AC Motors, Transformers, Instruments & Distribution Systems

Course Number: EE-02-310

PDH: 6

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Module 12: AC Motors

Learning Objectives

By the end of this section, you will be able to:

- **Describe** how a rotating magnetic field and torque are produced in various AC motors.
- **Calculate** percent slip using synchronous and rotor speeds.
- **Explain** operational relationships, such as the link between slip and torque, and the effects of synchronous motor excitation.
- **State** the specific industrial and commercial applications for induction, single-phase, and synchronous motors.

Executive Summary: AC motor operation depends on the interaction between a revolving magnetic field created in the stator and an opposing field in the rotor. While induction motors are the industrial standard due to their rugged simplicity, synchronous motors offer constant speed and power factor control, and single-phase motors provide solutions for smaller commercial needs.

AC Motor Theory

Principles of Operation

AC motor operation relies on the interaction of a revolving magnetic field (created in the stator by AC current) with an opposing magnetic field either induced on the rotor or provided by a separate DC source. This interaction produces usable torque coupled to facility loads.

Rotating Field Generation

A rotating magnetic field is produced by supplying three-phase AC to three windings symmetrically spaced around a stator.

- **Phase Displacement**: Windings are connected in wye; because currents in the three windings are 120° out of phase, the magnetic fields produced are also 120° out of phase.
- **Vector Combination**: At any instant, the magnetic field from each phase combines to produce a single field.
- **Physical Rotation**: As the electrical sine wave completes one full 360° cycle, the combined magnetic field physically rotates one complete revolution.

