The Equivalent Circuit of the Schräge Motor

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THIS ARTICLE presents the equivalent circuit of the Schräge motor in a rationalized form. The secondary winding and the adjusting winding, instead of being represented by two parallel equivalent impedances, now are represented by a single equivalent impedance.

The secondary winding and the adjusting winding are considered as one winding, and is termed the combined secondary winding. The total induced electromotive force in the combined secondary winding, $(s\check{E}_2+\check{E}_3)$, is balanced by a voltage $-\check{E}_1$ in the primary winding, and the current in the combined secondary winding, $\check{I}_2$, also is balanced by a current $\check{I}_2'$ in the primary winding. The ratio of $-\check{E}_1$ to $\check{I}_2'$, or $Z_2'=R_2'+jX_2'$, is the equivalent impedance of the combined secondary winding in primary terms. $-\check{E}_1$ is derived from $s\check{E}_2$ and $\check{E}_3$, the phase relations and turn ratios being taken into account; $\check{I}_2'$ is derived from $\check{I}_2$ by considering their magnetomotive forces. The expressions for R_2' and X_2' are as follows:

$$R_2'=\frac{[(1+s)b\cos A+s+b^2]a^2R_2+(1-s)sba^2X_2\sin A}{(1+2b\cos A+b^2)(s^2+2sb\cos A+b^2)} \quad (1)$$

$$X_2'=\frac{[(1+s)b\cos A+s+b^2]sa^2X_2-(1-s)ba^2R_2\sin A}{(1+2b\cos A+b^2)(s^2+2sb\cos A+b^2)} \quad (2)$$

where

a = ratio of primary effective turns per phase to secondary effective turns per phase.
b = ratio of adjusting winding effective turns per phase to secondary effective turns per phase.
R_2 = total resistance per phase of the combined secondary winding.
X_2 = total leakage reactance, per phase at line frequency, of the combined secondary winding.
A = angle by which the axis of the adjusting winding is displaced from the axis of the secondary winding in the direction against motor rotation.
s = slip of the motor.

By connecting the magnetizing impedance $Z_m=R_m+jX_m$ in parallel with Z_2' and connecting the primary leakage impedance $Z_1=R_1+jX_1$ in series with the parallel combination, an equivalent circuit similar to that of the ordinary induction motor is formed.

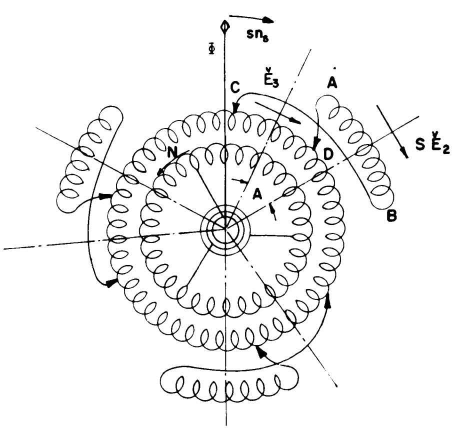

Fig. 1. Schematic diagram of the Schräge motor

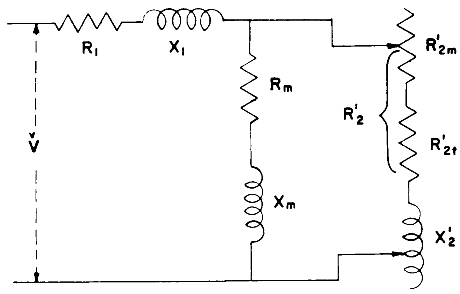

Fig. 2. Equivalent circuit of the Schräge motor

As in the case of the ordinary induction motor, R_2' can be separated further into two parts, R_{2t}' and R_{2m}', where R_{2t}' represents the true resistance of the combined secondary winding in primary terms, and R_{2m}' represents the mechanical load. The expressions for R_{2t}' and R_{2m}' are as follows:

$$R_{2t}'=\frac{a^2R_2}{1+2b\cos A+b^2} \quad (3)$$

$$R_{2m}'=R_2'-R_{2t}'=\frac{(1-s)[(b\cos A+s)a^2R_2+sba^2X_2\sin A]}{(1+2b\cos A+b^2)(s^2+2sb\cos A+b^2)} \quad (4)$$

The adjustable-speed and adjustable-power-factor nature of the motor can be seen from the equivalent circuit. The no-load speed n_o can be varied by varying the angle A and therefore is a function of A. n_o can be determined by considering the fact that at no load there is no mechanical output. The expressions for the slip at no-load, s_o, and the no-load speed n_o are as follows:

$$s_o=\frac{-bR_2\cos A}{R_2+bX_2\sin A} \quad (5)$$

$$n_o=(1-s_o)n_s=\frac{R_2+b(R_2\cos A+X_2\sin A)}{R_2+bX_2\sin A} \quad (6)$$

It can be found easily that n_0 is maximum when A is 0°, n_o is minimum when A is 180°, and n_o is still the synchronous speed when A is ±90°.

From equation 2 it is seen that X_2', instead of being constant as in the case of the ordinary motor, is a variable and is a function of A. It can be found that when A is 90°, the power factor of the motor is improved without affecting the speed.

Speed control and power factor improvement can be done at the same time. When A is between 0° and 90°, the speed is raised above synchronism with an improvement of power factor, and when A is between 90 and 180°, the speed is lowered below synchronism with the power factor improved.

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