4.4.26 Variable Speed Drives for HVAC Supply and Return Fans

**Description**

This measure is applied to variable speed drives (VSD) which are installed on HVAC supply fans and return fans. There is a separate measure for HVAC pumps and cooling tower fans. All other VSD applications require custom analysis by the program administrator. The VSD will modulate the speed of the motor when it does not need to run at full load. Since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

This measure was developed to be applicable to the following program types: TOS, RF. If applied to other program types, the measure savings should be verified.

**Definition of Efficient Equipment**

The VSD is applied to a motor which does not have a VSD. The application must have a variable load and installation is to include the necessary controls. Savings are based on application of VSDs to a range of baseline load conditions including no control, inlet guide vanes, outlet guide vanes and throttling valves.

**Definition of Baseline Equipment**

The time of sale baseline is a new motor installed without a VSD or other methods of control. Retrofit baseline is an existing motor operating as is. Retrofit baselines may or may not include guide vanes, throttling valves or other methods of control. This information shall be collected from the customer.

Installations of new equipment with VSDs which are required by IECC 2012 or 2015 as adopted by the State of Illinois are not eligible for incentives.

**Deemed Lifetime of Efficient Equipment**

The expected measure life for HVAC application is 15 years;[[1]](#footnote-1) measure life for process is 10 years.[[2]](#footnote-2)

**Deemed Measure Cost**

Customer provided costs will be used when available. Default measure costs**[[3]](#footnote-3)** are noted below for up to 20 hp motors. Custom costs must be gathered from the customer for motor sizes not listed below.

| **HP** | **Cost** |
| --- | --- |
| 1 -5 HP | $ 1,330 |
| 7.5 HP | $ 1,622 |
| 10 HP | $ 1,898 |
| 15 HP | $ 2,518 |
| 20 HP | $ 3,059 |

**Loadshape**

|  |
| --- |
| Loadshape C39 - VFD - Supply fans <10 HP |
| Loadshape C40 - VFD - Return fans <10 HP |
| Loadshape C41 - VFD - Exhaust fans <10 HP |

**Coincidence Factor**

The demand savings factor (DSF) is already based upon coincident savings, and thus there is no additional coincidence factor for this characterization.

**Algorithm**

**Calculation of Savings**

**Electric Energy Savings[[4]](#footnote-4)**

|  |  |
| --- | --- |
| kWhBase = |  |
| kWhRetrofit = |  |
| ∆kWhfan = |  |
| ∆kWhtotal = |  |

Where:

= Baseline annual energy consumption (kWh/yr)

= Retrofit annual energy consumption (kWh/yr)

= Fan-only annual energy savings

= Total project annual energy savings

= Conversion factor for HP to kWh

= Nominal horsepower of controlled motor

= Load Factor; Motor Load at Fan Design CFM (Default = 65%)[[5]](#footnote-5)

