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**H V A C**  
**VARIABLE SPEED DRIVE FOR HVAC**  
**FAN CONTROLS**  
**SWHC018-02**

**C O N T E N T S**

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## MEASURE NAME

Variable Speed Drive for HVAC Fan Controls

## STATEWIDE MEASURE ID

SWHC018-02

## TECHNOLOGY SUMMARY

The energy use of a constant-speed HVAC system can be reduced by installing an electronic variable speed drive (VSD) on a ventilation fan. A VSD is a more efficient method of regulating speed or torque than throttling valves, inlet vanes, and fan dampers. A VSD on the fan motor will enable the fan to slow down more efficiently when the building load determines, thereby reducing the energy use of the fan. Due to the fan affinity laws, a small reduction in fan speed will result in significant energy savings.

## MEASURE CASE DESCRIPTION

The measure case is defined as an installation of a variable speed drive (VSD) and associated controls on an existing constant speed HVAC supply or return fan.

### Measure Offerings

Statewide Measure Offering ID	Measure Offering Description
SWHC018A	VSD on HVAC Fan Control

## BASE CASE DESCRIPTION

The base case is defined as an AC-powered motor connected to forward curved fans with discharge dampers, otherwise known as a damper-controlled variable air volume (VAV) system.

## CODE REQUIREMENTS

This measure is governed by the California Building Energy Efficiency Regulations (Title 24), Section 140.4 (m).<sup>1</sup> However, installing a variable frequency drive is not required to meet performance compliance of the 2019 Title 24 regulations, nor is it a mandatory measure. Under this regulation, the following is required to meet prescriptive compliance:

1. Direct expansion (DX) systems  $\geq 75,000$  Btu/hr and chilled water cooling systems  $\geq 1$  hp control the capacity of the mechanical cooling directly based on occupied space temperature shall: a)

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<sup>1</sup> California Energy Commission (CEC). 2018. *2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24)*. CEC-400-2018-020-CMF..

have a minimum of stages of fan control with no more than 66 percent speed when operating on stage 1; and b) draw no more than 40% of the fan power at full fan speed, when operating at 66% speed.

2. All other systems, including but not limited to DX cooling systems and chilled water systems that control the space temperature by modulating the airflow to the space, shall have proportional fan control such that at 50% air flow the power draw is no more than 30% of the fan power at full fan speed.
3. Systems that include an air side economizer to meet 140.4(e)1 shall have a minimum of two speeds of fan control during economizer operation.

This measure is not governed by the California Appliance efficiency regulations (Title 20) or federal regulations.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20	None	n/a
CA Building Energy Efficiency Standards – Title 24 (2019)	Section 140.4(m)	January 1, 2020
Federal Standards	None	n/a

NORMALIZING UNIT

Per rated fan motor horsepower (hp)

PROGRAM REQUIREMENTS

*Measure Implementation Eligibility*

All combinations of measure application type, delivery type, and sector that are established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

*Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.*

Implementation Eligibility

Measure Application Type	Delivery Type	Sector
Add-on equipment (AOE)	DnDeemed	Com
Add-on equipment (AOE)	DnDeemDI	Com

*Eligible Products*

This measure requires the installation of a variable frequency drive and associated controls on a motor driving a ventilation fan. Eligibility requirements include:

- The fan must be  $\leq 100$  hp.
- As an *add-on equipment installation*, the drive must be applied to the existing HVAC supply or return air system.
- Any other throttling devices, such as inlet vanes or bypass dampers, and throttling valves, must be removed or permanently disabled.

#### *Eligible Building Types and Vintages*

This measure is applicable for the following nonresidential building types:

Education – Secondary School  
Education – Community College  
Education – University  
Health/Medical – Hospital  
Health/Medical – Nursing Home  
Lodging – Hotel  
Office – Large  
Retail – Multistory Large  
Grocery – Grocery

#### *Eligible Climate Zones*

This measure is applicable in all California climate zones.

#### PROGRAM EXCLUSIONS

Fans of size  $> 100$  horsepower (hp) are not eligible.

Replacement of multiple-speed or variable speed motors (VSM) are not eligible.

Variable frequency drives on cooling tower fans are not eligible.

#### DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

#### USE CATEGORY

HVAC

### ELECTRIC SAVINGS (kWh)

The prior workpaper revision (PGECOHC106 R5) referenced energy savings and demand reduction directly from DEER data (Measure ID: D03-051). For this revision, eQUEST 3.65-7175 energy modeling software was used to estimate savings, with DEER 2020 prototypes obtained from MASControl3 serving as the base case with the CZ2010 weather files and the same modifications for D03-051 to represent the measure case.

Specifications for the baseline and measure case simulations are provided below.

Item	PGECOHC106rev5 (prior revision)	PGECOHC106rev6 (current revision)
DEER prototypes	2005	2020
eQUEST version	Unknown	3.65-7175
DEER weather files	Unknown	CZ2010
MASControl version	N/A	MASControl3
Tech IDs	D03-051	NE-HVAC-Chlr-WtrCldScrewChlr-1Cmp-AllSizes-0.42kwpton*
Prototype modifications	Oldest vintage prototypes include VAV systems (instead of default CV reheat systems)	N/A - all chosen prototypes use VAV systems*
Baseline characteristics	Damper controlled VAV with 30% min-cfm-ratio FAN-EIR-FPLR = "ForCurve w Dischrg Dampers FPLR"	Damper controlled VAV with 30% min-cfm-ratio FAN-EIR-FPLR = "ForCurve w Dischrg Dampers FPLR"
Measure Characteristics	VFD with 30% min-cfm-ratio FAN-EIR-FPLR = "Variable Speed Drive FPLR"	VFD with 30% min-cfm-ratio FAN-EIR-FPLR = "Variable Speed Drive FPLR"

\*The Gro prototypes come from the NonResLtgRefMsr Tech ID, which instead has PVVT HVAC system types. However, the same modeling approach was used to modify the FAN-EIR-FPLR keywords for the non-refrigeration HVAC systems.

The baseline fans are simulated as forward curved fans with discharge dampers, and the measure fans are simulated as being controlled by variable speed drives. Variable speed drives on supply and return fans reduce fan energy compared to flow restricting technologies such as inlet vanes and discharge dampers because the variable speed drive will vary the fan speed with load, greatly reducing electrical input at low flow conditions.

The following building types were simulated: ECC, ESe, EUn, Gro, Hsp, Htl, Nrs, OfL, and Rt3. All 16 climate zones and all available vintages were modeled. The fan performance curves used are documented below in Figures 1 and 2.

#### Building Description and Used Models

Building Type	Building Type Code	Modeled
Assembly	Asm	No
Primary School	EPr	No
Secondary School	ESe	Yes
Community College	ECC	Yes
University	EUn	Yes
Grocery	Gro	Yes



<sup>2</sup> Pacific Gas and Electric Company (PG&E). 2019. "SWHC018-01 Models.zip."

<sup>3</sup> Itron, Inc. 2005. 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study - Final Report. Prepared for Southern California Edison.

Building Type	Building Type Code	Modeled
Hospital	Hsp	Yes
Nursing Home	Nrs	Yes
Hotel	Htl	Yes
Motel	Mtl	No
Bio/Tech Manufacturing	MBT	No
Light Industrial Manufacturing	MLI	No
Large Office	OfL	Yes
Small Office	OfS	No
Sit-Down Restaurant	RSD	No
Fast-Food Restaurant	RFF	No
Department Store	Rt3	Yes
Big Box Retail	RtL	No
Small Retail	RtS	No
Conditioned Storage	SCn	No
Unconditioned Storage	SUn	No
Refrigerated Warehouse	WRF	No

Climate Zone

Climate Zone	Climate Zone Description	Modeled
1	Arcata Area (CZ01)	Yes
2	Santa Rosa Area (CZ02)	Yes
3	Oakland Area (CZ03)	Yes
4	Sunnyvale Area (CZ04)	Yes
5	Santa Maria Area (CZ05)	Yes
6	Los Angeles Area (CZ06)	Yes
7	San Diego Area (CZ07)	Yes
8	El Toro Area (CZ08)	Yes
9	Pasadena Area (CZ09)	Yes
10	San Bernardino Area (CZ10)	Yes
11	Red Bluff Area (CZ11)	Yes
12	Sacramento Area (CZ12)	Yes
13	Fresno Area (CZ13)	Yes
14	China Lake Area (CZ14)	Yes
15	Blythe Area (CZ15)	Yes
16	Mount Shasta Area (CZ16)	Yes

All available vintages were modeled. The DEER2020 building weights<sup>4</sup> for vintages were applied to calculate the weighted impacts for "ex" vintage. For ease of implementation, the "old" and "recent" vintages were not considered.



