ECM Motors

APPLICATION GUIDE

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This document provides application highlights covering Electronically Commutated Motors (ECM™).

Additional information may be found at the Titus website, its address is www.titus-hvac.com.

Introduction

The ECM motor is a high efficiency, brushless DC motor with a unique microprocessor based motor controller. Motor efficiencies of 70% or better across the entire operating range of the motor saves considerable electrical energy when compared to conventional induction motors. The motor controller, when tuned to a Titus TQS fan powered terminal, provides a large turn down ratio and constant volume airflow regardless of changes in downstream static pressure operating against the fan. Additionally, Titus has developed a proprietary fan speed control that enables easy field adjustment of the unit if rebalancing is required. With the ECM motor, factory setting of the fan CFM is now possible.

ECM Features and Associated Benefits

- 70% motor efficiency across the entire operating range of the motor yields substantial electrical savings… payback in less than two years!
- Microprocessor based internal motor control maintains constant airflow regardless of changes in downstream static pressure.
- Motor operates efficiently down to 300 rpm providing a wide operating range covering most applications.
- Increased application flexibility due to larger operating range.
- Unique fan speed control provides simple manual or remote adjustment through the unit direct digital controls (DDC).
- Factory preset fan airflows minimize fan terminal balancing efforts.
- Ball bearing design and low heat rise characteristics substantially increase motor life.

Energy Savings Potential

The ECM motor when applied to a Titus TQS fan powered terminal offers significant energy savings over time to the owner when compared to conventional induction motors. However, the initial payback of the motor must be considered when applying ECM technology. Several variables will impact the payback of the ECM motor. Some of these are local electric rates, fan settings, whether occupancy schedules are in place for operating hours and the sizes of units installed in the application. Titus has evaluated an actual field trial and confirmed through bench testing an example of the potential energy savings when using the ECM motor. The following charts show the watt reduction associated with the ½ hp and 1 hp ECM motor when compared to standard TQS units of equivalent application range.

Titus retrofitted a floor of an existing building with ECM motors to conduct an energy comparison of ECM motors vs. standard permanent split capacitor (PSC) motors. The following charts (Figures 1 and 2) show the energy usage at several CFM points over the period of 12-18 months.

TQS Size 6 with 1 hp ECM motor watt comparison to standard permanent split capacitor motor. The average watt reduction over the above range is 335 watts.

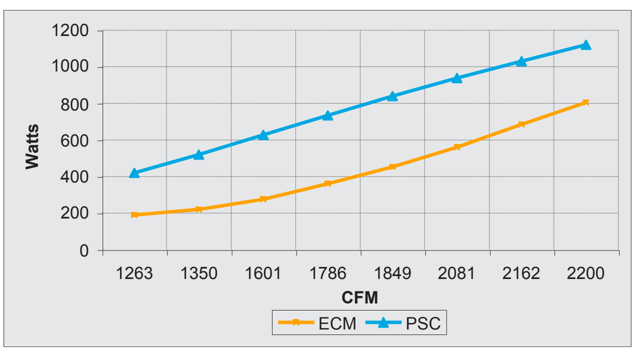

Figure 1. TQS Size 6 – 1 hp ECM Motor

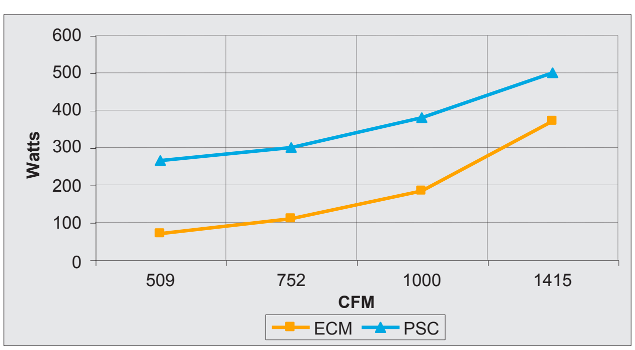

Figure 2. TQS Size 4 – ½ hp ECM Motor

TQS Size 4 with ½ hp ECM motor kW comparison to standard permanent split capacitor motor. The average watt reduction over the above range is 178 watts.

When evaluating this reduction in watts for energy usage the following table shows, at various usage rates, the annual savings per motor. Annual savings assume a run time of 3000 hours per year (250 days at 12 hours/day).

