Work Paper PGECOPRO115
Revision # 1

Pacific Gas & Electric Company

Measure Codes: PR088 to PR094

Dust Collection Fan VSD

August 15, 2019

AT-A-GLANCE SUMMARY

Measure Codes:	PR088 to PR094
Measure Description	Dust Collection Fan Variable Speed Drive (VSD) Control
Energy Impacts Units:	Per Horsepower (hp)
Base Case Description:	Fixed Speed Fan Motor
Measure Energy Consumption:	Variable on motor size (hp)
Energy Savings (Base Case – Measure):	Variable on motor size (hp)
Cost Common Units:	Variable on motor size (hp)
Base Case Equipment Cost ($/unit):	$0
Measure Equipment Cost ($/unit):	Variable on motor size (hp)
Measure Labor Cost ($/unit):	Variable on motor size (hp)
Gross/Total Measure Cost ($/unit):	Variable on motor size (hp)
Measure Incremental Cost ($/unit)	N/A
Measure Application Type:	Add-on Equipment (AOE)
Effective Useful Life (Years):	13 Years (DEER EUL ID: ProcDist-Motor_Spd)
Remaining Useful Life (Years):	5 Years (Deer EUL ID: Motors-HiEff)
Net-to-Gross Ratios:	NTG = 0.60 NTG ID: Agric-Default>2yrs
Important Notes:	For AOE the measure RUL is the lesser of the two: RUL of the host equipment or EUL of the measure. The RUL for the fan motor is 5 years which is 1/3 of the EUL of 15 years (EUL ID: Motors-HiEff). The EUL of the VSD is 13 years (ProcDist-Motor_Spd). Therefore, the proper RUL is 5 years for this VSD measure. For claimable savings reporting only one DEER EUL ID is allowed for each measure; therefore, the “Motors-HiEff” EUL ID is used in the workpaper to correctly report the 5-year RUL of the host equipment.

Revision History

Rev	Date	Author	Summary of Changes
1	6/29/18	Ethan Clifford, ERI	First Draft

Background and History

In 2014 PG&E adopted then SCE's process fan VFD workpaper. In January 2017 SCE submitted to WPA a revised process fan VFD workpaper titled SCE17PR008, and was subsequently adopted by both PG&E and SDG&E. On March 2, 2017 CPUC issued the "Disposition for Workpapers Covering Process Fan VFD" and was applicable to all versions of SCE's workpaper adopted by any PA. The disposition outlined the critical review issues:

- Submitted information does not establish a valid measure for the Process Fan VSD
- Lack of correlation between Fan Types and Fan Sizes used in the workpaper
- Type of Process Fans to be used and improper use of sources
- Insufficient evidence to justify "reasonable and conservative" static pressures
- Insufficient evidence to justify the definition of manual control as used in the workpaper
- Insufficient evidence to justify operating hours
- insufficient evidence to justify the minimum VFD Speeds
- Ex ante data submissions continue to have various errors inconsistent with the Ex Ante database specification and previous guidance

During the development of this workpaper for dust collection fan VFDs, detail was taken to collect information to support these short comings from previous VFD work products. This workpaper is developed based on quantifiable data from online surveys and conversations with customers and vendors on their current control and operation of dust collection fan systems, as well as solid engineering principles. The issues outlined in the 2017 Disposition are being addressed as follows:

- Measure defined for dust collection fan applications only
- Measure is specific to dust collection fans from 10 hp to 50 hp
- Measure in this WP is weather independent.
- Assigned correct EUL to the measure

Throughout the process of measure development, the measure a variety of external entities participated in the survey process:

- Agricultural customers with various Baghouse fan systems
- Vendors of Baghouse fan systems
- Design consultant of Baghouse fan systems

Survey data collected were specifically pertained to baghouse fan system operation as follows:

- Hour of operation
- Load factor
- VFD minimum speed setting
- Baseline control operation

SECTION 1. GENERAL MEASURE & BASELINE DATA

1.1 MEASURE DESCRIPTION & BACKGROUND

The measure outlined in this work paper is to install Variable Speed Drives (VSD) on existing fans for the dust collection systems, commonly known as baghouses, for Agricultural and Industrial customers. The VSD will reduce the speed of the fan based on the load of the dust collection system and the air velocity required by the system. Controls will be needed in the form of pressure transducers, flow sensors, or velocity sensors to provide feedback to the VSD during operation.