<sup>4</sup> California Public Utilities Commission (CPUC), Energy Division. (n.d.) "DEER2020-Building-Weights.xlsx."

The baseline and measure fan performance curves used are provided below.

The screenshot shows the 'Performance Curve Properties' dialog box. The 'Currently Active Curve' is 'ForCurve w Dischrg Dampers FPLR' and the 'Type' is 'Quadratic'. The 'Basic Specifications' tab is selected. The 'Curve Name' is 'ForCurve w Dischrg Dampers FPLR'. The 'Curve Type' is 'Quadratic' and the 'Input Type' is 'Curve Coefficients'. The 'Minimum Output' is 0.22 and the 'Maximum Output' is 1.00. The 'Curve Formula' is  $Z = a + bX + cX^2$ . The coefficients are:  $a = 0.19066702$ ,  $b = 0.31000000$ , and  $c = 0.50000000$ .

Figure 1 - Baseline FAN-EIR-FPLR

The screenshot shows the 'Performance Curve Properties' dialog box. The 'Currently Active Curve' is 'Variable Speed Drive FPLR' and the 'Type' is 'Quadratic'. The 'Basic Specifications' tab is selected. The 'Curve Name' is 'Variable Speed Drive FPLR'. The 'Curve Type' is 'Quadratic' and the 'Input Type' is 'Curve Coefficients'. The 'Minimum Output' is 0.10 and the 'Maximum Output' is 1.00. The 'Curve Formula' is  $Z = a + bX + cX^2$ . The coefficients are:  $a = 0.21976201$ ,  $b = -0.87478399$ , and  $c = 1.65259695$ .

Figure 2 - Measure FAN-EIR-FPLR

### PEAK ELECTRIC DEMAND REDUCTION (kW)

The peak demand reduction of a variable frequency drive and associated controls on a motor driving a ventilation fan were modeled in eQuest 3.65-7175 energy modeling software for the 4:00 p.m. to 9:00 p.m. peak period.<sup>5</sup> The Database for Energy Efficient Resources (DEER) 2020 prototypes obtained from MASControl3 served as the base case. See Electric Savings for additional details.

### GAS SAVINGS (Therms)

Not applicable.

### LIFE CYCLE

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would have remained in service and operational had the program intervention not caused the replacement or alteration.

The methodology to calculate the RUL conforms with Version 5 of the Energy Efficiency Policy Manual, which recommends “one-third of the effective useful life in DEER as the remaining useful life until further study results are available to establish more accurate values.”<sup>6</sup> This approach provides a reasonable RUL estimate without the requiring any a prior knowledge about the age of the equipment being replaced.<sup>7</sup> Further, as per Resolution E-4807, the California Public Utilities Commission (CPUC) revised add-on equipment measures so that the EUL of the measure is equal to the lower of the RUL of the modified system or equipment or the EUL of the add-on component.<sup>8</sup>

The EUL and RUL specified for this measure are presented below, both of which were adopted for the 2008 version of the Database of Energy Efficient Resources (DEER).

#### Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs) – measure (VFD for supply fan motor)	15.0	California Public Utilities Commission (CPUC). 2008. “EUL_Summary_10-1-08.xls.”
EUL (yrs) – host fan motor	15.0	California Public Utilities Commission (CPUC). 2008. “EUL_Summary_10-1-08.xls.”
RUL (yrs)	5.0	

<sup>5</sup> California Public Utilities Commission (CPUC). 2018. *Resolution E-4952*. October 11. OP 1.

<sup>6</sup> California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 32.

<sup>7</sup> KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc.

<sup>8</sup> California Public Utilities Commission (CPUC). 2016. *Resolution E-4807*. December 16. Page 13.

