FACULTY OF ENGINEERING & TECHNOLOGY

Electrical Machine-ii

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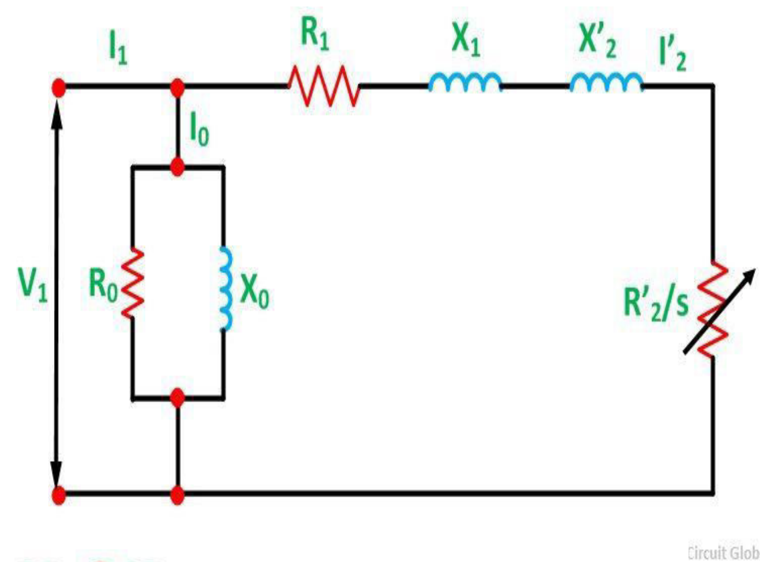
CIRCLE DIAGRAM OF AN INDUCTION MOTOR

The **Circle Diagram** of an **Induction motor** is very useful to study its performance under all operating conditions. The construction of the circle diagram is based on the approximate equivalent circuit shown below. It is the diagrammatic representation of the performance of the induction motor. The circle diagram provides the information about the power output, losses and the efficiency of the induction motor.



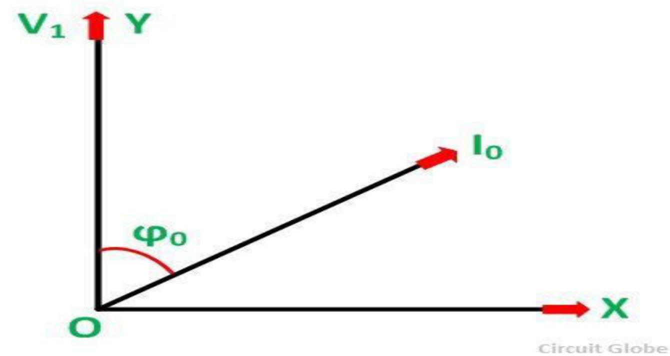
Applying KCL (Kirchhoff's Current Law)

$$I_1 = I_0 + I'_2$$

Let the phase voltage V_1 be taken along the vertical axis OY as shown in the figure below.

The **No Load current I_0 = OA** lags behind V_1 by an angle ϕ_0. The no-load power factor angle ϕ_0 is of the order of 60 to 80 degrees because of the large magnetising current needed to produce the required flux pole in a magnetic circuit containing the air gaps.

At no load condition, **s = 0** and **R_2/s** are **infinite**, or we can say that the R_2/s is an open circuit at no load.



$$I_0 = \frac{V_1}{Z_{nl}} \quad \text{where} \quad Z_{nl} = (R_0 \,||\, jX_0)$$

Here, all the rotational losses are considered under R_0 and the no-load loss is given by the equation shown below.

$$P_0 = V_1 I_0 \cos\varphi_0$$

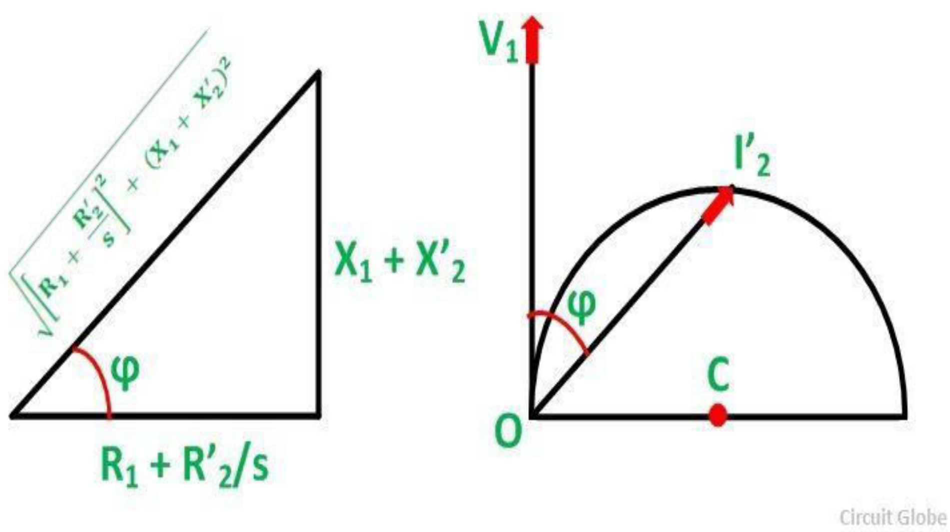
The rotor current referred to the stator is given by

$$I_2' = \frac{V_1}{\sqrt{\left(R_1 + \frac{R_2'}{s}\right)^2 + (X_1 + X_2')^2}} \dots \dots \dots . (1)$$

The current I'_2 lags behind the voltage V_1 by the impedance angle ϕ as shown in the figure below.

