ABB Low Voltage Drives
A Comparison of Motor Technologies: Induction, Electronically-Commutated, and Synchronous Reluctance

The Motors

Although motors date back to the 1880s, work is still being done to improve existing motors and create new designs. The motors below can be found in commercial HVAC applications. All use a three-phase AC stator which creates a rotating magnetic field that drives the motor's rotor. The stator is often powered by a variable frequency drive (VFD).

- **Asynchronous AC Induction Motor**
- **Electronically-Commutated Motor (ECM)**, which is also called a **Permanent Magnet (PM) Motor**
- **A Synchronous Reluctance Motor (SynRM)**

The Asynchronous AC Induction Motor – How it works

1. The small, light blue arrows in *Figure 1* represent the magnetic field produced by the stator coils.
2. The large dark blue arrow shows the direction of rotation of the magnetic field.
3. As the stator's magnetic field sweeps past the rotor bars, it generates ("induces") a current in the rotor bars. The faster the stator's magnetic field sweeps past the rotor's bars, the larger the current generated in the rotor.
4. When the load on the motor's shaft increases, the rotor's rotation slows somewhat.
5. As a result, the stator's magnetic field sweeps past the rotor bars at a higher speed. This increases the current induced in the rotor. "Slip" is the difference between the speeds of the magnetic field and the rotor.
6. The increased rotor current produces more torque in the motor.

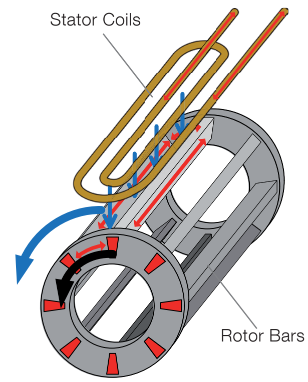

Figure 1: AC Induction Motor

The Asynchronous AC Induction Motor is the only motor in this report that responds to its load in this way. This allows the motor to be able to be started across the power line, while the others normally need to be run from a VFD. *Figure 2* shows this. When the motor is stationary and full line frequency is applied to it (i.e. the slip is 100%), this motor draws 625% of full load current and produces 135% of full load torque. This torque should be enough to start most HVAC loads.

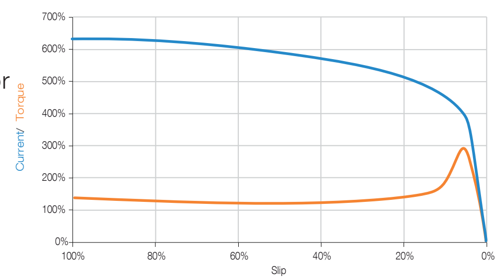

Figure 2: AC Induction Motor Current and Torque Curves

The Asynchronous AC Induction Motor – Its Efficiency

Modern Asynchronous AC Induction motors have been optimized to provide efficiencies which are significantly greater than they were in the past. As shown in *Figure 3*, Premium Efficiency AC induction motors from 5 HP through 100 HP have full load efficiencies from just under 89% to over 95%, with the larger motors having the higher efficiency. These motors also maintain their efficiencies down to below 60% of full load.

Although AC Induction motors are more efficient than they were in the past, there is always interest in increasing the efficiency of equipment. *Figure 4* shows the losses in the rotor of the AC Induction Motor compared to its total losses. Rotor losses are often the second largest losses in the motor (the stator losses are generally larger), so other motor designs have been developed in order to remove this source of losses.

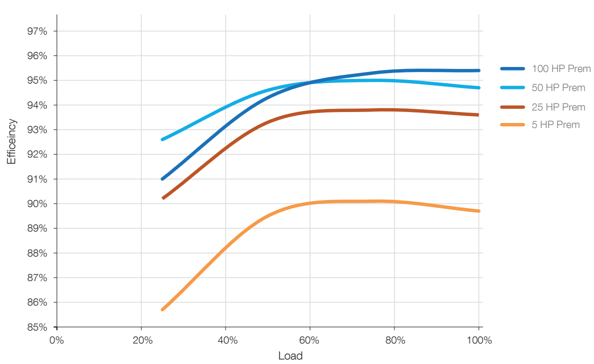

Figure 3: Efficiencies of Premium Efficiency Asynchronous AC Induction Motors

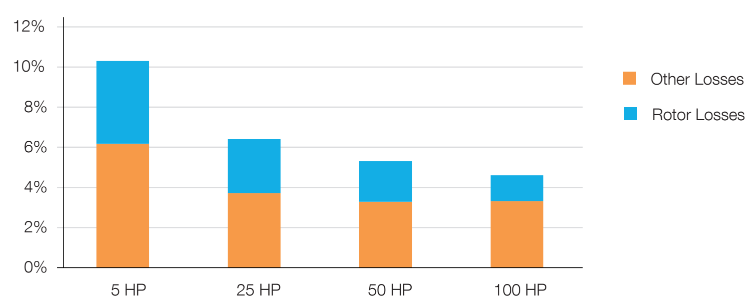

Figure 4: Rotor Losses in an AC Induction Motors

The Electronically Commutated Motor (ECM) – Notes

- Instead of turning the rotor into a large electromagnet, the ECM uses permanent magnets to create the rotor's magnetic field.
- The magnets in the ECM's rotor must be close to the magnetic field of the stator to produce significant torque. Therefore, most ECMs are powered by a PWM drive which monitor's the rotor's position and synchronizes the stator's magnetic field with it.
- As a result, an ECM cannot be started from the AC power line.
- Because the ECM doesn't drive current through the rotor, the rotor losses shown in *Figure 4* will not occur. This is evident in the full load efficiency comparison for all motors in *Figure 5*.
- *Figure 6* shows that the efficiency of an ECM at light load is quite high.

