**Work Paper PGECOPRO110**

**Process Fan VSD**

**Revision # 0**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**Process Fan VSD**

**Measure Codes PR002**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Applicable Measure Codes:** | PR002 |
| **Measure Description:** | VARIABLE SPEED DRIVE ON PROCESS FAN CONTROL |
| **Energy Impact Common Units:** | Rated-HP |
| **Base Case Description:** | Non-HVAC and non-refrigeration fan used for exhaust, ventilation, pressurization, or other process |
| **Base Case Energy Consumption:** | Source: SCE Calculations  1552.21 kWh |
| **Measure Energy Consumption:** | Source: SCE Calculations  853.96 kWh |
| **Energy Savings**  **(Base Case – Measure):** | Source: SCE Calculations  698.25 kWh |
| **Costs Common Units:** | Rated-HP |
| **Base Case Equipment Cost ($/unit):** | $0 |
| **Measure Equipment Cost ($/unit):** | Source: 2012 RS Means Electrical Cost Data  $157.90 |
| **Gross Measure Cost ($/unit)** | $196.04 |
| **Measure Incremental Cost ($/unit):** | $196.04 |
| **Effective Useful Life (years):** | Source: DEER 2011  EUL ID: Motors-fan, EUL = 15 years, RUL = 5 years |
| **Measure Application Type:** | REA |
| **Net-to-Gross Ratios:** | Source: DEER 2011  NTG ID: Ind-Default>2yrs, NTG = 0.60 |
| **Important Comments:** |  |

# Work Paper Approvals

The following Manager(s) approved this workpaper through the PG&E Electronic Data Routing System under Routing Requisition # \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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| --- |
|  |
| **Grant Brohard**  Manager, Technical Product Support |
| **Carolyn Weiner**  Manager, Core Products |

**PGECOPRO111 R0**

PG&E will use SCE’s workpaper for these measures. PG&E’s measure codes are defined as follows:

|  |  |
| --- | --- |
| Measure Code | Measure Description |
| PR002 | VARIABLE SPEED DRIVE ON PROCESS FAN CONTROL |

PG&E will use an EUL of 5 years for the VSD, which is equal to the RUL of the existing motor (EUL ID: Motors-fan, HVAC fan motors).

**Work Paper SCE13PR008**

**Revision 1**

**Southern California Edison Company**

**Process Fan VSD**

# At-a-Glance Summary

|  |  |
| --- | --- |
| ****Applicable Measure Codes:**** | *PR-90127* |
| **Measure Description:** | Add a variable frequency drive to an existing process fan (75 hp or less) |
| **Base Case Description:** | Non-HVAC and non-refrigeration fan used for exhaust, ventilation, pressurization, or other process |
| **Energy Impact Common Units:** | Horsepower (hp) |
| **Energy Savings :** | Refer to Excel Calculation Attachment |
| **Gross Measure Cost ($/unit)** | Refer to Excel Calculation Attachment |
| **Measure Incremental Cost ($/unit):** | Refer to Excel Calculation Attachment |
| **Effective Useful Life (years):** | 13 years, per UI and CL&P Program Savings Documentation |
| **Measure Application Type:** | Retrofit Add-on (REA) |
| **Net-to-Gross Ratios:** | 0.6 |
| **Important Comments:** | **This work paper document does not contain a data set in conformance with the 4/1/14 CPUC Ex Ante Database Specification; SCE will provide that data set separately.** |

# Document Revision History

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Workpaper and Revision # | Tech. Revision | MM/DD/YY | Author/Affiliation | Summary of Changes |
| SCE13PR008.0 | No | 4/30/2012 | Mike Casey/AESC | Original work paper for 2013-14 program cycle |
| SCE13PR008.1 | Yes | 4/16/2014 | Jason Wang/SCE | * Updated with Title 24 (2013) requirements * Added Agricultural building type * Updated using DEER 2014 operating hours * Work paper updated for reporting period, effective 7/1/14 – 12/31/14. |

# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

The measure case is a variable speed drive (VSD) on an existing process fan.

