CORRESPONDENCE: A METHOD OF INDUCTION MOTOR SPEED CONTROL*

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By using an auxiliary winding, either closed upon itself through an impedance or separately excited, the speed of an induction machine can be controlled. The equivalent circuits and, through an example, curves of torque versus slip presented.

As a further development of the facts on dual-winding motors presented by Alger [1,sec.13.3], here we will show that it is possible to control the speed of an induction motor by either shortcircuiting an auxiliary stator winding through an adjustable impedance or by varying the phase angle of the voltage applied to the auxiliary winding, keeping its value and frequency the same as that of the main winding.

Considering an idealized squirrel-cage machine in steady-state operation, supplied by sinusoidal voltages which form a balanced system, the voltage equations have been developed [2]; the corresponding equivalent circuits are given in Figure 1. The windings are indexed by 1 for the main stator winding, 2 for the rotor winding and 3 for the auxiliary stator winding. The circuit parameters and currents and voltages are referred to the main stator winding. The special notations introduced in the equivalent circuits are:

X = the mutual reactance between main and auxiliary stator windings,

$\underline{Z}'_{3e}$ = $R'_{3e} + X'_{3e}$ = the external adjustable impedance,

$\underline{I}_o$ = the magnetizing current,

$\underline{Z}^*_1$ = $\underline{Z}_1 - jX$, $\underline{Z}^*_3 = \underline{Z}_3 - jX$, $1/\underline{Z}_p = 1/\underline{Z}'_2 + 1/jX_M$

The torque expression is the usual one for an induction motor with one stator winding, because the torque depends on the power transfer to the rotor only.

As an example, using a UNIVAC 1108 various characteristics have been calculated for different parameters with different values for normalized parameters of the auxiliary stator winding (R'_3/R_1, X'_3/X_1) and for various coupling reactances X. These allowed us to generalize our conclusions. The characteristics presented in Figures 2, 3 and 4 were calculated for a squirrel-cage motor with basic parameters $R_1 = R'_2 = 0.15075\Omega$, $X_1 = X'_2 =$

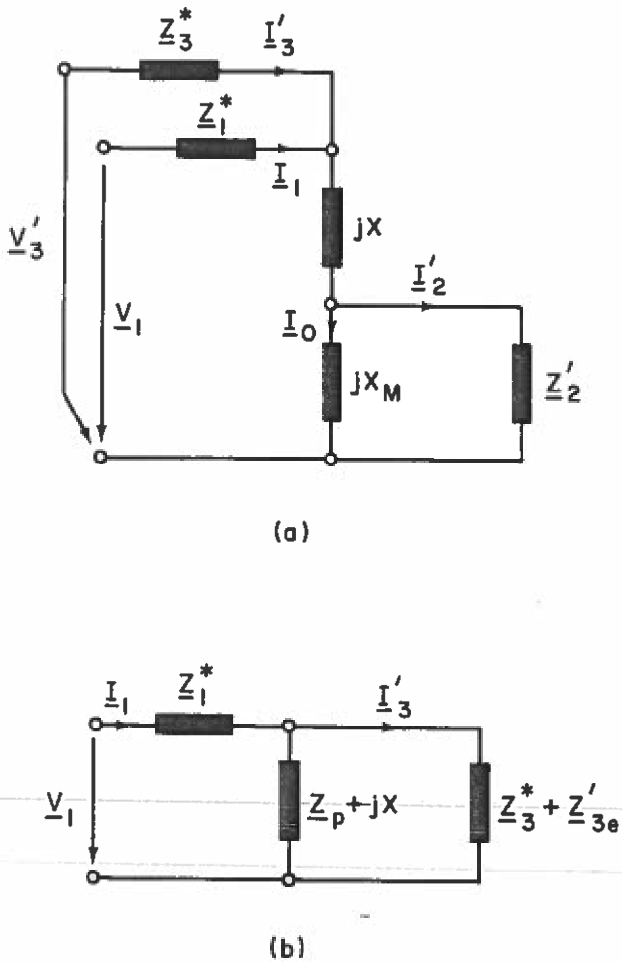

Figure 1

The equivalent circuits for dual-winding squirrel-cage inducation motor.
a. with the auxiliary winding supplied
b. with the auxiliary winding closed on an external impedance.