Table 1. Annual Dollar Savings

Usage Rate	kW/hr Reductions		
	0.2872	0.35	0.405
$0.05	$43.08	$52.50	$60.75
$0.06	$51.70	$63.00	$72.90
$0.07	$60.31	$73.50	$85.05
$0.08	$68.93	$84.00	$97.20
$0.10	$86.16	$105.00	$121.50
$0.12	$103.29	$126.00	$145.80
$0.14	$120.62	$147.00	$170.10

Reduction in demand charges must also be considered. Typically, demand charges are calculated during a 15-minute peak window. Some utilities will qualify the peak demand to only the summer months and use this peak as the monthly charge throughout the remainder of the year while other utilities will calculate demand charges using that month's peak kW requirement. The savings associated with reduced demand charges are substantial, as demand charges are usually several dollars per kW.

As an example, a typical multi-story office application may require 200 fan terminals. Each fan terminal equipped with an ECM motor may have a power reduction of approximately 0.4 kW. This translates to an 80 kW reduction in demand and with a demand rate of $10.00 per kW equates to a potential $800 per month reduction in the demand charges. While this model is simplistic, it is indicative of the payback potential of the motor. Utilities will vary not only in price but also in calculation methods with contract kW's versus actual kW usage therefore, actual savings must be calculated according to local market conditions.

Coupling the usage and demand savings associated with the ECM motors can provide a payback of the motor in less than two years to the owner and provide substantial savings then throughout the life of the building.

ECM motors may also be considered for the Leadership Energy and Environmental Design (LEED™) Optimize Energy Performance credit. The ECM motor has efficiencies of up to 70% across its entire operating (300-1200 rpm) and 80% over 400 rpm.

ECM vs. PSC Watt Comparison

The following table shows a watt comparison for the TQS size 4 and 6 vs. the appropriate size TQS with a standard PSC motor at various CFMs. As you turn down the ECM motor, the energy savings increases when compared to a standard motor operating at the same airflow.

For example, turning a size 4 TQS with ECM motor down to 509 CFM uses 75% less energy than a TQS size 2 operating at the same CFM. The ECM motor would be operating at a much lower rpm than the standard motor at this CFM.

Table 2. TQS Size 4 with ECM Motor

Fan CFM	Standard Box Size	ECM Watts	Standard Watts	% Energy Savings
509	2 (1/6 hp)	67	265	75%
752	2 (1/6 hp)	110	280	61%
1000	3 (1/4 hp)	180	380	53%
1415	3 (1/4 hp)	390	498	22%
1547	4 (1/3 hp)	490	520	6%

Table 3. TQS Size 6 with ECM Motor

Fan CFM	Standard Box Size	ECM Watts	Standard Watts	% Energy Savings
1263	5 (1/3 hp)	190	514	63%
1601	5 (1/3 hp)	330	610	46%
2162	6 (3/4 hp)	670	1040	36%
2387	6 (3/4 hp)	900	1130	20%
2626	6 (3/4 hp)	1200	1240	3%

TITAN™ ECM Programming Process

Any manufacturer can purchase the ECM motor. The difference is in the development and programming of the ECM motor to operate effectively and efficiency within the specific fan powered terminal's design and configuration. The ECM motor only provides a benefit if it is developed and programmed correctly within the specific fan box.

Titus uses the Titus Iterative Test & Analysis Network™ (TITAN™) ECM Programming Process in its ISO 9001:2000 certified lab, the Harold Straub Research & Training Center. The TITAN process ensures the performance of the ECM motor in all of the Titus fan-powered terminals.

THE HISTORY OF ECM MOTORS IN COMMERCIAL HVAC

Titus has been programming ECM motors for almost a decade. In early 1995, General Electric (GE™) contacted Titus about helping them bring their ECM motors into the commercial heating ventilation and air conditioning (HVAC) market. Titus provided GE with the requirements of the commercial market such as required motor voltages (the ECM motor was not available in 277V at the time) and market size and ECM motor potential.

Understanding that the ECM motor was a significant price increase over standard PSC motors, Titus retrofitted one floor of the Oryx Energy Tower in Dallas, TX with ECM motors and compared the energy usage of that floor against a floor with PSC motors over an eighteen month period to prove the energy savings would provide an acceptable payback of three years or less.