### BASE CASE MATERIAL COST (\$/UNIT)

Insofar as this measure is add-on equipment, it is considered discretionary modifications to the customer existing equipment and the alternative is to make no changes. Thus, the base case cost is assumed to equal to \$0.

### MEASURE CASE MATERIAL COST (\$/UNIT)

Measure case material costs were obtained from the *2010-2012 W0017 Ex Ante Measure Cost Study* conducted by Itron, Inc,<sup>9</sup> which derived equipment costs from distributor price lists. The cost for this measure was calculated as the average of material costs for variable frequency drives sized 5 hp to 100 hp; the 1.5 hp variable speed drive (VSD) was excluded from the calculation to avoid skewing the average. This average cost was then converted to 2019 value by applying the ratio of the 2013 and 2019 RSMMeans Historical Cost Index.<sup>10</sup>

### BASE CASE LABOR COST (\$/UNIT)

Insofar as this measure is add-on equipment, it is considered discretionary modifications to the customer existing equipment and the alternative is to make no changes. Thus, the base case cost is assumed to equal to \$0.

### MEASURE CASE LABOR COST (\$/UNIT)

Measure case labor costs were obtained directly from the 2019 RSMMeans for variable speed drives (VSDs) sized 5 hp to 100 hp. The installation labor cost for this measure was calculated as the average of labor costs for VSDs sized 5 hp to 100 hp; the 1.5 hp VFD was excluded from the calculation to avoid skewing the average.

### NET-TO-GROSS (NTG)

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. This is the “default” NTGs applicable to all energy efficiency measures that have been offered through commercial sector programs for two years and for which impact evaluation results are not available.

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<sup>9</sup> Itron, Inc. 2014. *2010-2012 W0017 Ex Ante Measure Cost Study Final Report*. Prepared for the California Public Utilities Commission.

<sup>10</sup> Gordian. (n.d.) “RSMMeans Cost Index 2019.pdf.”

Net-to-Gross Ratios

Parameter	Value	Source
NTG – Commercial	0.60	Itron, Inc. 2011. <i>DEER Database 2011 Update Documentation</i> . Prepared for the California Public Utilities Commission. Page 15-4 Table 15-3.

GROSS SAVINGS INSTALLATION ADJUSTMENT (GSIA)

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method.

Gross Savings Installation Adjustment Rates

Parameter	GSIA	Source
GSIA	1.0	California Public Utilities Commission (CPUC), Energy Division. 2013. <i>Energy Efficiency Policy Manual Version 5</i> . Page 31.

NON-ENERGY IMPACTS

Non-energy benefits for this measure have not been quantified.

DEER DIFFERENCES ANALYSIS

This section provides a summary of inputs and methods derived from the Database of Energy Efficient Resources (DEER), and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	No
Scaled DEER measure	No
DEER Base Case	Yes
DEER Measure Case	Yes
DEER Building Types	Yes
DEER Operating Hours	No
DEER eQUEST Prototypes	No
DEER Version	DEER 2020
Reason for Deviation from DEER	No Deviation
DEER Measure IDs Used	NE-HVAC-Chlr-WtrCldScrewChlr-1Cmp-AllSizes-0.42kwpton
NTG	Source: DEER. The NTG of 0.60 is associated with NTG ID: <i>Com-Default&gt;2yrs</i>
GSIA	Source: DEER. The GSIA of 1.0 is associated with GSIA ID: <i>Def-GSIA</i>
EUL/RUL	Source: DEER. The value of 15 years is associated with EUL ID: <i>HVAC-VSDSupFan</i> . The RUL is based upon EUL ID: <i>Motors-fan</i>

## REVISION HISTORY

### Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision
01	09/30/2018	Jennifer Holmes Cal TF Staff	Draft of consolidated text for this statewide measure is based upon: SCE13HC050, Revision 2 (January 29, 2016) PGECOHC106, Revision 5 (March 8, 2016) Consensus reached among Cal TF members.
	06/27/2019	Adan Rosillo, PG&E Randy Cole, PG&E  Jennifer Holmes, Cal TF Staff	Revisions for submittal of version 01.
02	2/06/2020	Tai Voong, PG&E	Added building type GROCERY (Gro) by eQuest modelling.