The base case is an existing process fan with rated motor capacity ≤ 75 hp. The base case fan will either operate continuously or have on/off controls.

Table 1 Measure Names

|  |  |
| --- | --- |
| Solution Code | Measure name |
| PR-90127 | ≤ 75 HP Variable Speed Drive on Process Fan Control |

The existing fan shall meet the following requirements:

* Must not be a HVAC or refrigeration fan.
* May be used for exhaust, ventilation, pressurization, or other process applications. Air compressor systems are not eligible.
* Must have a motor horsepower rating ≥ 3 hp and ≤ 75 hp because savings for motors below 3 hp are minimal and do not justify the cost of a VSD retrofit.
* Must operate continuously or be manually operated with an ON/OFF control switch. Two-speed fans do not qualify.

This measure is applicable only to the following building types:

* Manufacturing - Bio/Tech
* Manufacturing - Light Industrial
* Industrial
* Agricultural

## 1.2 Technical Description

VSD control: The demand on process fans is often variable, so 100% speed fan operation is not always required. A VSD enables the fan to operate at a reduced speed during part load conditions in order to match the demand; typically there are sensors in the system, which send control signals to the VSD. This saves energy due to the cubic nature of the fan affinity laws. Fan power is proportial to the fan speed, e.g. operating at half speed theoretically requires only one-eighth of the power draw at full speed. Depending on the system, there may be minimum and maximum speed requirements that apply, e.g. minimum speed of 30%.

## 1.3 Measure Application Type

Note: See Appendix A for a comparison of the application types used by and incorporated into SCE systems versus the application types available in the newest revision of DEER 2014. Appendix A will serve as a translation between the outputs of this workpaper and application types used by READi.

The delivery methods are:

* Financial Support – Down-Stream Incentive – Deemed
* Partnership – Down-Stream Incentive – Deemed

The program/install type is Retrofit Add-On (REA).

## 1.4 Measure and Base Case Cost Effectiveness Data

### 1.4.1 DEER Measure and Base Case Analysis

This specific measure is not included in the Database for Energy Efficient Resources (DEER) Version 2014.

Table 2 DEER Difference Summary

|  |  |
| --- | --- |
| DEER Difference Summary Table | |
| Modified DEER Methodology | No |
| Scaled DEER Measure | No |
| DEER Building Prototypes Used | No |
| Deviation from DEER | DEER does not contain this type of measure. |
| DEER Version | N/A |
| DEER Run ID and Measure Name (Sample) | N/A |

**Net to Gross**

The NTG value was obtained from the “DEER2011\_NTGR\_2012-05-16.xls” on the DEER website as required by Version 5 of the California Public Utilities Commission (CPUC) Energy Efficiency Policy Manual [351]. The relevant NTGR for this measure is shown in Table 3 below.

Table 3 Net-to-Gross Ratio

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| NTGR\_ID\* | Description\* | Sector\* | BldgType\* | ProgDelivID | NTG\* |
| Com-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | Com | Any | Any | 0.6 |
| Ind-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | Ind | Any | Any | 0.6 |
| Agric-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | Ind | Any | Any | 0.6 |

\*Denotes that the column is taken from the DEER NTG Table.

**Installation Rate**

The installation rate (IR) is identified in the calculation attachment. This value is obtained from the support table available in READi. Currently there is no versioning on the installation rate table. To address appropriate selection of the installation rate the date of the workpaper will serve as the last date checked for updated IR values. The installation rate varies by end use, sector, technology, application, and delivery method. The relevant IR values for this measure are shown in Table 4 below.

Table 4 Installation Rate

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| GSIA\_ID\* | Description\* | Sector\* | BldgType\* | ProgDelivID | GSIAValue\* |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1 |

**Spillage Rate**

Spillage rate will also be applied to measures however the values will not be tracked in the workpapers. The spillage rate will be tracked in an external table to be supplied to the Energy Division.

**READi Technology Fields**

To support the development of the ED ex ante tables, select fields from the ex ante database will be identified in the workpaper. For a full set of values associated with the measures in the workpaper refer the Excel calculation template. (In the event that the READi IDs do not support the technology in this workpaper simply indicate “Non-DEER”.)

