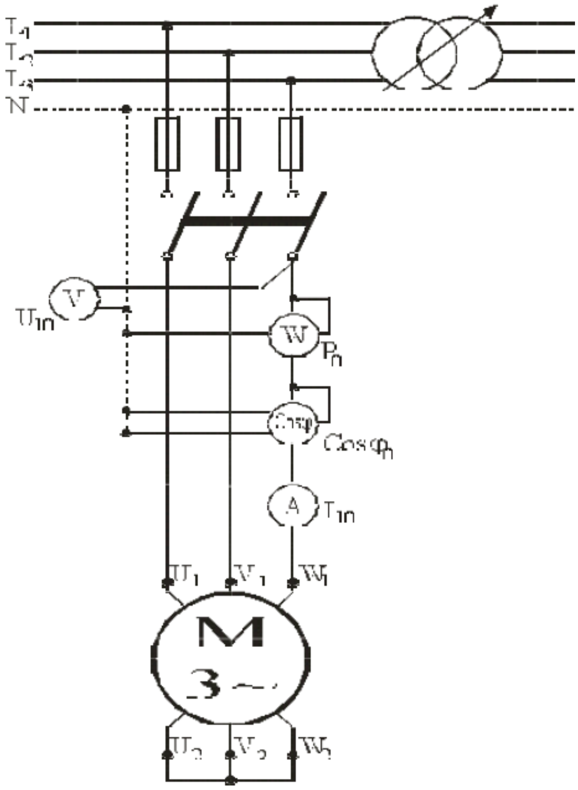

Figure 1. Idle operation wiring diagram

To carry out the idle operation experiment connection diagram on the NE7010 experiment set, make the connections in figure 4 and figure 5. Since the shaft of the asynchronous motor is unloaded, it rotates at a speed close to synchronous speed. So the slip is s ≈ 0. In this case, fill in table 1 accordingly. Reduce the voltage applied to the asynchronous motor gradually, starting from its nominal value, using the auto transformer. Continue reducing this voltage value up to 25%.

Table-1. Idle operation test measurement results.

Nominal Gerilim Yüzdesi	R_s (Ω)	U_0 (V)	I_0 (A)	P_0 (W)	n (d/dk)
100					
75					
50					
25					

4.3.2. Locked Rotor Experiment of Three Phase Asynchronous Motor:

The locked rotor test of an induction motor is similar to the locked rotor test of transformers. Because a locked induction motor secondary is like a short-circuited transformer. In the short circuit test, the rotor is prevented from rotating and a voltage is applied to the stator, starting from zero and gradually increasing. Since the motor does not rotate, no mechanical losses occur. The voltage applied to the motor continues to be increased until the current drawn by the motor reaches 1.2 times the nominal current value written on the motor nameplate. When the current drawn by the motor exceeds its nominal current, it is necessary to complete the experiment more quickly, due to overheating that will occur in the motor windings. In the short circuit experiment, since the voltage applied to the stator windings is very small and the iron losses vary with the square of the voltage, these losses are small enough to be neglected.

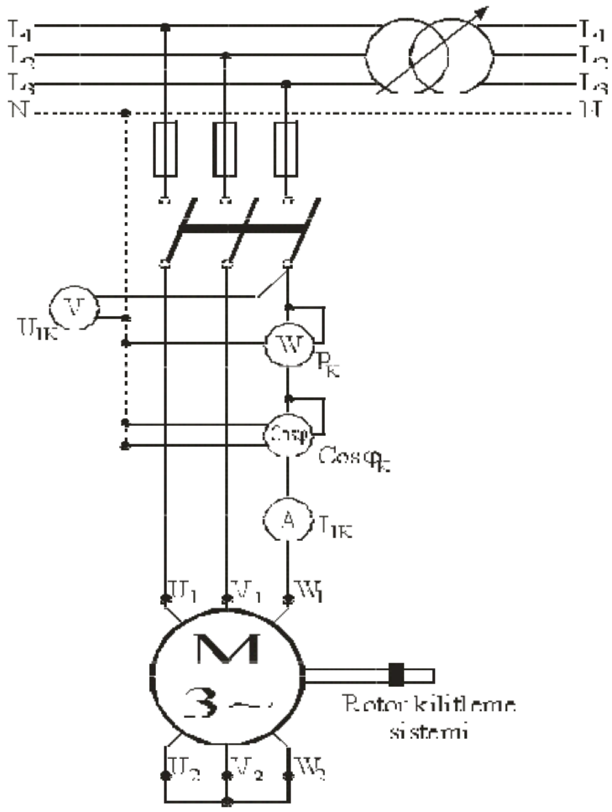

Figure 2. Locked rotor experiment wiring diagram

Carry out the locked rotor experiment connection diagram of the asynchronous motor. Lock the rotor of the asynchronous motor properly. Apply voltage to the windings of the asynchronous motor gradually, starting from zero, using the auto transformer. Continue increasing the voltage until the current value (Ik) read from the ammeter is 1.2 times the nominal current value written on the motor nameplate. When the increase process is completed, record the measurement results in table 2. Since the windings of the asynchronous motor will heat up very quickly in the locked rotor experiment, record these measurement results quickly and complete the experiment.

