TECH TIPS | Fan-Powered Terminal Units

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There have been several different research projects that have investigated the efficiency of series and parallel fan powered terminal units (FPU) in regards to overall efficiency – which type is best for design purposes as a component in the overall building HVAC system design. Selecting the type of FPU is complicated by the issue of permanent split capacitor (PSC) motors verses electronically commutated motors (ECM). Several local codes have adopted rules that limit the motor type in series FPU to only ECM, but fail to address the motor type in the parallel FPU. At the national code level, there is some discussion on making the ECM motor the default type for use in series FPU as well. This article discusses the differences between series and parallel FPU as well as the energy consumption characteristics of the ECM and PSC motor types.

FAN POWERED TERMINALS

A basic series FPU (often referred to as constant volume or constant fan) consists of an air inlet assembly similar to a single duct, a housing, a motor/blower assembly, a return air opening/plenum opening, and a high voltage connection (see Figure 1). All the discharge air from the series FPU goes through the motor/blower assembly. This discharge air is a mixture of supply air from the air inlet assembly and the return air opening. The percentage of supply air and return/plenum air will vary based on the regulation of the supply air inlet valve due to room cooling calls by the thermostat. The fan volume for a series FPU is typically constant and is sized to handle the peak cooling load in the occupied zone.

A basic parallel FPU (sometimes referred to as intermittent) consists of an air inlet assembly, a housing, a blower/motor assembly with a back draft damper either at the blower discharge or upstream of the blower in the return air opening, a mixing chamber, a return air opening, and a high voltage connection (see Figure 2). In cooling mode, the discharge air from the parallel FPU consists only of the air from the air inlet assembly. In heating mode, the discharge air is a mixture of air inlet supply (typically at minimum flow) and return air from the blower, with or without supplemental heating as required. The fan in a parallel FPU is sized for the heating air flow required for the zone.

The major issue in selecting either a series or a parallel FPU is the energy efficiency of the unit in the overall HVAC system design. Recent research by ASHRAE and Texas A&M University [Furr, 2007] has demonstrated that many of the energy savings due to intermittent fan cycling (in the parallel FPU) are offset and may in fact be significantly less than the energy loss associated with the conditioned primary air leaking out of the return air opening into the plenum cavity through the back draft damper and the mixing chamber housing. If leakage through the back draft damper is of a concern, the designer should either use a series FPU or other terminal type, or require that the leakage from the parallel FPU back draft damper and mixing chamber housing be tested and certified to some specified amount. The ability to test the leakage of a parallel terminal back draft damper and mixing chamber housing for each terminal as it is manufactured and to quantify this leakage is not common practice for all manufacturers of these devices. Price can perform this testing upon request.

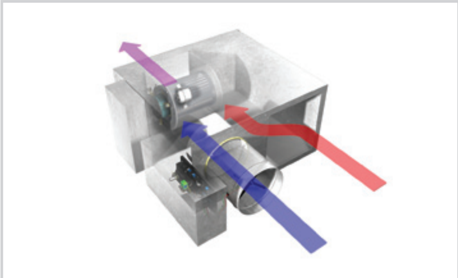

Figure 1: Series Fan Powered Terminal Unit (Overhead Applications) Air Pathway

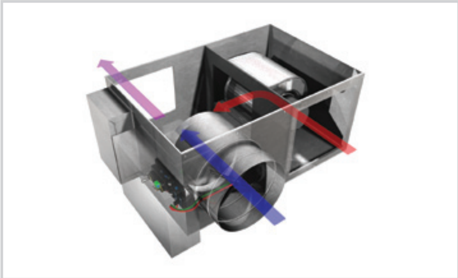

Figure 2: Parallel or Intermittent Fan Powered Terminal Air Pathway

MOTORS

Fan powered terminals, and their motors, are rated as an assembly using Standard UL 1995, Heating and Cooling Equipment. This standard only applies to equipment manufacturers and not international or local codes, nor field issues. Nameplate ratings on the motor may not match the nameplate rating on the FPU. In particular, the amperage listed on the nameplate of the FPU may be above or below that shown on the motor nameplate. Also, the voltage may differ on both nameplates. Due to over-current protection requirements in the UL code, always use the nameplate rating of the FPU, not the motor nameplate rating, when sizing the supply circuit wiring and fusing. This over-current rating requirement is intended to provide the safest possible operation of the FPU and any electrical accessories.

A PSC motor is a type of single-phase AC motor and is a type of split-phase induction motor. The PSC motor uses a capacitor as a component of the start windings in the motor. This provides a greater starting torque than a standard split-phase induction motor. The capacitor allows the motor to be operated at variable speeds by the use of a thyristor (speed controller). This modification of the AC Sine Wave reduces the RMS value of the voltage supplied to the motor, resulting in a reduced torque and lower rpm. As long as the motor and blower are sized properly, and not operating near an extreme on the fan curve, the modified current draw is very similar to the unmodified current draw with just a slightly higher amount of current being used. Note that at some speed settings, significant power may be dissipated by the thyristor (speed controller), which will lower the overall efficiency of the FPU as this power will be dissipated as heat. Due to the heat dissipating nature of the speed controller, the overall motor efficiency is considered to be around 35% when the motor is operated below 70% capacity.