Where,

$$\sin\varphi = \frac{X_1 + X_2'}{\sqrt{\left(R_1 + \frac{R_2'}{s}\right)^2 + (X_1 + X_2')^2}} \dots \dots \dots . (2)$$



Combining equation (1) and (2) we get

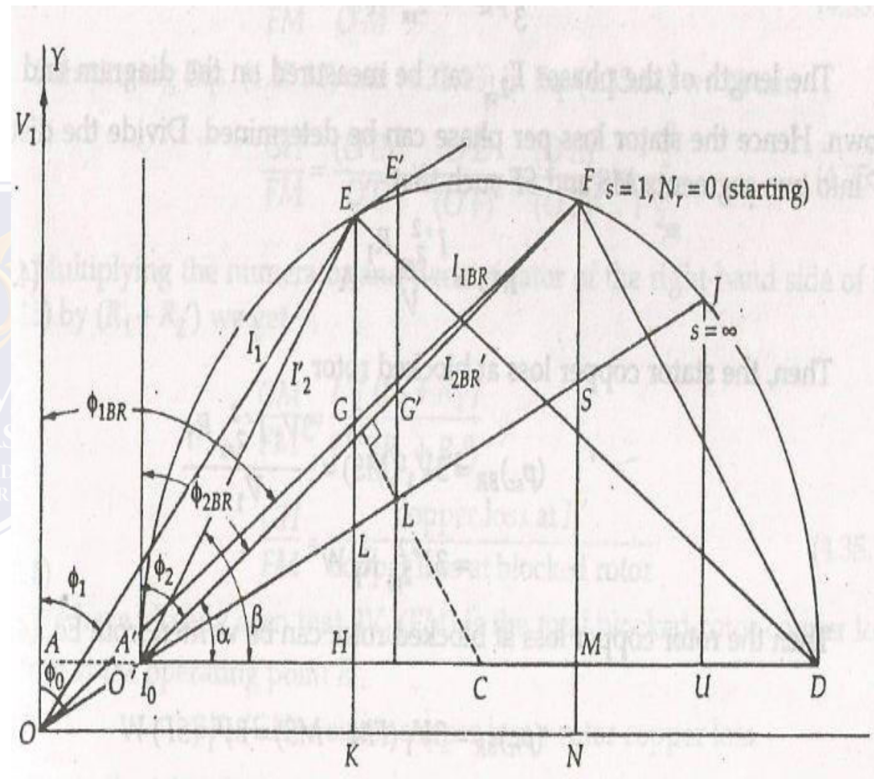
$$I_2' = \frac{V_1}{X_1 + X_2'} \sin\varphi \dots \dots \dots . (3)$$

The above equation (3) is of the form **r = a sin φ** which represent a circle in polar form with the diameter a.

From the above figure shown the following points are illustrated.

- The locus of I'_2 is a circle of the diameter $V_1/ X_1 + X'_2$
- The radius of the circle $O'C = V_1/ 2(X_1 + X'_2)$
- The center C has the coordinates $[V_1/ 2(X_1 + X'_2), 0]$

The **resulting circle diagram** of the induction motor is shown below.



It is seen that the tip of the phasor I_1 coincides with that of the phasor I'_2. Thus, the locus of the both I_1 and I'_2 is the upper semicircle. I_1 and I'_2 radiate from the origin O and O' respectively. When the motor is started **s = 1** with the rated voltage, the tip of I_1 and I'_2 will be at some point F of the circle.

As the motor accelerates, the tips of I_1 and I'_2 move around the circle in an anti-clockwise direction. This process continues until the output torque matches the load torque. If there is no shaft load, the motor accelerates to synchronous speed. At this point $\mathbf{I'_2 = 0}$ and $\mathbf{I_1 = 0}$.

CONSTRUCTION OF THE CIRCLE DIAGRAM

The following data are required for constructing the circle diagram.

- Stator phase voltage $V_1 = V_L/\sqrt{3}$
- No load current I_0
- No load power factor $\cos\phi_0$
- Blocked rotor current and power factor
- Stator phase resistance R_1.
- Steps to draw Circle Diagram of an Induction Motor
- Take the phasor voltage V_1 along the y-axis.
- Choose a convenient current. With O as origin, draw a line OO' = I_0 at an angle ϕ_0 with V_1.
- Draw the line OKN perpendicular to V_1. Similarly, draw a line O'D perpendicular to V_1.
- From the point O draw the line of equal to the blocked rotor current I_{1BR} to the same scale as I_0. This line lags behind V_1 by the blocked rotor power factor angle ϕ_{1BR}.
- Join O'F and measure its magnitude in amperes. The line O'F represents I'_{2BR}.
- From the point F, draw a line FMN parallel to V_1. This line is perpendicular to O'D and ON.
- Calculate MS = $I'^2_{2BR}R_1/V_1$ and locate point S. Join O'S and extends it to meet the circle at J.
- Draw the perpendicular bisector of the chord O'F. This bisector will pass through the centre of the circle at the point C.

Now with the radius CD' or CD draw the circle.