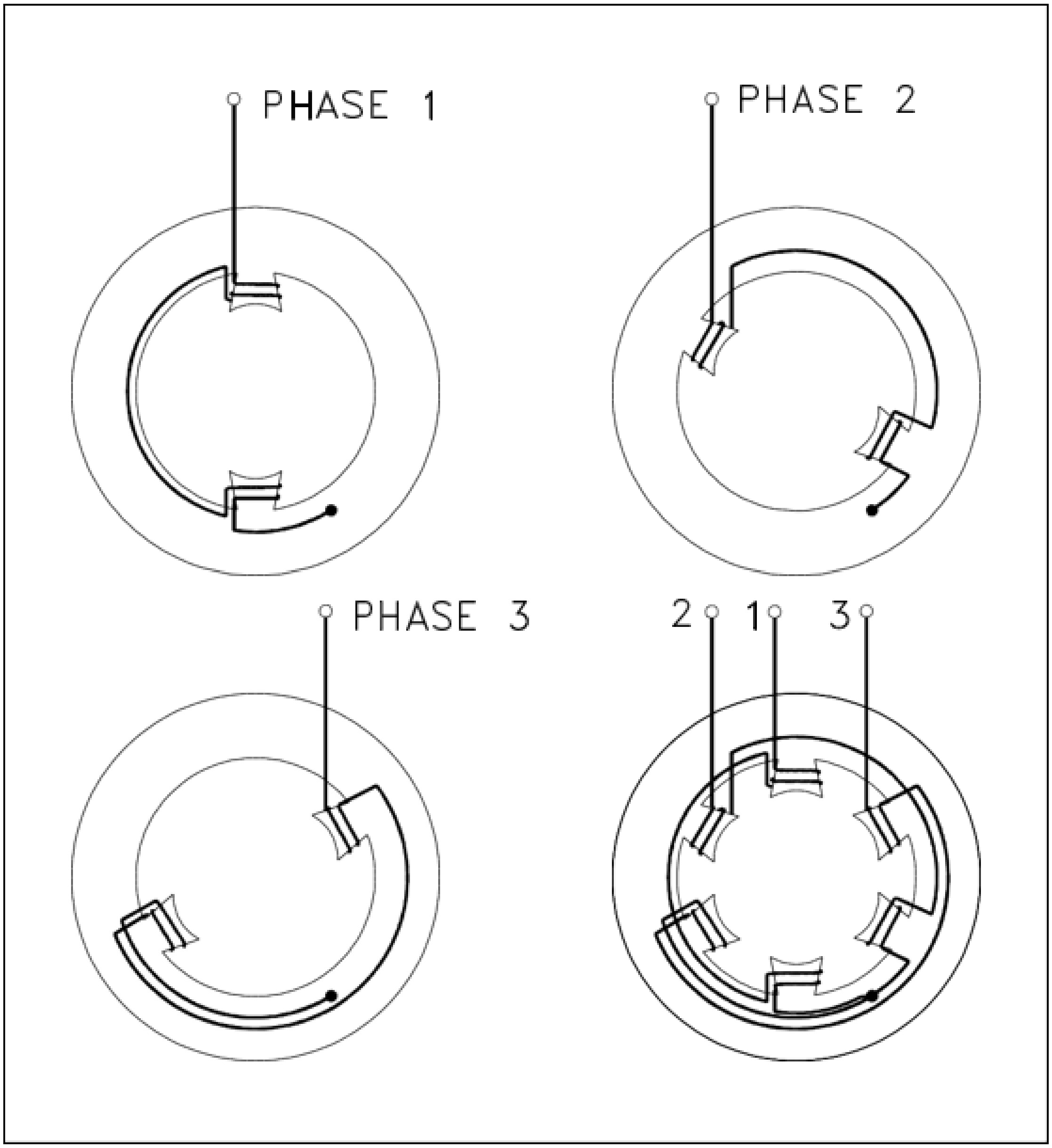

Figure 1. Three-Phase Stator

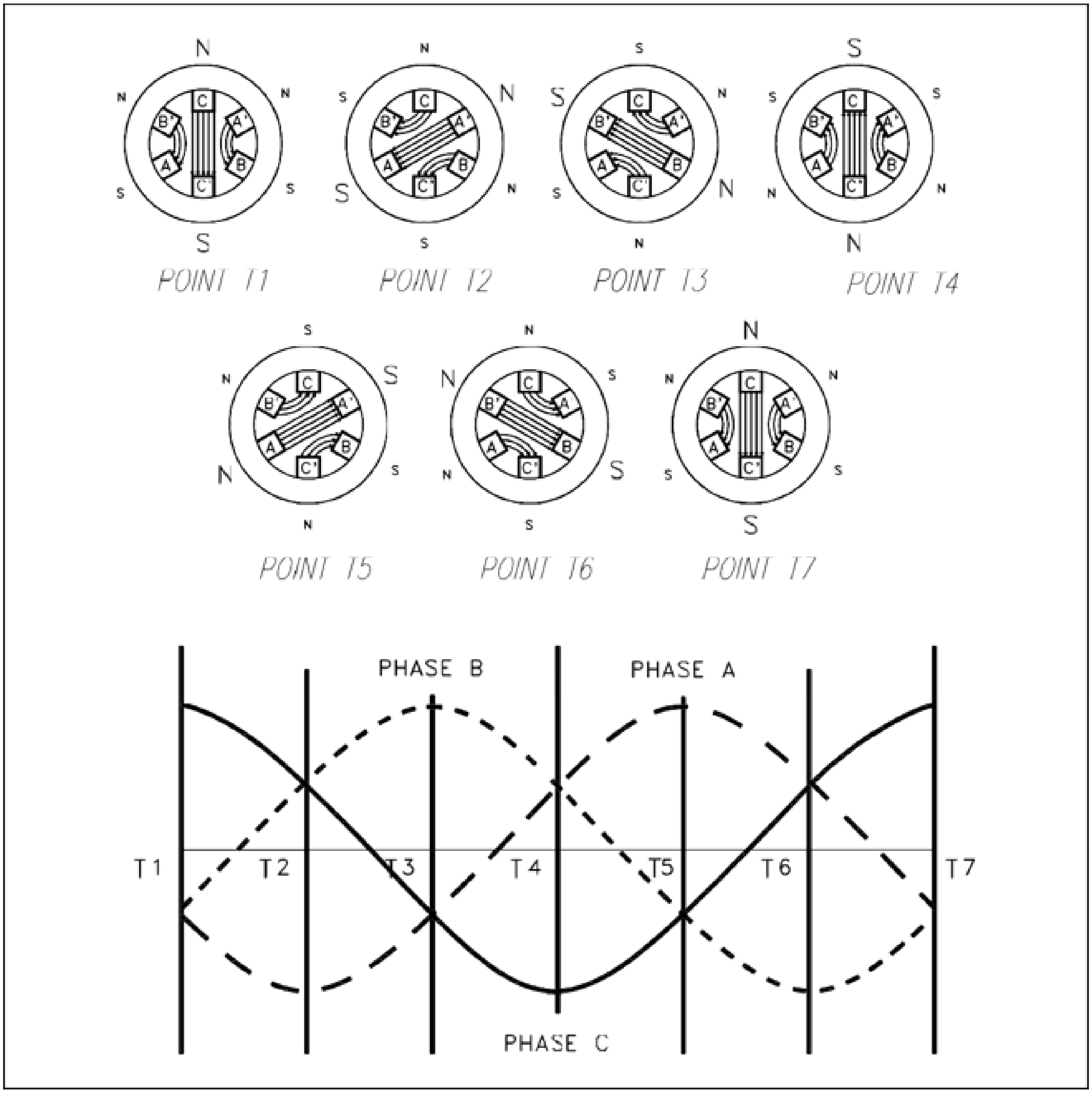

Figure 2. Rotating Magnetic Field

Torque Production

When AC is applied to the stator, the resulting rotating magnetic field cuts the rotor bars and induces a current via generator action. This induced current creates a rotor magnetic field opposite in polarity to the stator field. As the stator field rotates, the rotor field attempts to align with it, following behind to produce torque.