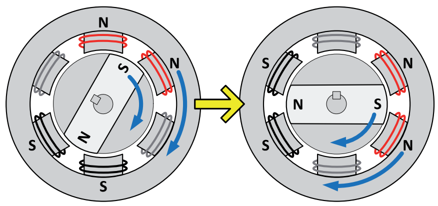

Figure 5: As the stator's magnetic field rotates, the magnets in the ECM's rotor follow it.

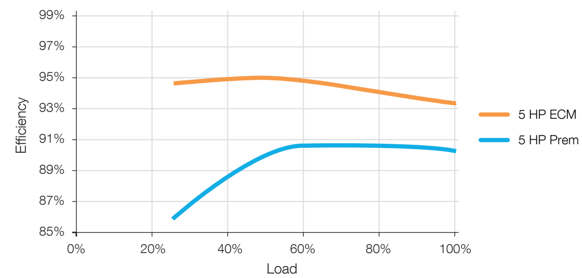

Figure 6: Efficiencies of 5 HP Induction Motor and ECM

Types of ECMs

To many people, an ECM is a motor with an integrated VFD, as shown in *Figure 7*. This provides a compact, high efficiency package which eliminates the need to wire between the VFD and the motor.

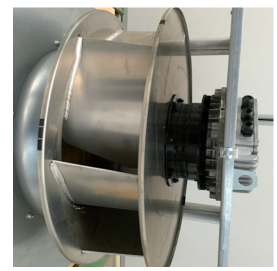

Figure 7: An ECM which is integrated with a VFD (on the right) and the driven fan

Concerns with this package are:

- Most of these packages can't be field-serviced.
- There often is no control panel; all set-up and troubleshooting must done through the serial communications bus.
- When a number of these are in a facility, the harmonic distortion which they cause on the facility's power grid must be considered.

Figure 8 shows a separate ECM, which is often called a Permanent Magnet (PM) motor. This has many of the same advantages as the integrated package, except that the motor must be wired to the VFD.

Figure 8: A separate ECM. Sometimes called a Permanent Magnet (PM) Motor.

When selecting a VFD for an ECM, it is important to know the design of the motor in order to ensure that the VFD can synchronize the stator's magnetic field with the motor's rotor. A motor with non-salient poles is the more common ECM. Its permanent magnets are mounted to the surface of the rotor and generate a sine wave feedback signal to the VFD. A motor with salient poles uses magnets which are embedded in the rotor. They produce a trapezoidal feedback to the VFD.

The Synchronous Reluctance Motor (SynRM)

Like the ECM, the SynRM's rotor doesn't carry any current. It instead provides a path for the stator's magnetic field. The regions of high magnetic permeability in the rotor align with the stator's magnetic field. Like the ECM, the SynRM generally must be run from a VFD in order to maintain synchronization.

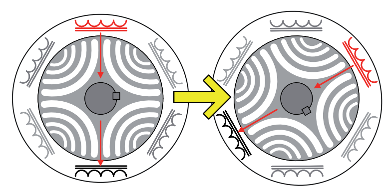

Figure 9: The regions of high magnetic permeability in the SynRM's rotor follow the stator's magnetic field.

Because the rotor doesn't contain permanent magnets, servicing the motor is simplified. The SynRM has a low power factor, which ranges from 0.64 for a 2 HP motor to 0.73 for a 125 HP motor. This increases its current draw. This has a minor impact on the motor's efficiency. It does make it necessary to select a VFD for it based on the motor's rated current, not its power rating.

Summary

Motor Design	Efficiency	Size/Weight	Ease of Service	Can Run in Bypass	Multi Motors on VFD?
Asynchronous Induction	basis of comparison			yes	yes
ECM	~ +2%	often smaller	difficult	no	no
SynRM	~ +1%	often normal	normal	no	no

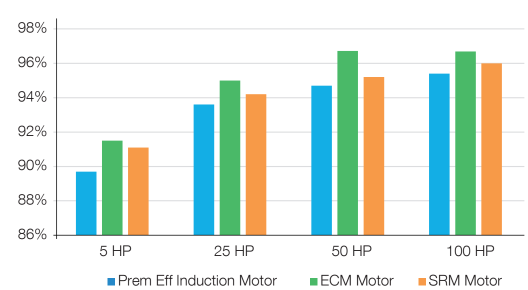

Figure 10: A Comparison of the Efficiencies of All Three Motors

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