Table 5 READi Tech IDs

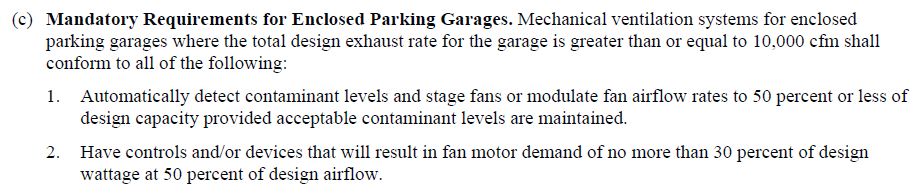
|  |  |
| --- | --- |
| READi Field Name | Values included in this workpaper |
| Measue Case UseCategory | Non-DEER |
| Measure Case UseSubCats | Non-DEER |
| Measure Case TechGroups | Motor\_Spd |
| Measure Case TechTypes | ASD |
| Base Case TechGroups | Motor\_gen |
| Base Case TechTypes | GenPurpose |

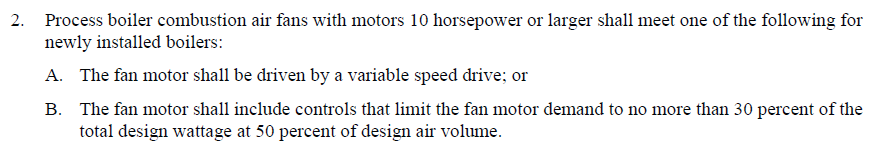
### 1.4.2 Codes and Standards Analysis

Title 24 (2013), Section 120.6 [355] provides the following mandatory requirements for covered processes:

* 120.6(a)3 Evaporators:

|  |
| --- |
|  |

* 120.6(c) Enclosed Parking Garagees:
* 120.6(d)2 Boilers:



* 120.6(e) provides requirements for air compressor systems, but air compressor systems are not covered in this work paper.

The Title 24 (2013) requirements mentioned above do not affect this work paper because they apply to new systems only. The Process VSD measure is an add-on to an existing system and therefore does not trigger Title 24.

Table 6 Code Summary

|  |  |  |
| --- | --- | --- |
| Code | Applicable Code Reference | Effective Dates |
| Title 24 (2013) | Section 120.6 Mandatory Requirements for Covered Processes | July 1, 2014 |

### 1.4.3 Non-DEER Study Review

No studies were used in this work paper. The SCE Online Application Tool was used.

### 1.4.4 Measure and Base Case Effective Useful Life

DEER14 update documentation provides EUL and RUL information to be used for the 2013-14 program cycle on [www.deeresources.com](http://www.deeresources.com). The DEER documentation “Summary of EUL-RUL Analysis for the April 2008 Update to DEER” provides the RUL value as a flat 1/3 of the EUL value. The RUL value will only be applied to the first baseline period for retrofit measures that have applicable code that will affect the energy savings. In all other installation types and retrofit with no applicable code that affects the energy savings, the RUL is not applicable to either the first or second baseline period.

The EUL is taken from program savings documentation from The Connecticut Light and Power Company and The United Illuminating Company [353]. Table 7 below identifies the value/methodology used for the measures in this work paper.

Table 7 DEER14 EUL Value/Methodology

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| READi EUL ID | Market | Enduse | Measure | EUL (Years) | RUL (Years) |
| NonDEER | Non-Residential | Process | Variable Speed Drive on Process Fan Control | 13 | N/A |

# Section 2. Energy Savings & Demand Reduction Calculations

This measure achieves energy savings and demand reduction by enabling a process fan to operate more efficiently at part load conditions. Savings do not vary by climate zone or building type.

