ELECTRONICALLY COMMUTATED MOTORS

Part 1: History and Overview of ECMs

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OVERVIEW OF ECM TECHNOLOGY

Electronically commutated motor (ECM) technology has been in use for over 20 years in the HVACR industry. Predominantly used in variable-speed indoor blower motors, ECMs were introduced in 1987 by GE (rebranded Genteq™ in 2009). These innovative motors provide improved efficiency, as well as programming and comfort options not possible with PSC induction motors. However, they are still widely misunderstood, misapplied, and misdiagnosed.

What is ECM technology? ECM technology is based on a brushless dc (direct current) permanent magnet design that is inherently more efficient than the ac (alternating current) shaded-pole and permanent split-capacitor (PSC) motors commonly found in air handlers, furnaces, heat pumps, air conditioners, and refrigeration applications throughout the HVACR industry. By combining electronic controls with brushless dc motors, ECMs can maintain efficiency across a wide range of operating speeds. Plus, the electronic controls make the ECM programmable, allowing for advanced characteristics that are impossible to create using conventional motor technologies. The information that follows pertains to direct-drive indoor blower motors and outdoor fan motors built in ⅕-, ⅓-, ½-, ¾-, and 1-hp sizes. These motors are used in residential and light commercial HVAC systems of 5 tons or less.

In the mid 1900s, alternating current (induction) PSC motors became the standard for fractional-horsepower motors used in residential and light commercial HVAC systems for both indoor and outdoor (split-system and package) units. The PSC motor (built with run and start windings and an external run capacitor) is more efficient and provides better starting torque than its predecessor, the shaded-pole motor (built with a run winding and shading coils). The physical design of these motors makes them simple and easy to operate, but also limits their operational range and efficiency. The operational range is limited by the number of speeds or speed taps, the number of poles in the stator, and the frequency of the delivered power (which is typically 60 Hz in the U.S.). The poles of the motor as constructed cannot be changed, and the delivered frequency is fixed by the utility company, which means that the only adjustments that can be made to the output of the motor are the speeds. These are essentially adjustments to the horsepower by tapping the winding at multiple locations.

Once the speed is selected, the output is also greatly affected by the resistance of the air-side components, the dirt load, the duct sizing, and the registers and grilles. Some of these resistances are fixed, while others change over the life of the system. Due to air-side resistance and the fixed design of the motor, the bottom line is that once a speed has been selected for the HVAC system demand, the amount of airflow that the motor can produce cannot be controlled.

At the top of the next page is a chart that shows the limitations of PSC indoor blower motors (which are typically 6-pole motors) and outdoor fan motors (typically 8-pole motors). *Synchronous speed* is frequency (Hz) multiplied by 120 divided by the number of poles. PSC motors do not run at synchronous speed due to *slip* (electrical and mechanical losses in the motor and external load).

The *rated speed* (data plate rating) is the actual operating speed of the motor at one test point (typically high speed) under a given load. The *operational range* of the motor refers to how fast or slow the motor is capable of operating due to load and speed selection.

PSC MOTORS		
Fixed frequency (60 Hz U.S.)	6 poles	8 poles
Synchronous speed (60 Hz)	1200 rpm	900 rpm
Rated speed (data plate)	1075 rpm	825 rpm
Operational range	900–1100 rpm	600–850 rpm

The typical maximum efficiency of a multispeed PSC motor is around 60% at its design rated speed and load. This efficiency may decrease further, depending on load and operating speed. A large factor in PSC motor efficiency is rotor loss. In PSC motors, the magnetic field (north and south poles) of the rotor is created by an inductive magnetic force from the stator. This magnetic force comes from power applied to the stator winding.

Electric motors basically have two components—the rotating section, or *rotor*, surrounded by the stationary section, or *stator* (see Figure 1). The stator does not move, but the magnetic force in the stator does, creating a rotating (north and south) magnetic effect. The rotor, with an induced north and south field, simply follows the rotating field created in the stator.

An ECM can be described simply as a basic electric motor, operated by a microprocessor-based motor control.

Instead of line voltage being provided directly to the winding (speed taps) to energize the motor (as in PSC and shaded-pole motors), line-voltage power is supplied continuously to the motor control. To operate the motor, a separate communication signal is sent to the motor control specific to the HVAC system airflow requirement for each demand (heat, cool, fan, etc.). This communication, in conjunction with the unique programming in the motor control, allows the microprocessor to operate the motor at a very specific and controlled speed, torque, or combination of the two to create the required airflow. These controls greatly increase the range of operation, as well as the efficiency over that operating range. They also provide more precise control, and allow the operation of the motor to be adjusted internally to compensate for air-side restrictions that cannot be controlled by PSC motors.