The ECM motor is a brushless DC permanent magnet motor. The ECM motor has been on the market since 1985 and is a proven technology. ECM motors are microprocessor-controlled, programmable motors that incorporate a built-in power inverter (converts AC to DC). In FPUs, the ECM motor is typically of higher efficiency (lower power consumption) at most operating conditions. Control of the rpm of the ECM motor is achieved by varying the DC voltage supplied to the motor. As a result of this type of control, very little heat is dissipated, which gives an overall motor efficiency around 65% when the motor is operated below 70%.

In selecting a motor type, unless the code mandates a type, the question is a matter of energy consumption verses initial cost. The ECM motor is more expensive than the PSC motor; however, since there are now at least two suppliers of the ECM type motor, the cost may drop over time. With energy savings typically being the driving force between selecting an ECM over a PSC motor, the question becomes how fast can I get a return on my investment for the more expensive motor?

For the sake of discussion, I am going to set the additional cost for an ECM motor over that of a PSC motor at $350. This is a conservative amount; the actual cost will vary based on the terminal units, motor size, and controls selected. Based on the maximum (26 cents/kWh) and minimum (7 cents/kWh) for the United States in May 2010, with the average cost being 10 cents/kWh [EIA 2010], two different loading profiles were developed and are shown in Figures 3 and 4. The payback period is based on the number of years required to return a savings of $350 and 10 cents/kWh, which is shown in Figure 5. The actual payback period will vary based on the actual cost differential for the ECM motor over the PSC, the terminal unit motor size, and the actual motor operating point. A note of caution: in these calculations, no attempt was made to account for demand-based energy surcharges. Also, the terminal size, motor hp, and operation point will all impact the energy consumption.

SUMMARY

The payback period for a 24 hour, 365 days per year operation cycle is less than 1.7 years for all airflow volumes for this size and model of series FPU. For a 12 hour per day, 260 days per year operation cycle, the payback period is less than 3.5 years at the normal selection point for this size and model of series FPU.

It is suggested that the building HVAC designer evaluates the energy consumption profile of the building design using the power consumption characteristics for the FPU to assist in making the proper motor type selection. Also, if a parallel terminal is the basis of design, the leakage rate of primary air into the plenum cavity should be characterized and accounted for.

References:

1. *Furr, J. C., O'Neal, D. L., Davis, M., Bryant, J. A., & Cramlet, A. (2007). Phase 1 FINAL REPORT ASHRAE Project 1292-RP: Comparison of the total energy consumption of series versus parallel fan powered VAV terminal units. Atlanta, GA: American Society of Heating, Refrigeration and Air-Conditioning Engineers.*

2. *U.S. Energy Information Administration (EIA)," www.eia.gov/electricity/epm/table5_6_a.html"; Department of Energy, Washington, D.C.; August 2010.*

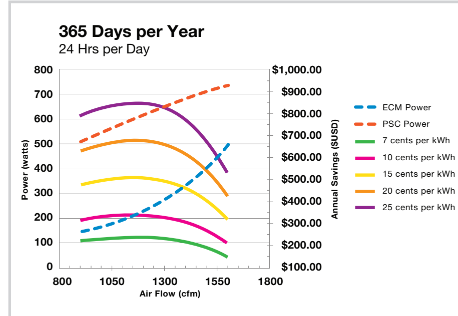

Figure 3: Power consumption and energy savings of ECM over PSC motor for a 24 hours per day, 365 days per year operation. This chart is for a ½ hp motor in a size 40 Price FDCG series terminal unit. Power consumption and energy savings for other terminal unit sizes and models will vary based on motor size, fan powered terminal unit model, inlet static and discharge static pressures.

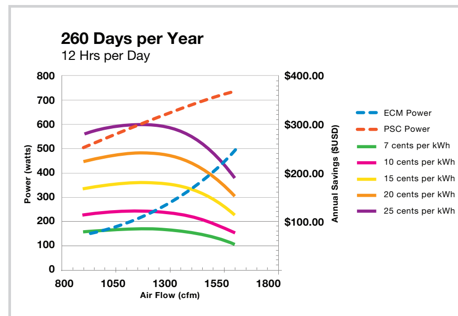

Figure 4: Power consumption and energy savings of ECM over PSC motor for a 12 hours per day, 260 days per year operation. This chart is for a ½ hp motor in a size 40 Price FDCG series terminal unit. Power consumption and energy savings for other terminal unit sizes and models will vary based on motor size, fan powered terminal unit model, inlet static and discharge static pressures.

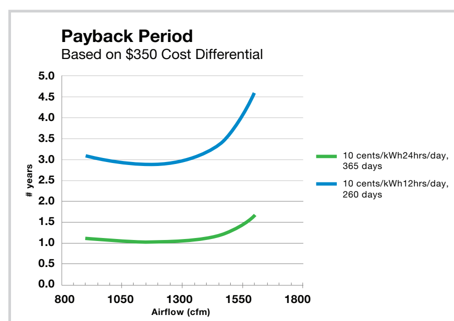

Figure 5: Number of years to payback the initial cost differential through energy savings. Calculations are based on 10 cents/kWh and do not include any demand or other charges. This chart is for a ½ hp motor in a size 40 Price FDCG series terminal unit. Other terminal units will vary based on motor size, fan powered terminal unit model, inlet static and discharge static pressures.