**Online Application Tool**

The Fan Systems Upgrade Tool in SCE’s Online Application Tool is a preferred calculation tool for the Statewide Customized Offering. It allows the user to input a baseline fan system and calculate the savings associated with the installation of a VSD on the fan drive motor. This software tool uses information from the FSAT (Fan System Assessment Tool created under the direction of the DOE) in conjunction with fan affinity laws; see Attachment 4 for the Fan Systems Upgrade Tool documentation. See the equation below for the relationship between fan power (P) and speed (n):

Savings were modeled for eleven different baseline fan systems, using NEC standard motor sizes (5 hp, 7.5 hp, 10 hp, 15 hp, 20 hp, 25 hp, 30 hp, 40 hp, 50 hp, 60 hp, 75 hp). Inputs were used to create a typical process fan system. Centrifugal fans are more common for process fans due to their size advantage, and were therefore assumed as the baseline fan type. Since process fans are not weather dependent, the savings will not vary among climate zones. For simulation purposes only, Los Angeles was selected as a typical city, and since the calculations are not dependent on climate zone, the results are applicable to all climate zones. Fan static pressures vary widely by application and the Fan Tool allows for a range from 0-35“ Wg to be chosen. An average static pressure of 5“ Wg was assumed because process fans vary from exhaust fans that can have less than 1“ Wg static pressure to large dust collection fans that can have around 10“ Wg static pressure. Brake horsepower (BHP) is equal to flow times pressure. For each run, BHP is held constant because energy savings are normalized over hp. Energy savings are not affected by the chosen pressure since the CFM was adjusted in the simulations to keep the BHP constant. CFM was determined using specification sheets from a fan manufacturer (see Attachment 5). For each motor, the BHP was calculated for each of the eleven baseline fan systems, and a fan was selected that best met both the BHP and the 5“ Wg static pressure assumption (see Attachment 6). The appropriate CFM was then identified from the specification sheets and used for the maximum and design flow software inputs. CFM selected will be consistent across various manufactures since the specific fan type being modeled was chosen because it is the typical type used for process fan. As such the fans efficiency and operating points will not vary significantly across different manufacturers. Based on the specified CFM and pressure, fan efficiency was calculated using the following equation:



Since the CFM changed based on hp, the fan efficiency varied with each run. The motor efficiency was set to the minimum efficiency allowed per NEMA standards [357]. Nominal motor and fan revolutions per minute (RPM) were chosen to be 1800 since most motor process applications are expected to utilize this RPM. Initially, the software model was run at different RPMs; however, the results were consistent. As such, 1800 RPM was kept as a constant input. The tool was then run at an assumed 70% average flow. 70% loading was chosen as the midpoint of a range between which savings would be minimal at the high end and the motor would be considered oversized at the low end. The Fan Systems Upgrade tool defaults for VFD full load efficiency and minimum operating speeds were used for the proposed system. Operating hours were determined using DEER14 for the Industrial building type, 3375 hours/year, and the Agricultural building type, 3094 hours/year.

For each of the software runs, the following inputs were kept constant:

* Fan System Type: Centrifugal
* Number of Fans: 1
* Location/City: Los Angeles CO (Los Angeles)
* Exhaust Fan? : No
* Estimate Ambient Air Temperature? : No
* Inlet Air Temperature: 85 oF
* Sys. Total Static Press. @ Max Flow: 5.0 “Wg
* Fan Type: Centrifugal Airfoil DIDW
* Control Type: Centrifugal On/OFF
* Drive Type: Std. V-Belt Drive
* Fan Speed: 1800 rpm
* Total Static Pressure: 5“ Wg
* Speed (RPM): 1800
* Service Factor: 1.15
* FL Speed: 1790
* Enclosure: ODP
* Annual Operating Hours: 3372 (the previous work paper revision used DEER11 operating hours of 3372 hours/year, so the savings were scaled for the DEER14 Industrial building type by a factor of 3375/3372, and the Agricultural building type by a factor of 3094/3372)
* VFD Full Load Efficiency: 96%
* VFD Minimum Operating Speed: 50%

The Fan tool yielded kWh/year energy savings and kW peak demand, which were divided by hp ratings to obtain specific energy savings (kWh/hp/year and kW/hp) and then averaged. Table 8 shows the energy savings from the measures covered in this work paper.