Table-2. Locked rotor experiment measurement results.

Anma Akımı Oranı	U_K (V)	I_K (A)	P_K (W)	R_S (Ω)
0.4				
0.6				
0.8				
1.0				

Calculate the necessary parameters after the idle operation and locked rotor test of the asynchronous motor and fill them in table 3. Draw the equivalent circuit of ASM in line with these calculated values.

Table-3. Asynchronous motor equivalent parameter values.

R_s (Ω)	R_r'' (Ω)	X_s (Ω)	X_r' (Ω)	R_{fe} (Ω)	X_m (Ω)	I_m (A)	P_{Cu} (W)	P_{s+v} (W)	P_{Fe} (W)	S

4.3.3. Loaded Operation Experiment of Three Phase Asynchronous Motors

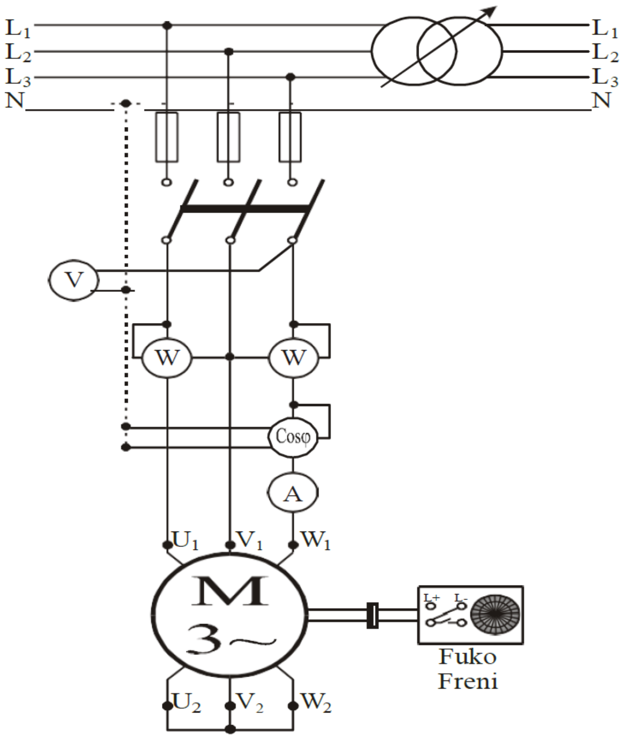

Figure 3. Connection diagram of the loaded operation experiment

Load the shaft of the idle-rotating asynchronous motor with a brake device or a shunt-excited direct current generator connected to the base of the asynchronous motor. In this case, the idle current of the very small motor will not meet the torque corresponding to this mechanical load. As with all drive machines, as a result of the increase in load, the engine will primarily meet the increase in energy required from the mechanical energy of the rotating parts. This means that the engine speed decreases. A decrease in rotor speed also causes slip to increase. Accordingly, the emf induced in the rotor grows and as a result, the rotor current will increase. The rotor slip increases until the rotor current reaches the torque required by the braking torque. From these explanations, it is understood that the slippage in ASMs depends on the torque taken from the motor shaft. On the contrary, the power coefficient increases. As the engine is loaded, its efficiency increases.

Make the connections in figure a and figure b to create the connection diagram for the loaded operation experiment. After starting the three-phase asynchronous motor and allowing it to run at idle, load torque into the motor using a shunt excited direct current generator. Record the necessary measurement results in Table-4 and fill in the blank spaces in the table by making calculations.

Table – 4. Measurement and calculation results of the full load operating experiment

M (Nm)	U (V)	I (A)	P_e (W)	P_m (W)	n (d/dk.)	η	S
0.5							
1.0							
2.0							
2.5							
3.0							
4.0							
5.0							