Based on a survey of customers and vendors on typical flow control for dust collection, for fan motors below 50hp it is common for there to be no flow control (damper, VSD, guide vanes) in existing and new systems. There are no State or National energy codes that are applicable to controls of fans for baghouses. Depending on the system or process there are OSHA and NFPA codes that need to be adhered for safety.

Table 1: Measures Codes and Descriptions

Measure Codes	Measure Descriptions
PR088	Dust Collection Fan VSD (10hp motor)
PR089	Dust Collection Fan VSD (15hp motor)
PR090	Dust Collection Fan VSD (20hp motor)
PR091	Dust Collection Fan VSD (25hp motor)
PR092	Dust Collection Fan VSD (30hp motor)
PR093	Dust Collection Fan VSD (40hp motor)
PR094	Dust Collection Fan VSD (50hp motor)

1.2 PROGRAM REQUIREMENTS

Eligibility requirements:

The following customer and system specifications need to be met to be eligible under this work paper:

- The PG&E customer must be within the following NAICS Code:
  - 111000 to 112990
  - 311000 to 339999
  - 211120 to 213115
- The existing dust collection fan and motor need to be in functioning operation
- The dust collection fan's motor needs to be compatible with a VSD[1] or replaced during installation to be compatible
- There must be no previous VSD or failed VSD installed on the dust collection fan's motor
- The installed VSD must be controlled based on static pressure, air flow rate (CFM), or velocity of the airstream in a feedback loop
- The minimum fan size has to be 10-hp and not to exceed 50-hp

[1] Motors that are compatible with VSDs vary based on motor manufacturers. Compatible motors must be labeled as inverter duty, VSD ready, or have insulation classification F.

Implementation and installation requirements

The following system requirements need to be met to be eligible under this work paper:

- The VSD needs to be installed and wired to the dust collection (baghouse) fan motor
- Control the VSD on the Dust Collection Fan Motor by one of the following methods:
    - Static Pressure across the fan's discharge and inlet. The static pressure setpoint should be selected to meet the flow and pressure requirements of the particulate matter being conveyed.
    - Air Flow Rate (CFM) at the inlet of the baghouse fan (between the fan and baghouse) or velocity (feet/min) of the main duct (between the baghouse and served equipment). Using the airflow rate or velocity, the facility needs to determine the setpoint required to serve the process, meet static pressure requirement across the baghouse, and velocity necessary to keep the particulates in suspension.

1.3 Technical Description

Baghouses (Dust collection system) are used in buildings and processes to remove dust, particulates, or other air suspended material from a specific area or equipment. These systems are used by a wide variety of customers for harvest, processing, and manufacturing of products. A typical baghouse uses a blower or fan to provide suction to the system. The collected air with suspended particulate is pulled through ducting to the entrance of the baghouse to be filtered. The filters within the baghouse use compressed air, vibrations, or a combination of both to periodically clean the filters. After filtering, the air stream is vented to the atmosphere or away from the serviced area.

During the design of a baghouse, the velocity (feet per minute) of the airstream is selected to ensure the particulate, dust, or other air suspended object is removed by the baghouse and does not settle in the ducting. Within a baghouse system, the main duct entering the baghouse typically contains the largest diameter duct and therefore the lowest airstream velocity. Lighter particulates have a lower minimum velocity while heaver particulates need higher minimum velocities to operate effectively. The following table is a sample of velocity requirements based on particulates:

Particulate	Minimum Velocity (Feet/min)		
	Min	Average	Max
Gases	1,000	1,500	2,000
Fumes	2,000	2,250	2,500
Oil Mist	2,000	2,250	2,500
Very Fine Light Dust	2,500	2,750	3,000
Dry Dust and Powders	3,500	3,750	4,000
Typical Industrial Dust	3,000	3,500	4,000
Heavy Dust	4,000	4,250	4,500
Heavy or Moist	4,500	4,500	4,500