Table 8 Annual Energy Savings and Demand Reduction

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Solution Code** | **Measure name** | **Building Type** | **Annual Electric Savings (kWh/HP/year)** | **Demand Reduction (kW/HP)** |
| PR-90127 | ≤ 75 HP Variable Speed Drive on Process Fan Control | Manufacturing - Bio/Tech, Manufacturing - Light Industrial, Industrial | 698.87 | 0.40304 |
| Agricultural | 640.69 | 0.36949 |

Savings calculations are in Attachment 2.

# Section 3. Load Shapes

The difference between the base case load shape and the measure load shape would be the most appropriate load shape; however, only end-use profiles are available. Therefore, the closest load shape chosen for this measure is the Industrial load shape. See Table 9 for a list of all Building Types and Load Shapes. See the KEMA report [31] for a more thorough discussion regarding the load shapes for this measure.

Table 9 Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| Building Type | E3 Alt. Building Type | Load Shape |
| Manufacturing - Bio/Tech | Industrial | Industrial |
| Manufacturing - Light Industrial | Industrial | industrial |
| Industrial | Industrial | Industrial |
| Agricultural | Industrial | Industrial |

# Section 4. Base Case & Measure Costs

## 4.1 Base Case Cost

For this measure category, the base case cost is assumed to be zero because these are discretionary modifications (retrofit add-on) to the customers’ existing equipment. The alternative is to make no changes to their existing system.

## 4.2 Measure Case Cost

For retrofit add-on measures, the gross measure cost is the full measure cost to purchase and install, as shown in Table 10. The measure cost shown above was obtained using data from the 2012 edition of RS Means Electrical Cost Data. RSMeans covers VFDs from 3 hp to 75 hp [358]. The total cost from RSMeans for each drive was divided by the rated HP to get a normalized cost. These were then averaged to get an overall $/hp which comes to $196.04/hp. The labor costs were calculated similarly and came out to $38.14/hp. Material costs per hp was taken as the difference between total cost and labor cost, $157.90/hp. See Attachment 2 for more details.

GMC is represented by the equation below:

GMC = Measure Equipment Cost + Measure Labor Cost

Table 10 Measure Cost

|  |  |
| --- | --- |
| **Description** | **GMC ($/hp)** |
| ≤ 75 HP Variable Speed Drive on Process Fan Control | $196.04 |

## 4.3 Gross and Incremental Measure Cost

### 4.3.1 Gross Measure Cost

For retrofit add-on measures, the gross measure cost is the full measure cost to purchase and install, as shown in Table 10.

### 4.3.2 Incremental Measure Cost

Incremental Measure Cost (IMC) is the premium cost to install an energy efficient measure over a standard efficiency measure or code baseline measure. For deemed retrofit add-on measures, the IMC is equal to the gross measure cost, as there exists no base case from which to compare the measure.

# References



[31] Load Shape Update Initiative - KEMA / JJ Hirsch and Assoc. / Itron Inc. - November 17, 2006

[351] Energy Efficiency Policy Manual-Version 5

[353] UI and CL&P Program Savings Documentation for 2011 Program Year

[355] 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24)

[357] NEMA Premium Product Scope and Nominal Efficiency Levels

[358] RSMeans Electrical Cost Data 2012

# Appendix A – SCE/ED Application Types

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| SCE Program Type | ED Application Type | 1st Baseline Savings | 2nd Baseline Savings | 1st Baseline Cost | 2nd Baseline Cost | 1st Baseline Life | 2nd Baseline Life |
| New | New Construction (Nc) | Above Code/Standard | N/A | Incremental Cost | N/A | EUL | 0 |
| Replace on Burnout (ROB) | Replace on Burnout (Rob)/Normal Replacement (NR) | Above Code/Standard | N/A | Incremental Cost | N/A | EUL | 0 |
| Retrofit (RET) | Early Replacement (ER) | Above Cust. Existing | Above Code/Standard | Full Cost | Incremental Cost | RUL | EUL-RUL |
| Retrofit – First Baseline Only (REF) | Early Replacement RUL (ErRul) | Above Cust. Existing | N/A | Full Cost | N/A | EUL | 0 |
| Retrofit Add-on (REA) | N/A | Above Cust. Existing | N/A | Full Cost | N/A | EUL | 0 |