0.25125r, X_M = 10.07Ω [1,p.137] and with $R_3'/R_1 = X_3'/X_1 = 1$

Keeping the supply frequency f_1, the number of pole pairs P, and the main supply voltage V_1 as constants, normalized expressions for torque

$$T_n = T \cdot \frac{2\pi f_1}{m_1 P} \cdot \frac{1}{V_1^2} ,$$

and main current

$$I_{1n} = I_1/V_1 ,$$

are ploted.

As it is possible to see from the characteristics presented in Figure 2, when the external impedance $Z_{3e}' \to \infty$ the motor is developing its normal torque, and, when the Z_{3e}' is zero, the

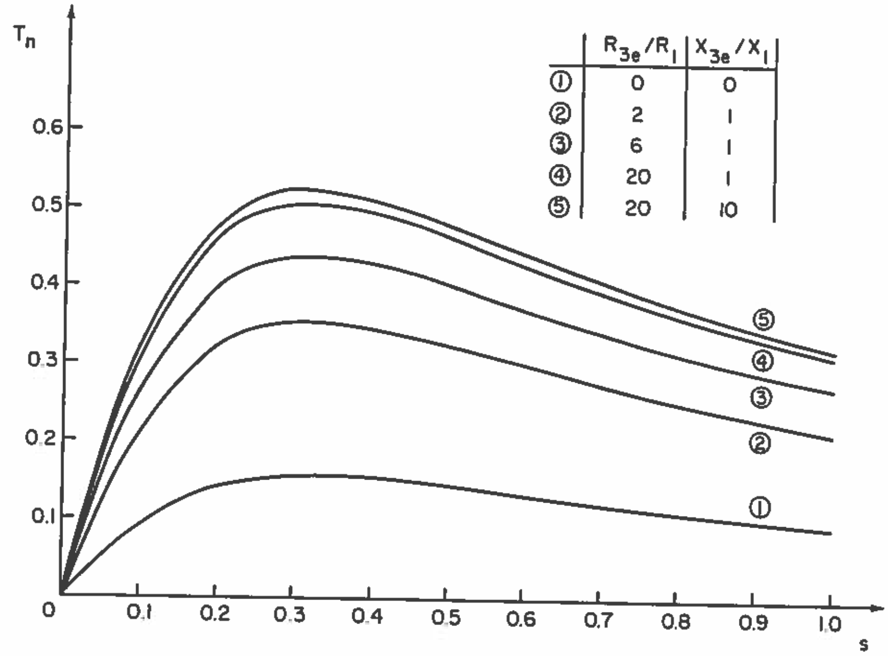

Figure 2
Normalized torque versus slip with $V_3'=0$, for different values of external impedance parameters, R_{3e}'/R_1 and X_{3e}'/X_1.