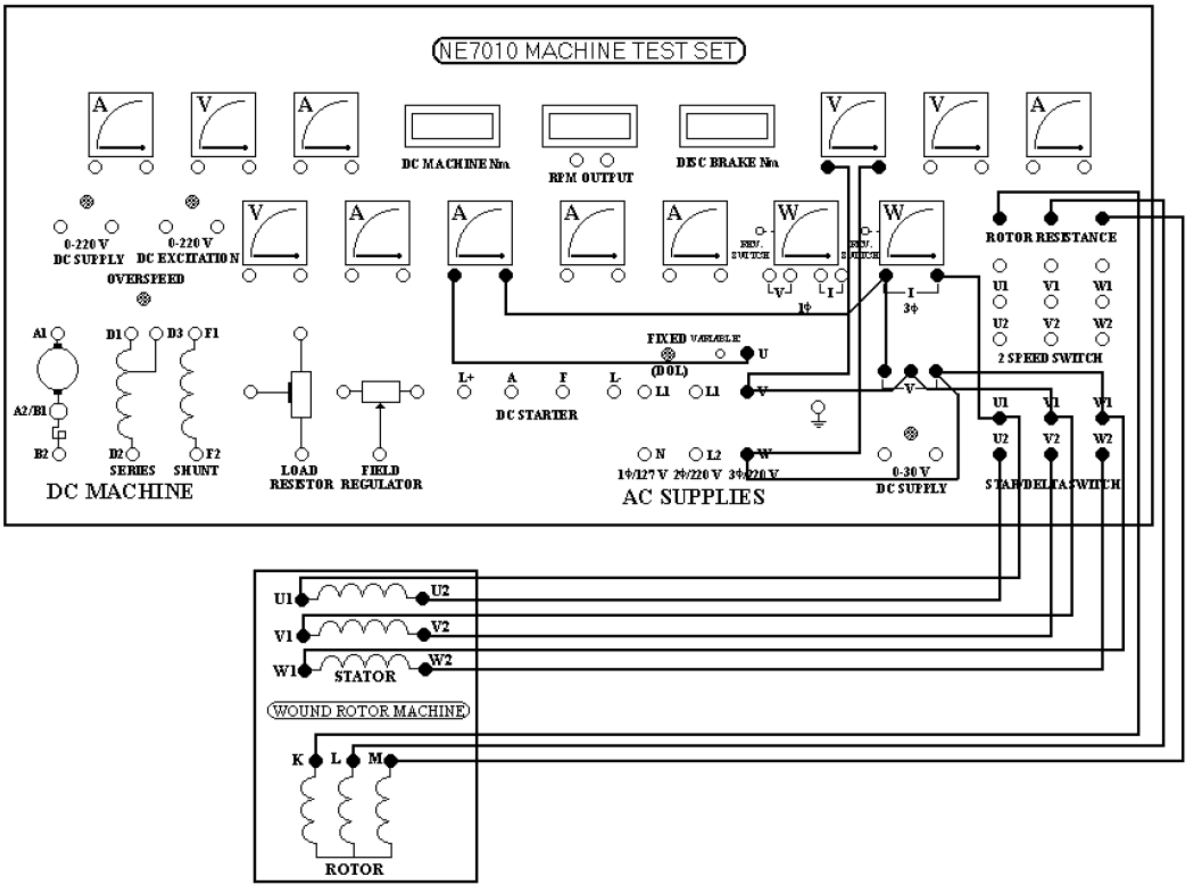

Figure – 4. Experimental Connection Diagram of Three-Phase Asynchronous Motor with Winding Rotor

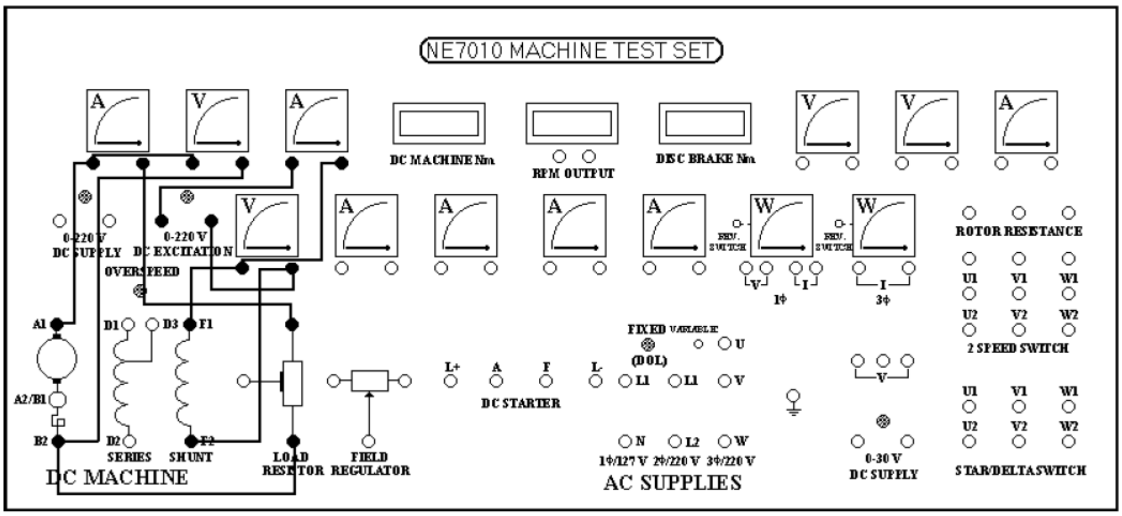

Figure – 5. Experimental Connection Diagram of Shunt Excited Direct Current Generator