The air flow demand for a baghouse is dependent on the quantity of pick-up points and their individual flow requirements to properly ventilate the area or equipment. The dust collection filters are then sized based on the air flow requirements with additional capacity for future addition onto the system or increase at the pickups. The dust collection fans are selected based on both the necessary airflow requirements of the system and the static pressure based on the geometry and distance of the ducting.
The use of a variable speed drive on a dust collection fan will allow the system to modulate based on either air flow or static pressure requirements. For a steady state system with no change in pick-ups,

these parameters will not vary significantly and the speed of the variable frequency drive will be based on the minimum allowable velocity based on the particulate in suspension. Based on conversations with baghouse vendors, a typical steady state system will have energy savings potential stemming from fan optimizing system capacity based on end use requirements. For systems with variable pick-ups or automatic shut off gates to equipment, the static pressure and airflow needs will vary significantly through the systems operation. During conversations with vendors and customers, systems with less than 50 hp fan motors typically have a few to a single pick-up with no automatic shut-off gates.

1.4 Measure Application Type

This measure adds a new VSD to the existing fan motor control that has no VSD or no air flow control. The measure application type is Add-On Equipment (AOE)

Installation Type Descriptions

Installation Type	Savings		Life	
	1st Baseline (BL)	2nd BL	1st BL	2nd BL
Add-On Equipment (AOE)	Above Customer Existing	N/A	RUL	N/A

1.5 Measure Parameters

1.5.1 DEER Data

This specific measure is not included in the Database for Energy Efficient Resources (DEER) Version 2016.

DEER Difference Summary

DEER Item	Used for Workpaper?
Modified DEER methodology	No
Scaled DEER measure	No
DEER Base Case	No
DEER Measure Case	No
DEER Building Types	No
DEER Operating Hours	No
DEER Prototypes	No
DEER Version	N/A

Net-to-Gross Ratio

The NTG values were obtained using the DEER READI tool. The relevant NTG values for the measures in this work paper are in the table below.

NTGR ID	Description	Sector	BldgType	Measure Delivery	NTGR
Agric-Default>2yrs	All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years	AGR	Any	DnDeemed	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	DnDeemed	0.6

Spillage Rate

Spillage rates are not tracked in work papers; they are tracked in an external document which will be supplied to the Commission Staff.

Installation Rate

The IR values were obtained using the DEER READI tool. The relevant IR values for the measures in this work paper are in the table below.

GSIA ID	Description	Sector	BldgType	ProgDelivID	GSIAValue
Def-GSIA	Default GSIA values	AGR	Any	Any	1

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.

GSIA ID	Description
Def-GSIA	Default GSIA values
Measure Case UseCategory	ProcDist
Measure Case UseSubCats	Controls
Measure Case TechGroups	Motor_Spd
Measure Case TechTypes	ASD
Base Case TechGroups	Motor_gen
Base Case TechTypes	GenPurpose

1.6 Codes and Standards Analysis

There are no California State or National energy codes that are applicable to VSD/VSD being installed on baghouse fans for Agricultural or Industrial processes. Depending on the customer and their processes, there may be applicable OSHA or NFPA regulations that set limits on the velocity requirements for safety standards.

1.7 Effective and Remaining Useful Life

The EUL and RUL values were obtained using the DEER READI tool. DEER defines the RUL as 1/3 of the EUL value. Only the RUL value is applicable to the first baseline period for an AOE measure. The relevant EUL and RUL values for the measures in this work paper are in the table below. For AOE measures the RUL is the lesser of the two: EUL of the measure or 1/3 EUL of the host equipment. For claimable savings reporting only one DEER EUL ID is allowed for each measure; therefore, the “Motors-HiEff” EUL ID is used in the workpaper to correctly report the 5-year RUL of the host equipment.

EUL ID	Description	Sector	EUL (Years)	RUL (Years)
Motors-HiEff	Premium-Efficiency Motors	Com	15	5
ProcDist-Motor_Speed	Variable Speed Drive on Process Fan Control	Com	13	NA

SECTION 2. CALCULATION METHODOLOGY

There are two survey used for the development of this work paper. The first survey was a web-based questioner sent to customers between the NAICS code 111000 to 112990 and 31100 to 312140 within PG&E territory. The questioner was responded by 15 customers within the specified NAICS codes. The survey was designed to collect data on the facilities operating hours, production rates, and various fan use types used within their operation. Based on the responses from the survey, the use of VFDs on baghouse fans is not common practice and baghouses are commonly used systems.

