Speed Control Of Wound Rotor Induction Motor Using Rotor Resistance Control

Aim

- To use variable resistance in the rotor circuit to control wound rotor induction motor speed

Theory

Polyphase induction motors are mainly of two types by construction, squirrel cage and wound-rotor (with slip-rings). In the case of a squirrel cage induction motor, the rotor is inaccessible and rotor circuit resistance is fixed, whereas the wound-rotor machines are provided with slip-rings by which additional resistance can be connected in series with the machine rotor. Terminals are brought out from each phase for connecting external resistances.

The motor speed is a function of its rotor resistance. This is evident from the equivalent circuit shown in Fig. (1) and the subsequent equations (1-3).

![Per phase equivalent circuit of Induction Motor](image)

To determine expressions for torque and power, the equivalent circuit in Fig. (1) must be analyzed using its Thevenin equivalent looking into the network from the rotor side. The stator impedance $R_s + jX_{s1}$ and the magnetization branch $jX_m$ (neglecting resistance) converted to Thevenin impedance are given by $R_e + jX_e$. The equivalent Thevenin voltage is given by $V_e$. With this, the rotor current $I_r'$ is given by

$$I_r' = \frac{V_e}{(R_e + \frac{R'_{r}}{s}) + j(X_e + X'_{r1})} \quad (1)$$

The rotor mechanical torque developed is given by (1).

$$T_{mech} = \frac{P_{mech}}{\omega_m} = \frac{P_{air-gap}}{\omega_s} \quad (2)$$
The mechanical torque produced is thus a function of rotor resistance and the slip. It builds up with increase in rotor speed. The total or three phase torque is given by

\[ T_e = 3I_r^2 R' \frac{r}{s} \]

\[ = 3\frac{V_e^2/\omega_s}{(R_e + R'_r/s)^2 + (X_e + X'_r/1)^2} \left( \frac{R'_r}{s} \right) \]  

(3)

At low values of slip (s), i.e near synchronous speed, the term \( \frac{R'_r}{s} \) dominates the other denominator terms, the effective torque thus reduces to

\[ T_e = 3\frac{sV_e^2/\omega_s}{R'_r} \]  

(4)

The above expression in (4), can be used to determine the effect of varying rotor resistance on the electromagnetic torque developed in the motor. As the rotor resistance is reduced, the torque increases almost linearly for near-synchronous speed operation. For slip-ring induction motors, rotor terminals are brought out and rheostats of suitable range can be connected in each phase.

**Procedure**

A. Note down the machine ratings and calculate rated current of the machine if not available

B. Connect a rheostat in each of the rotor phases brought out via the terminal box mounted on top of the machine. Keep the rheostats at the maximum positions

C. With the rheostats in maximum resistance position, slowly apply the three-phase input voltage to the stator terminals using the three-phase variac.

D. As the machine speeds up, adjust the rheostats such that each phase has equal resistances cut out (decreased) in steps.

E. Cut out the full external rotor resistance in steps and simultaneously record the machine speed.

F. Slowly decrease the applied stator voltage to zero.

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Figure 2: Circuit Diagram for blocked-rotor test on 3 Phase Induction Motor
Observation

• For different values of rotor circuit external resistances in circuit \( R'_{r,ext} \), record the corresponding machine speed \( \omega_m \).
• Plot \( \omega_m \) Vs. \( R'_{r,ext} \)

Follow-up questions

1. What are some of the other methods for induction machine speed control?

References

(1) M.G.Say, “Alternating Current Machines”, 5th Ed., Ch.7-9
(2) P.S.Bimbhra, “Electrical Machinery”, Ch.5
(3) A.E. Fitzgerald, C. Kingsley Jr., S.Umans, “Electric Machinery”, 6th Ed., Ch.6