Titus shipped the first ECM fan powered terminal to a school district in Houston in 1997. Titus has been shipping ECM motors ever since. This extensive history and commitment to the development of the ECM motor for commercial applications, makes Titus an expert in ECM development. This expertise is the basis of the TITAN ECM Programming Process.

PROCESS SUMMARY

The TITAN ECM Programming Process is an iterative process of developing constants for the ECM motor to operate at the optimum efficiency and provide pressure independent airflow. Up to a dozen test runs are preformed using the GE ECM motor programming interface equipment to ensure the correct motor constants. Developing the correct motor constants allows optimal control of the speed and torque of the motor in the particular fan box design.

The minimum and maximum fan curves are determined based on minimum and maximum rpm of the ECM motor (300 rpm and 1200 rpm respectively). The GE interface unit plots rpm versus torque of the motor and determines the difference between measured venturi CFM and the ECM calculated CFM. This test is repeated until the difference in venturi CFM and the ECM calculated CFM equals zero. Once the CFM difference is zero, or as close to zero as possible, the ECM constants are saved for that unit's airflow characteristics.

All Titus fan-powered terminals with ECM motors are provided with a factory installed pulse width modulation (PWM) controller. The PWM voltage signal is calibrated to provide 100% fan at full voltage (10.0V) and minimum fan at minimum voltage (1.0V). The calibrated PWM allows the ECM motor to operated as programmed by Titus regardless of what manufacturer's DDC controller provides the voltage signal to the PWM controller. This ensures the pressure independent operation of the motor with any DDC controller. The PWM signal can also be controlled manually using two dial pots much like a SCR on a standard PSC motor.

The TITAN ECM Programming Process extends from the lab to the ISO 9001:2000 certified factories where individual ECM motors are programmed with the appropriate ECM program for each order

Building Codes

With energy considerations growing, there has been an increased interest in "green" buildings, sustainable design, and energy savings. Thirty-two states have mandatory energy codes. Most state energy codes are based on the International Energy Conservation Code (IECC) or ASHRAE/ IESNA 90.1.

The IECC covers design of energy-efficient building envelopes and the installation of energy-efficient mechanical, lighting and power systems through requirements emphasizing performance. Chapter 7 of the IECC references ASHRAE/ IESNA 90.1. The standard ASHRAE/IESNA 90.1 was developed to provide minimum requirements for the energy-efficient design of buildings except low-rise residential buildings. Section 6 of the standard covers Heating, Ventilation, and Air Conditioning.

Although the U.S. Green Building Council is not a government agency, many local governing bodies are requesting, and in some cases requiring, green design features into their new construction requirements. Some states and cities offer tax incentives for buildings that meet green building codes or become LEED certified and other will most likely offer incentives in the future.

New York was the first state to implement a green building tax program. The credit allows builders who meet energy goals and use environmentally preferable materials to claim up to $3.75 per square foot for interior work and $7.50 per square foot for exterior work against their state tax bill. Maryland has implemented green building a tax credit program and Massachusetts is currently reviewing a green building program. Oregon's tax credit program uses LEED certification levels to determine the level of tax credit.

The Seattle Energy Code specifies ECM motors in Chapter 14, Building Mechanical Systems states that Fan motors less than 1 hp in series terminal units shall be either electronically-commutated motors, or have a minimum motor efficiency of 65% when rated in accordance with National Electrical Manufacturers Association (NEMA) Standard MG-1 at full load rating conditions.

The appendix shows the state energy code requirements (as of May 2004).

Suggested Specification

Fan motor assembly shall be forward curved centrifugal fan with a direct drive motor. Motors shall be General Electric ECM, variable-speed, DC, brushless motors specifically designed for use with single phase, 277 volt (or 120 volt), 60 hertz electrical input. Motor shall be complete with and operated by a single-phase integrated controller/inverter that operates the wound stator and senses rotor position to electronically commutate the stator. All motors shall be designed for synchronous rotation. Motor rotor shall be permanent magnet type with near zero rotor losses. Motor shall have built-in soft start and soft speed change ramps. Motor shall be able to be mounted with shaft in horizontal or vertical orientation. Motor shall be permanently lubricated with ball bearings. Motor shall be direct coupled to the blower. Motor shall maintain a minimum of 70% efficiency over its entire operating range. Provide manual (or optional remote) fan speed output control for field adjustment of the fan airflow setpoint. Inductors shall be provided to minimize harmonic distortion and line noise. Provide isolation between fan motor assembly and unit casing to eliminate any vibration from the fan to the terminal unit casing. Provide a motor that is designed to overcome reverse rotation and not affect life expectancy.