Early HVAC literature listed these motors as "ICMs" (integrated control modules), meaning that a control was *integrated* or used in conjunction with a motor to control its operation. The terminology was later changed to "ECM" (electronically commutated motor), as they are typically referred to today. The definition of *commutate* is to change or reverse the

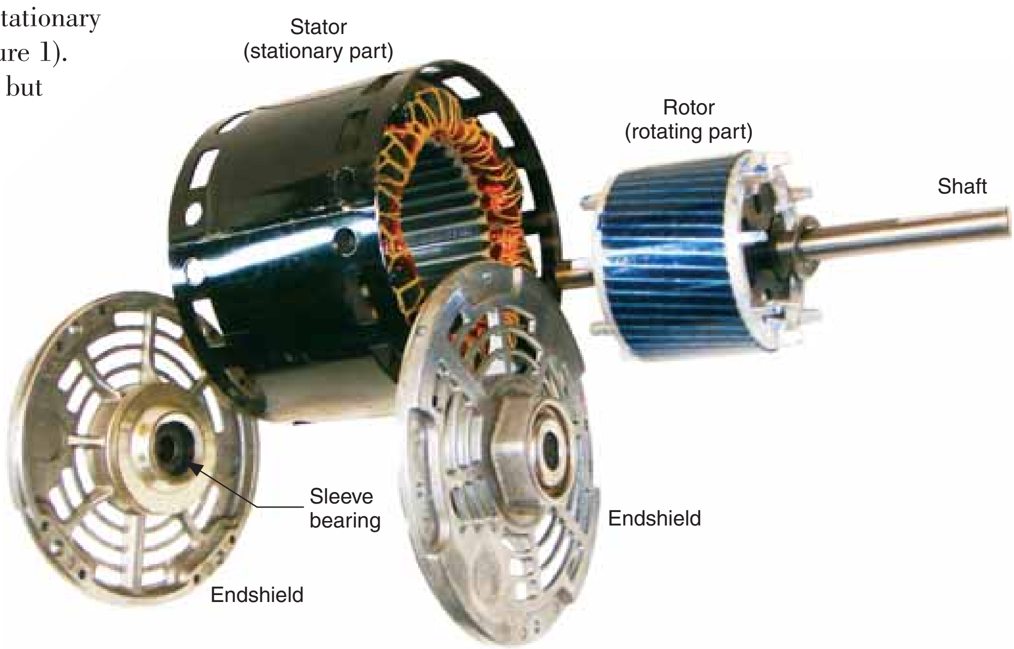

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Figure 1. Typical ac induction electric motor

direction of an electric current (the means by which all electric motors rotate). In an ECM, this process is controlled electronically by a microprocessor and electronic controls, which provide the ability to increase or decrease the speed of the motor.

The type of ECM currently used by most residential HVAC systems is a brushless dc three-phase motor with a permanent magnet rotor. Motor phases are sequentially energized by the electronic control, powered from a single-phase supply. An ECM is actually made of two components—a motor control (the *control module*) and a motor (sometimes called the *motor module*). Depending on the style of ECM, the motor control may be a separate component apart from the motor or it may be integrated into the motor shell (see Figure 2).

The *motor control* serves as the "brains" of the device, where single-phase (1Ø) 120-, 240-, 277-, or 460-V ac 60-Hz power is connected. Input voltage is determined by each model. Some models operate at a single discrete voltage, while others are capable of dual voltages. The control then converts ac power to dc power to operate the internal electronics (thus the description of an ECM as a "dc motor"). The microprocessor in the motor control is programmed to convert dc power (by means of electronic controls) to a three-phase (3Ø) signal to drive the motor (thus its description as a "three-phase motor"). The microprocessor also has the ability to adjust the frequency (which controls the speed in revolutions per minute) and the level of current (torque or power) that it delivers to the motor. The operation of the motor is determined by the programming in the microprocessor and the communication inputs it receives from the HVAC system controls. The communication may be in the form of ac or dc voltage, PWM (*pulse width modulation*, or duty cycle), or DSI (*digital serial interface*) from the HVAC system controls to determine the level at which to operate the motor for the desired airflow by demand (heat, cool, fan, etc.). This communication is model-specific for each OEM (original equipment manufacturer) and must be selected (consult the individual HVAC manufacturer's installation and service manuals) to provide all of the features and benefits of each unique system.

