AC Induction Motors

- Simplest and most rugged electric motor
- Consists of ____________ and ____________
- AC in the primary member (stator) ____________ current in the secondary member (rotor)
- Combined electromagnetic effects of the stator and rotor currents produce the force (torque) to create rotation.

AC Motor Construction

- Asynchronous AC induction motors are commonly used in industrial applications. An asynchronous motor is designed to operate at a speed different from the speed of the rotating magnetic field. In general, the speed of an AC induction motor is equal to the synchronous speed of the rotating field, due to slip.
- The illustration shows a type of three-phase, 440 VAC asynchronous induction motor. The three primary parts are the stator, the rotor, and the enclosure.

Three-Phase Electrical Power

- Uses three sets of armature windings to produce three separate outputs
- Armature windings are physically separated _______ from each other, and therefore, each phase is _______ apart from another
- _______ power may be generated by a generator of a given size and weight

Single-Phase v. Three-Phase
AC Motor Speed

- The magnetic field rotates at the synchronous speed of the motor
- Determined by the number of poles in the stator and the frequency of the AC power

\[ n_s = \text{synchronous speed (in RPM)}, \]
\[ f = \text{frequency (in Hz)}, \]
\[ p = \text{the number of poles} \]

AC Motor - Speed vs. Torque

**AC Motor Speed**

- Synchronous speed is the absolute upper limit of motor speed.
- When running, the rotor always rotates slower than the magnetic field (or no torque!)
- The speed difference, or slip, is normally referred to as a % of synchronous speed:
  - \( s = \text{slip (in %)}, \)
  - \( n_s = \text{synchronous speed} \)
  - \( n_a = \text{actual speed} \)

**Single-phase AC Motors**

- Single phase AC motors require a "trick" to generate a 2nd "phase" to develop
- Three common methods:
  - split-phase (auxiliary winding is rotated 90°)
  - capacitor
  - shaded-pole

**Split-Phase AC Motor**

Motor starts with both main and auxiliary winding
A centrifugal switch opens and removes the aux winding

**AC Motor Speed**

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- Determined by the number of poles in the stator and the frequency of the AC power

\[ n_s = \text{synchronous speed (in RPM)}, \]
\[ f = \text{frequency (in Hz)}, \]
\[ p = \text{the number of poles} \]
**AC Motors** 29.3

**Split-Phase AC Motor**

**Advantages**
- Operate at speed, 4 pole, 60 Hz:
  - 1780 RPM (no load)
  - 1700/1725 RPM at full load
- ________ at low speed
- Rapid acceleration
- Relatively low cost

**Disadvantages**
- Repeated start/stop cycles ________ the windings (high start resistance)
- Less useful for large inertial loads
- Requires ________ to handle starting currents

**Single-Phase Capacitor Motors**

- Permanent split capacitor (__________)
- Capacitor-start (later switched out)
- Start-capacitor, run-capacitor (switched)

**Permanent Split Capacitor (PSC)**

- ________, smoother than split phase
- Reduced starting current
  - Longer life
  - Higher reliability
- Capable of ________ start/stop cycles

**Advantages**
- More __________ for same HP
- ________ performance when starting
- Need to always use manufacturer's desired capacitor value

**Disadvantages**

- Low starting and running torque
- Low ________
- Available in sub-fractional to ~ 1/4 hp sizes

**Shaded Pole AC Motor**

- ________ in design and construction
- Suitable for ________ ________, high volume app's
- Relatively quiet and free from vibration
- "Fail safe" design - starts in only 1 direction

**Advantages**
- ________ in design and construction
- Suitable for ________ ________, high volume app's
- Relatively quiet and free from vibration
- "Fail safe" design - starts in only 1 direction

**Disadvantages**
- Low starting and running torque
- Low ________
- Available in sub-fractional to ~ 1/4 hp sizes
NEMA - National Electrical Manufacturers Association

- NEMA is responsible for several North American electric motor industry "standards"
- ______ _________ (1/4 , 1/2 , 1 )
- Frame size
  - diameter, length, shaft size, etc.
- ______ _________
- Housing/protection types and ratings

IEC – International Electrotechnical Commission

- IEC is responsible for European and Asian electric motor standards
- Similar to (but not the same as!) NEMA standards

Service Factors

- A multiplier ( < ) applied to the rated ______
- Indicate how much the motor can be overloaded without overheating
- Generally used for
  - handling a known, occasional overload
  - provide a ______ where environment or service condition is not well known

Motor Enclosures


- DP - dripproof
- DPFG - dripproof, fully guarded
- SP - splashproof
- FV - forced ventilation (separate/attached fan)
- TENV - totally enclosed, non-ventilated
- TEFC - totally enclosed, fan cooled
- TEUC - totally enclosed, unit cooled (heat-X)

AC Motor Efficiency

- Efficiency, $\eta$

- Small universal motors have $\eta \sim 30$
- Large 3-phase motors have $\eta \sim 95$
- Depends on actual motor load vs. rated load
  - efficiency best near rated load
  - efficiency drops rapidly for both under- and over-load conditions