The terminal unit manufacturer shall provide a factory installed PWM controller for either manual or DDC controlled fan CFM adjustment. The manual PWM controller shall be field adjustable with a standard screwdriver. The remote PWM controller shall be capable of receiving a 0-10 Vdc signal from the DDC controller (provided by the controls contractor) to control the fan CFM. When the manual PWM controller is used, the factory shall preset the fan CFMs as shown on the schedule.

Abbreviations

The following table lists abbreviations used within this document.

Abbrev.	Term
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
CFM	cubic feet per minute
DC	Direct current
DDC	Direct digital control
ECM	Electronically Commutated Motor
GE	General Electric
hp	horsepower
HVAC	Heating Ventilation and Air Conditioning
IECC	International Energy Conservation Code
IESNA	Illuminating Engineering Society of North America
ISO	International Standards Organization
kW	kilowatt
LEED	Leadership Energy and Environmental Design
NEMA	National Electrical Manufacturers Association
PSC	Permanent Split Capacitor
PWM	Pulse Width Modulation
rpm	revolutions per minute
TITAN	Titus Iterative Test & Analysis Network
USGBC	United States Green Building Council
V	Volt
Vdc	Volt direct current

Appendix – State Energy Code Requirements

State	Website	Current Status Commercial	Mandatory Statewide
AK	http://www.ahfc.state.ak.us	None statewide.	No
AL	http://www.bsc.auburn.edu/aderhrw2/codes/	ASHRAE/IESNA 90.1-1989 for only state-owned or -funded buildings.	Yes
AR	http://www.1800arkansas.com/energy/	ASHRAE/IESNA 90.1-1989	Yes
AZ	http://www.azcommerce.com/Energy/default.asp	ASHRAE/IESNA 90.1-1999 Voluntary statewide, mandatory for state-owned or -funded buildings	No
CA	http://www.energy.ca.gov/title24/index.html	State-developed code, Part 6 of Title 24, which meets or exceeds ASHRAE/IESNA 90.1-1999, is mandatory statewide	Yes
CO	http://www.coloradoenergy.org	Voluntary state provisions are based on ASHRAE/IESNA 90.1-1989	No
CT	http://www.opm.state.ct.us/default.htm	ASHRAE/IESNA 90.1-1989 is mandatory statewide;	Yes
DC	www.dcenergy.org	2000 IECC	Yes
DE	N/A	ASHRAE/IESNA 90.1-1989	Yes
FL	http://www.floridabuilding.org	State-developed code, which meets or exceeds ASHRAE/IESNA 90.1-1989	Yes
GA	http://www.gefa.org/energy_program.html	ASHRAE/IESNA 90.1-2001	Yes
HI	http://www.hawaii.gov/dbedt/ert/model_ec.html	A modified version of ASHRAE/IESNA 90.1-1989 adopted by all counties except Maui. Portions of ASHRAE 90.1-1999 adopted by Honolulu County	No
IA	http://www.state.ia.us/government/dnr/energy/	ASHRAE/IESNA 90.1-1989 is mandatory statewide	Yes
ID	N/A	2000 IECC is mandatory statewide	Yes
IL	http://www.commerce.state.il.us/com/energy/	State-owned buildings and city-owned buildings must comply with ASHRAE/IESNA 90.1-1989	No
IN	http://www.state.in.us/sema/press_newcodes.html	The state-developed code, which does not meet ASHRAE/IESNA 90.1-1989, is mandatory statewide	Yes
KS	http://www.kcc.state.ks.us/energy/energy.htm	ASHRAE/IESNA 90.1-2001 / 2003 IECC is mandatory statewide	Yes
KY	http://www.state.ky.us/agencies/cppr/dhbc/index.htm	2000 IECC for exterior building envelope only mandatory, 2002 KY Building Code	Yes
LA	http://www.dps.state.la.us/sfm/energycd.htm	ASHRAE/IESNA 90.1-1989	Yes
MA	http://www.state.ma.us/bbrs/energy.htm	MA State Building Code based on ASHRAE/IESNA 90.1-1999 and 2000 IECC with state specific amendments	Yes
MD	http://www.energy.state.md.us/	ASHRAE/IESNA 90.1-1989 is mandatory statewide	Yes
ME	http://www.state.me.us/spo/ceo/ceohome.htm	ASHRAE/IESNA 90.1-2001	Yes
MI	http://www.cis.state.mi.us/opla/eo/resid/	ASHRAE/IESNA 90.1-1999 is mandatory statewide	Yes
MN	http://www.admin.state.mn.us/buildingcodes/	Minnesota State Building Code, which exceeds ASHRAE/IESNA 90.1-1989	Yes
MO	http://www.dnr.state.mo.us/de/homede.htm	None, except state-owned buildings must comply with ASHRAE/IESNA 90.1-1989	No
MS	http://www.mississippi.org/programs/energy/energy_overview.htm	ASHRAE Standard 90-1975 is mandatory for state-owned buildings, public buildings, and high-rise buildings.	Yes
MT	http://discoveringmontana.com/dli/bsd/bc/index.htm	ASHRAE/IESNA 90.1-1989	Yes
NC	http://www.ncdoi.com http://www.ncdoi.com/OSFM/default.asp	State code based on ASHRAE/IESNA 90.1-1999 and 2000 IECC, is mandatory statewide	Yes