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Figure 2. Electronically commutated motor (ECM) styles

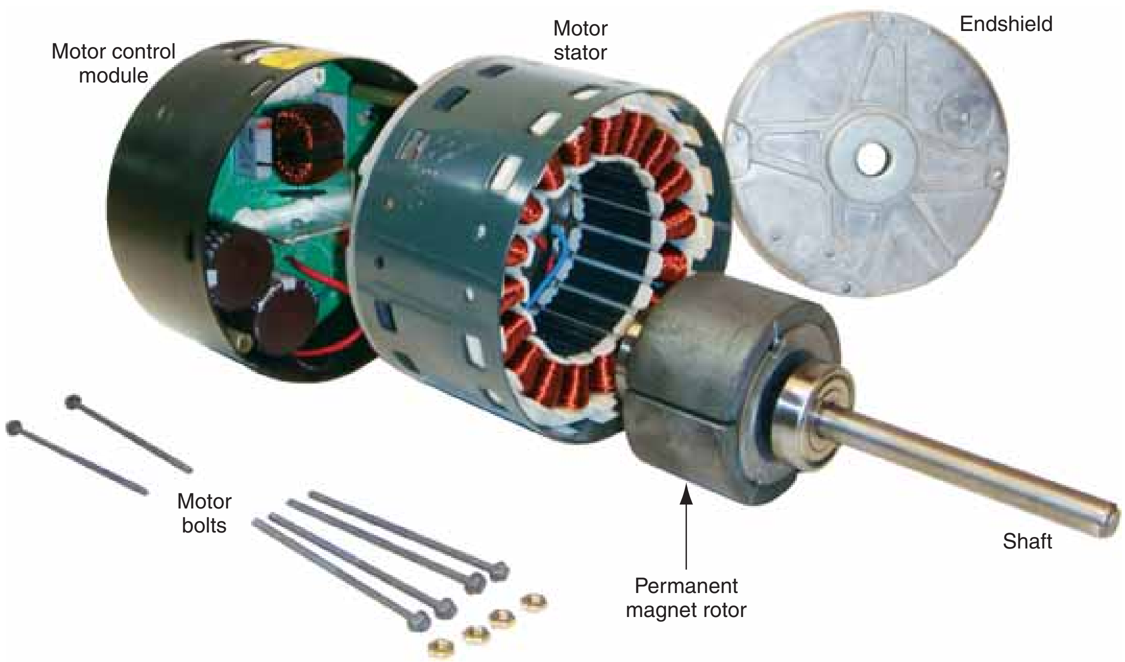

Figure 3. ECM exploded view

The unique features, programmability, and wide range of operation come from the motor control. The motor (described in detail in the next paragraph) has a fixed number of stator poles like a PSC motor. However, unlike a PSC motor, the ECM's motor control can be programmed to maintain constant airflow, constant torque, or constant speed by monitoring and controlling the current and the frequency delivered to the motor. The typical ECM can be programmed to operate at speeds between 600 and 1,200 rpm, with a potential operating range of 200 to 1,500 rpm.

The *motor* is essentially a three-phase motor with a permanent magnet rotor (see Figure 3). The permanent magnet rotor contributes to the electrical efficiency of the ECM and also to its sensorless ability to control the rpm (revolutions per minute) and commutation (when to alternate the cycle). Typical dc motors require brushes to provide the commutation function. This is why the ECM is described as a "brushless" dc motor. The permanent magnet rotor and other inherent design improvements over the PSC motor contribute to the 80% efficiency rating of the ECM, and allow the ECM to operate at near 80% efficiency across its entire operating range.

The remaining chapters in this series will examine three unique types of ECMs:

- *constant-airflow* (variable-speed indoor blower motors)
- *constant-torque* (indoor blower motors)
- *constant-speed* (outdoor fan motors and commercial refrigeration models).

The use of ECM technology is growing rapidly. Today, there is an ECM application for all motors used in residential and light commercial HVAC (indoor and outdoor) and commercial refrigeration (evaporator and condenser), in both OEM and aftermarket. The benefit of this technology is increased electrical efficiency and the ability to program more precise and controlled operation of the motor, over a wide range of HVAC system performance needs, in order to enhance consumer comfort. These features, depending on the model, include enhanced dehumidification, precise and unlimited airflow selections for multistage and modulating systems, quieter constant fan operation, operational profiles, soft start/soft stop, and better airflow.