= Installed nominal/nameplate motor efficiency

Default motor is a NEMA Premium Efficiency, ODP, 4-pole/1800 RPM fan motor

**NEMA Premium Efficiency Motors Default Efficiencies[[6]](#footnote-6)**

| Size HP | Open Drip Proof (ODP) | | | Totally Enclosed Fan-Cooled (TEFC) | | |
| --- | --- | --- | --- | --- | --- | --- |
| # of Poles | | | # of Poles | | |
| 6 | 4 | 2 | 6 | 4 | 2 |
| Speed (RPM) | | | Speed (RPM) | | |
| 1200 | 1800 Default | 3600 | 1200 | 1800 | 3600 |
| 1 | 0.825 | 0.855 | 0.770 | 0.825 | 0.855 | 0.770 |
| 1.5 | 0.865 | 0.865 | 0.840 | 0.875 | 0.865 | 0.840 |
| 2 | 0.875 | 0.865 | 0.855 | 0.885 | 0.865 | 0.855 |
| 3 | 0.885 | 0.895 | 0.855 | 0.895 | 0.895 | 0.865 |
| 5 | 0.895 | 0.895 | 0.865 | 0.895 | 0.895 | 0.885 |
| 7.5 | 0.902 | 0.910 | 0.885 | 0.910 | 0.917 | 0.895 |
| 10 | 0.917 | 0.917 | 0.895 | 0.910 | 0.917 | 0.902 |
| 15 | 0.917 | 0.930 | 0.902 | 0.917 | 0.924 | 0.910 |
| 20 | 0.924 | 0.930 | 0.910 | 0.917 | 0.930 | 0.910 |
| 25 | 0.930 | 0.936 | 0.917 | 0.930 | 0.936 | 0.917 |
| 30 | 0.936 | 0.941 | 0.917 | 0.930 | 0.936 | 0.917 |
| 40 | 0.941 | 0.941 | 0.924 | 0.941 | 0.941 | 0.924 |
| 50 | 0.941 | 0.945 | 0.930 | 0.941 | 0.945 | 0.930 |
| 60 | 0.945 | 0.950 | 0.936 | 0.945 | 0.950 | 0.936 |
| 75 | 0.945 | 0.950 | 0.936 | 0.945 | 0.954 | 0.936 |
| 100 | 0.950 | 0.954 | 0.936 | 0.950 | 0.954 | 0.941 |
| 125 | 0.950 | 0.954 | 0.941 | 0.950 | 0.954 | 0.950 |
| 150 | 0.954 | 0.958 | 0.941 | 0.958 | 0.958 | 0.950 |
| 200 | 0.954 | 0.958 | 0.950 | 0.958 | 0.962 | 0.954 |
| 250 | 0.954 | 0.958 | 0.950 | 0.958 | 0.962 | 0.958 |
| 300 | 0.954 | 0.958 | 0.954 | 0.958 | 0.962 | 0.958 |
| 350 | 0.954 | 0.958 | 0.954 | 0.958 | 0.962 | 0.958 |
| 400 | 0.958 | 0.958 | 0.958 | 0.958 | 0.962 | 0.958 |
| 450 | 0.962 | 0.962 | 0.958 | 0.958 | 0.962 | 0.958 |
| 500 | 0.962 | 0.962 | 0.958 | 0.958 | 0.962 | 0.958 |

= Annual operating hours for fan motor based on building type

Default hours are provided for HVAC applications which vary by HVAC application and building type[[7]](#footnote-7). When available, actual hours should be used.

|  |  |
| --- | --- |
| Building Type | **Total Fan Run Hours** |
| Assembly | 7235 |
| Assisted Living | 8760 |
| College | 6103 |
| Convenience Store | 7004 |
| Elementary School | 7522 |
| Garage | 7357 |
| Grocery | 7403 |
| Healthcare Clinic | 6345 |
| High School | 7879 |
| Hospital - VAV econ | 8760 |
| Hospital - CAV econ | 8760 |
| Hospital - CAV no econ | 8760 |
| Hospital - FCU | 8760 |
| Manufacturing Facility | 8706 |
| MF - High Rise | TBD |
| MF - Mid Rise | 8760 |
| Motel | TBD |
| Movie Theatre | 7505 |
| Office - High Rise - VAV econ | 6064 |
| Office - High Rise - CAV econ | 5697 |
| Office - High Rise - CAV no econ | 5682 |
| Office - High Rise - FCU | 6163 |
| Office - Low Rise | 6288 |
| Office - Mid Rise | 6125 |
| Religious Building | 7380 |
| Restaurant | 7809 |
| Retail - Department Store | 6890 |
| Retail - Strip Mall | 6846 |
| Warehouse | 6786 |



= Percentage of run-time spent within a given flow fraction range

Default Fan Duty Cycle Based on 2012 ASHRAE Handbook; HVAC Systems and Equipment, page 45.11, Figure 12.

| **Flow Fraction  (% of design cfm)** | **Percent of Time at Flow Fraction** |
| --- | --- |
| 0% to 10% | 0.0% |
| 10% to 20% | 1.0% |
| 20% to 30% | 5.5% |
| 30% to 40% | 15.5% |
| 40% to 50% | 22.0% |
| 50% to 60% | 25.0% |
| 60% to 70% | 19.0% |
| 70% to 80% | 8.5% |
| 80% to 90% | 3.0% |
| 90% to 100% | 0.5% |

= Part load ratio for a given flow fraction range based on the baseline flow control type

= Part load ratio for a given flow fraction range based on the retrofit flow control type