Appendix – State Energy Code Requirements (continued)

State	Website	Current Status Commercial	Mandatory Statewide
ND	http://www.state.nd.us/dcs	ASHRAE/IESNA 90.1-1989 is contingent on adoption by local jurisdiction	No
NE	http://www.nol.org/home/NEO/	For conventionally funded projects: 1983 MEC is mandatory statewide. State-owned and -funded buildings must comply with ASHRAE/IESNA 90.1-1989.	Yes
NH	http://www.puc.state.nh.us/energypg.html	ASHRAE/IESNA 90.1-1999	Yes
NJ	http://www.state.nj.us/dca/codes/	ASHRAE/IESNA 90.1-1999 mandatory statewide	Yes
NM	http://www.emnrd.state.nm.us/ecmd	2003 IECC	Yes
NV	http://www.energy.state.nv.us	1986 MEC with state amendments; state owned facilities must comply with ASHRAE/IESNA 90.1-2001	No
NY	http://www.dos.state.ny.us/code/energycode/nyenergycode.htm	State code based on 2000 IECC w/amendments including ASHRAE/IESNA 90.1-1999	Yes
OH	http://www.odod.state.oh.us/cdd/oee/	ASHRAE/IESNA 90.1-1999	Yes
OK	http://www.state.ok.us	ASHRAE/IESNA 90.1-1989 is mandatory for jurisdictions that do not adopt their own code and for state	Yes
OR	http://www.energy.state.or.us/code/codehm.htm	State-developed code that meets or exceeds ASHRAE/IESNA 90.1-1989 is mandatory statewide.	Yes
PA	http://www.dli.state.pa.us/landi/cwp/view.asp?a=124&Q=61120%20	2003 IECC	Yes
RI	N/A	2000 IECC and ASHRAE/IESNA 90.1-1999	Yes
SC	http://www.state.sc.us/energy	ASHRAE/IESNA 90.1-1989 is mandatory statewide	Yes
SD	N/A	None	No
TN	N/A	ASHRAE 90A-1980 and 90B-1975 are mandatory statewide	Yes
TX	http://www.seco.cpa.state.tx.us	2001 IECC with amendments, ASHRAE/IESNA 90.1 2001 for state agencies and institutions of higher learning	Yes
UT	http://www.energy.utah.gov/	2000 IECC including ASHRAE/IESNA 90.1-1999 is mandatory statewide	Yes
VA	http://www.mme.state.va.us/de/	2000 IECC is mandatory statewide	Yes
VT	http://www.state.vt.us/psd/ee/ee19.htm	2001 Vermont Guidelines for Energy Efficient Commercial Construction based on 2000 IECC with amendments to incorporate and exceed ASHRAE/IESNA 90.1-1999	No
WA	http://www.energy.wsu.edu	State-developed code, based on ASHRAE/IESNA 90.1-1999 for equipment, lights, and motors	Yes
WI	http://www.commerce.state.wi.us/sb/sb-homepage.html	2000 IECC w/amendments	Yes
WV	http://www.wvdo.org/community/eep.htm	2000 IECC	No
WY	N/A	1989 MEC may be adopted by local jurisdictions	No

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