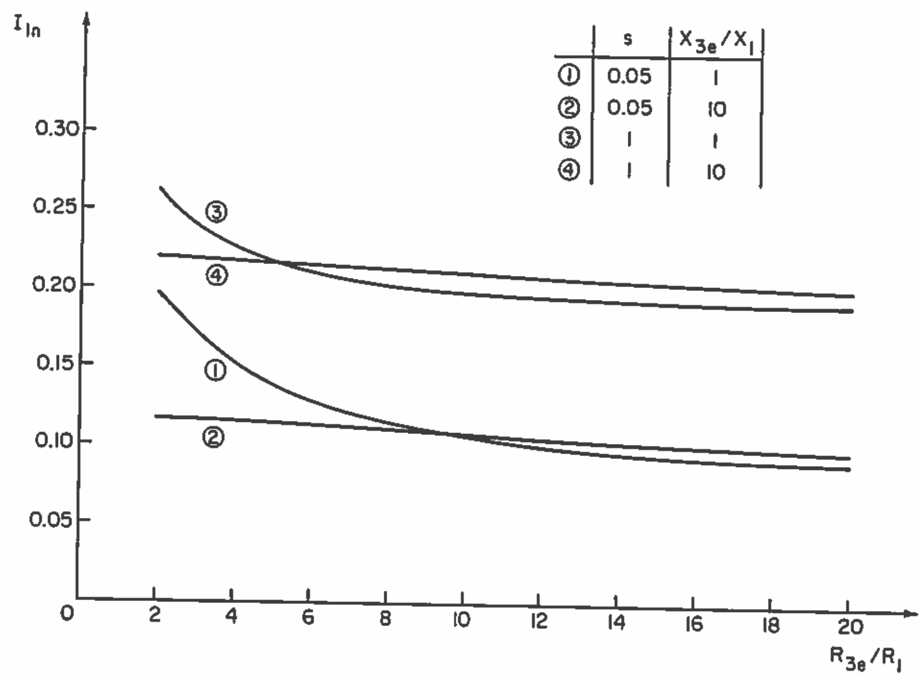

Figure 3
Normalized main current versus R_3'/R_1 with $V_3'=0$ for different s and X_{3e}'/X_1.

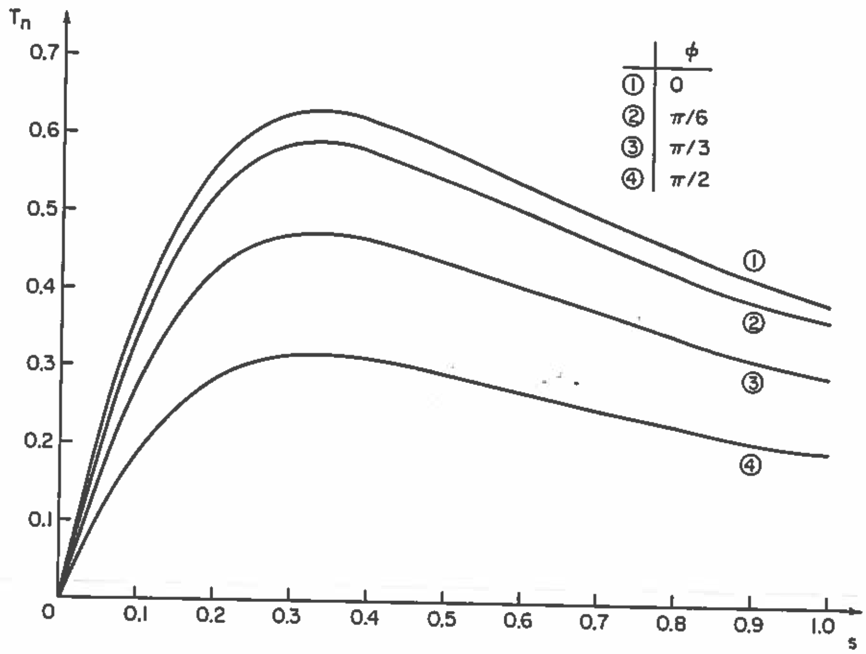

Figure 4
Normalized torque versus slip with $V_3' = V_1$ for different phase shift ϕ between stator voltages.

maximum torque is greatly reduced, the shape of the slip torque curve remains the same in both cases.

Figure 3 shows that the line current is increased when the external impedance and the maximum torque are decreased.

With the auxiliary winding supplied by an external voltage, the maximum torque is obtained where the supply voltages are in phase, and the torque is reduced by an increase in the phase difference ϕ as shown in Figure 4.

Thus by changing the phase angle between the applied voltages it is possible to obtain the same results as by varying the external impedance in the case discussed above.

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References

1. P. L. Alger "Induction Machines, Their Behavior and Uses" Gordon and Breach Science Publishers, New York, 1970.

2. I. A. Viorel and R. W. Newcomb "A Method of Induction Machine Speed Control" Internal Report, University of Maryland.

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