### 4.6 Circle Diagram for Three Phase Induction Motors

#### **Tests Required**

#### **No-load Test**

Run the induction motor on no-load at rated supply voltage. Observe the supply line voltage  $V_0$ , No-load line current  $I_0$  and no-load power  $P_0$ .

Phase angle for no-load condition  $\Phi_0 = \cos^{-1}(\frac{P_0}{\Gamma})$ 

## **Blocked Rotor Test**

Block the rotor firmly and apply a reduced voltage to obtain rated current at the motor terminals. Observe the supply line voltage  $V_{SC}$ , No-load line current  $I_{SC}$  and no-load power  $P_{SC}$ .

Phase angle for blocked rotor condition  $\Phi SC = \cos^{-1}(-1)$ 

Current drawn if rated voltage is applied at blocked rotor condition  $I_{SN} = I_{SC}$ 

### **Resistance Test**

# OBSERVE OPTIMIZE OUTSPREAD

By voltmeter-ammeter method determine per phase equivalent stator resistance,  $R_1$ .

If the machine is wound rotor type, find the equivalent rotor resistance  $R_2'$  also after measuring rotor resistance and required transformations are applied.

#### **Construction of Circle Diagram**

- 1. Draw horizontal axis OX and vertical axis OY. Here the vertical axis represents the voltage reference.
- 2. With suitable scale, draw phasor OA with length corresponding to  $I_0$  at an angle  $\Phi_0$  from the vertical axis. Draw a horizontal line AB.
- 3. Draw OS equal to  $I_{SN}$  at an angle  $\Phi_{SC}$  and join AS.
- 4. Draw the perpendicular bisector to AS to meet the horizontal line AB at C.
- 5. With C as centre, draw a semi circle passing through A and S. This forms the circle diagram which is the locus of the input current.
- 6. From point S, draw a vertical line SL to meet the line AB.
- 7. Fix the point K as below.
  - For wound rotor machines where equivalent rotor resistance  $R_2'$  can be found out: Divide SL at point K so that SK: KL = equivalent rotor resistance : stator resistance.
  - For squirrel cage rotor machines:

Find Stator copper loss using  $I_{SN}$  and stator winding resistance  $R_1$ . Rotor copper loss = total copper loss – stator copper loss.

Divide SL at point K so that SK : KL = rotor copper loss : stator copper loss

- *Note*: If data for separating stator copper loss and rotor copper loss is not available then assume that stator copper loss is equal to rotor copper loss. So divide SL at point K so that SK= KL
- 8. For a given operating point P, draw a vertical line PEFGD as shown.

Then, PD = input power, PE = output power, EF = rotor copper loss, FG = stator copper loss, GD = constant loss (iron loss + mechanical loss)

- 9. Efficiency of the machine at the operating point  $P_{,} = PE/PD$
- 10. Power factor of the machine at operating point  $P = cos_1$
- 11.Slip of the machine at the operating point P, s = EF/PF
- 12. Starting torque at rated voltage (in syn. watts) = SK
- 13. To find the operating points corresponding to maximum power and maximum torque, draw tangents to the circle diagram parallel to the output line and torque line respectively. The points at which these tangents touch the circle are respectively the maximum power point  $(T_{max})$  and maximum torque point  $(P_{max})$ .



#### Figure 4.6.1 Circle diagram

[Source: "A Course in Electrical Machine Design" by A.K.Sawhney, page-10.54]