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Control Type** | **Flow Fraction** | | | | | | | | | |
| **10%** | **20%** | **30%** | **40%** | **50%** | **60%** | **70%** | **80%** | **90%** | **100%** |
| No Control or Bypass Damper | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Discharge Dampers | 0.46 | 0.55 | 0.63 | 0.70 | 0.77 | 0.83 | 0.88 | 0.93 | 0.97 | 1.00 |
| Outlet Damper, BI & Airfoil Fans | 0.53 | 0.53 | 0.57 | 0.64 | 0.72 | 0.80 | 0.89 | 0.96 | 1.02 | 1.05 |
| Inlet Damper Box | 0.56 | 0.60 | 0.62 | 0.64 | 0.66 | 0.69 | 0.74 | 0.81 | 0.92 | 1.07 |
| Inlet Guide Vane, BI & Airfoil Fans | 0.53 | 0.56 | 0.57 | 0.59 | 0.60 | 0.62 | 0.67 | 0.74 | 0.85 | 1.00 |
| Inlet Vane Dampers | 0.38 | 0.40 | 0.42 | 0.44 | 0.48 | 0.53 | 0.60 | 0.70 | 0.83 | 0.99 |
| Outlet Damper, FC Fans | 0.22 | 0.26 | 0.30 | 0.37 | 0.45 | 0.54 | 0.65 | 0.77 | 0.91 | 1.06 |
| Eddy Current Drives | 0.17 | 0.20 | 0.25 | 0.32 | 0.41 | 0.51 | 0.63 | 0.76 | 0.90 | 1.04 |
| Inlet Guide Vane, FC Fans | 0.21 | 0.22 | 0.23 | 0.26 | 0.31 | 0.39 | 0.49 | 0.63 | 0.81 | 1.04 |
| VFD with duct static pressure controls | 0.09 | 0.10 | 0.11 | 0.15 | 0.20 | 0.29 | 0.41 | 0.57 | 0.76 | 1.01 |
| VFD with low/no duct static pressure | 0.05 | 0.06 | 0.09 | 0.12 | 0.18 | 0.27 | 0.39 | 0.55 | 0.75 | 1.00 |

Provided below is the resultant values based upon the defaults provided above:

| **Control Type** |  |
| --- | --- |
| No Control or Bypass Damper | 1.00 |
| Discharge Dampers | 0.80 |
| Outlet Damper, BI & Airfoil Fans | 0.78 |
| Inlet Damper Box | 0.69 |
| Inlet Guide Vane, BI & Airfoil Fans | 0.63 |
| Inlet Vane Dampers | 0.53 |
| Outlet Damper, FC Fans | 0.53 |
| Eddy Current Drives | 0.49 |
| Inlet Guide Vane, FC Fans | 0.39 |
| VFD with duct static pressure controls | 0.30 |
| VFD with low/no duct static pressure | 0.27 |

= HVAC interactive effects factor for energy (default = 15.7%)

**Summer Coincident Peak Demand Savings**

|  |  |
| --- | --- |
| kWBase = |  |
| kWRetrofit = |  |
| ∆kWfan = |  |
| ∆kWtotal = |  |

Where:

= Baseline summer coincident peak demand (kW)

= Retrofit summer coincident peak demand (kW)

= Fan-only summer coincident peak demand impact

= Total project summer coincident peak demand impact

= The part load ratio for the average flow fraction between the peak daytime hours during the weekday peak time period based on the baseline flow control type (default average flow fraction during peak period = 90%)

= The part load ratio for the average flow fraction between the peak daytime hours during the weekday peak time period based on the retrofit flow control type (default average flow fraction during peak period = 90%)

= HVAC interactive effects factor for summer coincident peak demand  
 (default = 15.7%)

**Fossil Fuel Impact Descriptions and Calculation**

There are no expected fossil fuel impacts for this measure.

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

N/A

**Measure Code: CI-HVC-VSDF-V02-160601**

1. Efficiency Vermont TRM 10/26/11 for HVAC VSD motors [↑](#footnote-ref-1)
2. DEER 2008 [↑](#footnote-ref-2)
3. Ohio TRM 8/6/2010 varies by motor/fan size based on equipment costs from Granger 2008 Catalog pp 286-289, average across available voltages and models. Labor costs from RS Means Data 2008 Ohio average cost adjustment applied. [↑](#footnote-ref-3)
4. Methodology developed and tested in Del Balso, Ryan Joseph. “Investigation into the Reliability of Energy Efficiency/Demand Side Management Savings Estimates for Variable Frequency Drives in Commercial Applications”. A project report submitted to the Faculty of the Graduate School of the University of Colorado, 2013. [↑](#footnote-ref-4)
5. Lawrence Berkeley National Laboratory, and Resource Dynamics Corporation. (2008). “Improving Motor and Drive System Performance; A Sourcebook for Industry”. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Golden, CO: National Renewable Energy Laboratory. [↑](#footnote-ref-5)
6. Douglass, J. (2005). Induction Motor Efficiency Standards. Washington State University and the Northwest Energy Efficiency Alliance, Extension Energy Program, Olympia, WA. Retrieved October 17, 2013, from <http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/motor_efficiency_standards.pdf> [↑](#footnote-ref-6)
7. Hours per year are estimated using the eQuest models as the total number of hours the fans are operating for heating, cooling and ventilation for each building type. [↑](#footnote-ref-7)