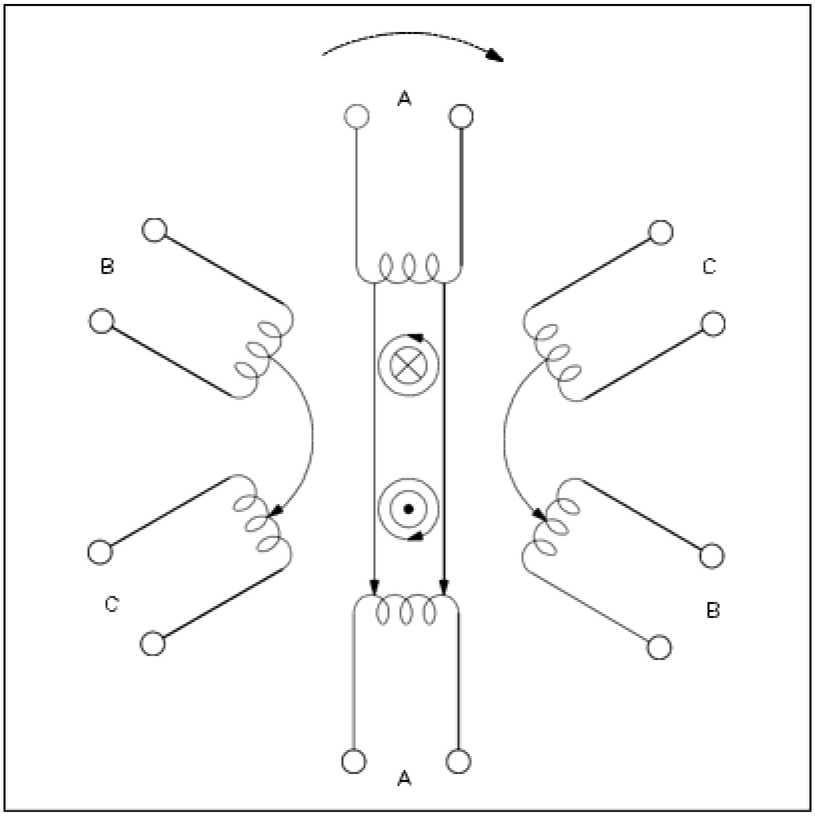

Figure 3. Induction Motor

Slip

The rotor of an induction motor must rotate slower than the stator field to maintain the relative motion necessary to induce current. **Slip** is the percentage difference between the synchronous speed of the field and the actual rotor speed.

Equation 12-1:

$$SLIP = \frac{N_s - N_r}{N_s} \times 100\%$$

Where:

- **Ns** = synchronous speed (rpm)
- **Nr** = rotor speed (rpm)

Equation 12-2:

$$N_s = \frac{120 \times f}{P}$$

Where:

- **Ns** = speed of rotating field (rpm)
- **f** = frequency of current (Hz)
- **P** = total number of poles

Torque Characteristics

Torque is directly proportional to rotor current, which increases proportionally with slip during normal operation.

- **Linear Zone**: Torque increases linearly as slip increases from 0 to ~10%.
- **Breakdown Torque**: Maximum torque is reached at ~25% slip; exceeding this point causes the motor to stall.
- **Starting Torque**: The value at 100% slip, typically 150-200% of full-load torque.

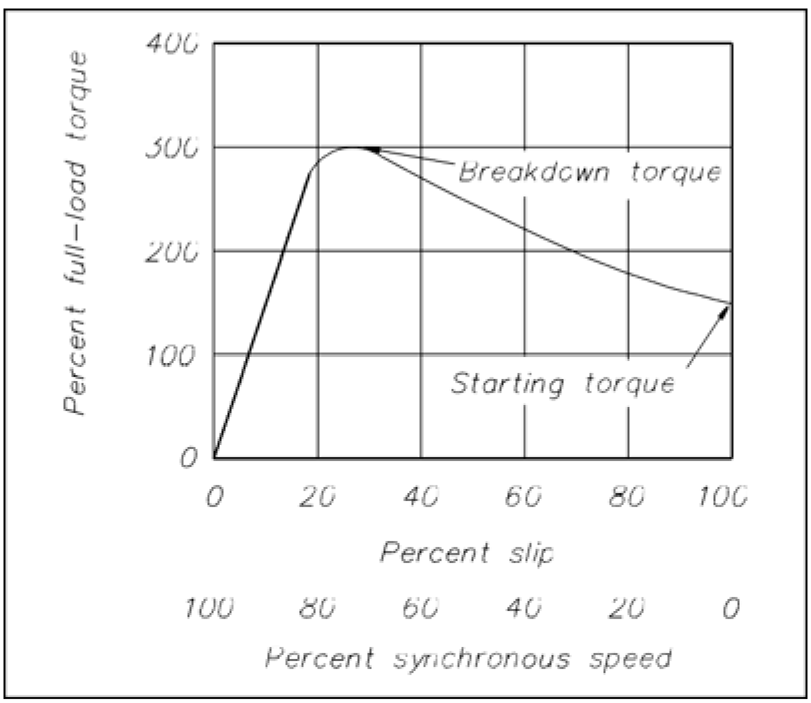

Figure 4. Torque vs Slip