winding circuit. The relay then keeps these contacts open because there is sufficient voltage induced in the starting winding, when the motor is running, to hold the relay in the open contact position.

CONTROL FOR ALTERNATING CURRENT MOTORS

Squirrel-Cage motors are usually linestarted where power company limitations permit. In sizes up to 5 hp at 220 volts, or 7½ hp at 440 volts, polyphase motors may be started by means of manual switches having overload current elements for motor protection. In larger ratings a linestarter is usually provided with either an additional safety switch or circuit breaker for disconnecting and short circuit protection. Reduced voltage starting may be used when the current inrush on full voltage exceeds the limitations set by the power company. The magnitude of this inrush current is entirely independent of the load on the motor, and is the same whether the motor is lightly loaded or heavily loaded.

TABLE 7. COMPARISON OF SQUIRREL CAGE AND SYNCHRONOUS MOTOR STARTING METHODS

Type of Starter	Percent of Motor Rated Values		
	Line Voltage	Starting Torque	Line Current
Full Voltage Starter	100	100	100
Autotransformer			
80 percent tap	80	64	68
65 percent tap	65	42	46
50 percent tap	50	25	30
Resistor, single step	80	64	80
Reactor			
50 percent tap	50	25	50
45 percent tap	45	20	45
37.5 percent tap	37.5	14	37.5
Part Winding	60	50	60

Restrictions on starting current may limit the maximum current inrush or may limit the increments of current inrush which may be drawn on each step. Table 7 shows a comparison of the various methods of reduced voltage starting. The choice may depend upon the limitation to be met. Fig. 5 shows examples for maximum current limitations. Fig. 6 shows examples for increment limitations. The increment starters would not be satisfactory for meeting maximum current limitations as they exceed the maximum value before the motor reaches full speed. Both Curves B and C of Fig. 6 would be satisfactory if the increment limitation were 400 percent but only the starter illustrated by Curve C would meet a limitation of 200 percent increments.

When increment starters are used the motor may not develop enough torque to start until the last step. Fig. 6 shows that with the resistor step starter the motor does not start until step 3 or after 2 seconds on Curve C. Part-winding motors may start and then stall at about half speed until the second step which applies full torque.

The load inertia (WK^2) may also affect the selection of reduced current starting method since the reduced torques may not be sufficient to accelerate the load without overheating the motor or in the case of synchronous motors, may not reach sufficient speed to pull into synchronous speed.

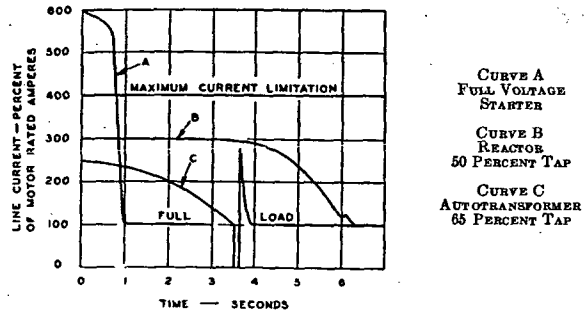


FIG. 5. STARTERS FOR MAXIMUM CURRENT LIMITATIONS

In these cases the solution may be to use the wound-rotor induction motor or some means of reducing the load such as suction dampers on compressors. Fig. 7 illustrates recommended control practice for squirrel-cage motors.

Wound Rotor motors require control of both primary and secondary circuits. The primary* control may be the same as for squirrel-cage motors, manual or magnetic, at full voltage. Secondary* control provides means of varying secondary resistance for starting and speed control. The secondary controller should be specified for starting duty only, or for speed regulating duty. If the secondary controller is to be used for speed regulating duty, the percent speed reduction, the number of speed control points, and the type of load (variable or constant torque) should be specified. Fig. 8 illustrates recommended control practice for wound rotor motors.

Synchronous motor starters should provide pull-out protection, automatic synchronization or automatic stopping of the motor after pull-out, and insurance of complete starting sequence, as well as overload and low voltage protection. The control may be either magnetic or semi-magnetic at full or reduced voltage. Semi-magnetic starters provide automatic field control, but require hand operation for closing the line contactors to start and transfer to full voltage.

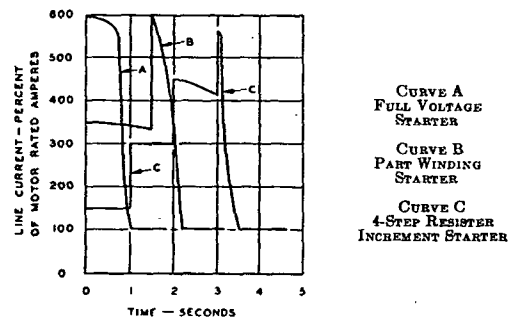


FIG. 6. STARTERS FOR INCREMENT LIMITATIONS

* Refer to Glossary at end of chapter.