A second survey was performed for baghouse vendor and designers to learn on common installation practices, design parameters, and baghouse sizes for new and existing systems. Based on the vendor outreach, 4 baghouse designers shared insights on the design and selection processes for a variety of parameters. A common theme during these discussions is the custom nature that each system is designed based on their original end-use the system was operating. All the vendors agreed that they recommend customers install VFDs on new baghouse systems if the customer have the additional capital. As a result of the survey, ERI developed correlations between fan motor size to baghouse size and ducting diameter that is used for the development of the energy savings calculations.

The measure outlined in this workpaper will reduce the electrical energy consumption and demand of a baghouse fan by varying the speed of the motor to meet the airflow or pressure requirements. The baseline and installed energy consumption for each measure varies based on the horsepower of the baghouse fan motor. Based on a survey of agricultural customers who utilize baghouses, it was determined that, on aggregate, seasonal and non-seasonal customers operate 4,806 hours[2] per year. The following calculation is used to quantify the baseline power draw for baghouse fan motor:

$$kW_{baseline} = HP_{fan} \times LF \times C_1 \times (1/EFF)$$

where

HP_{fan}	=	Motor Nameplate Power, HP
LF	=	Load Factor, 66% for Fans[3]
C_1	=	Conversation Factor, 0.756 kW per HP
EFF	=	NEMA Premium Motor Efficiency

The proposed power draw of a baghouse fan motor with a VSD is dependent on the average operating speed when in use. In order to determine the average operating speed, a survey of baghouse vendors was performed to determine the actual velocity of the air stream based on typical baghouse capacities (CFM) and duct diameters (inches) for a various fan size (hp). It should be noted that when systems are designed to their specific requirements for air flow and velocity, the use of a VSD to control the fan will result in low to no energy savings. Based on the vendor survey, most existing systems are operating at

[2] The annual operating hours are derived from the customer survey between NAICS codes 111000 to 112990 and 31100 to 312140. For Industrial customers, it is assumed that the annual operating hours will on average be greater than 4,806 hours per year. For this workpaper, these operating hours will be used for all customers within the specific NAICS codes to be conservative on energy and demand savings.

[3] Based on DOE's "Determining Electric Motor Load and Efficiency", the average motor load is 75%. Using ERI's experience for fans and to generate a conservative approach, 66% motor load has been applied.

less than the designed capacity and therefore have opportunity to reduce the fan speed and yield energy savings. The proposed velocity of the air stream is quantified using a weighted average of minimum velocities over all agricultural customers. Using the vendor survey and proposed velocity, the average operating speed can be quantified to determine the proposed power draw. The following formula is used to quantify the proposed power draw:

$$kW_{prop.} = HP_{fan} \times LF \times C_1 \times (1/EFF) \times OS^{2.7} \times (1/EFF_{VSD})$$

where

HP_{fan}	=	Motor Nameplate Power, HP
LF	=	Load Factor, 66% for Fans
C_1	=	Conversation Factor, 0.756 kW per HP
EFF	=	NEMA Premium Motor Efficiency
OS	=	Average Operating Speed of the VSD[4]
EFF_{VSD}	=	Efficiency of the VSD, 97%[5]

Fan Motor HP	Baseline Energy Use (kWh/yr)	Baseline Peak Demand (kW)	Proposed Energy Use (kWh/yr)	Proposed Peak Demand (kW)	Energy Saving (kWh/yr)	Peak kW Demand Saving (kW)
10 HP	25,946.1	5.40	23,267.5	4.84	2,678.6	0.56
15 HP	38,559.7	8.02	25,842.6	5.38	12,717.1	2.65
20 HP	50,915.2	10.59	31,816.4	6.62	19,098.8	3.97
25 HP	63,235.8	13.16	28,762.0	5.98	34,473.7	7.17
30 HP	75,680.7	15.75	38,361.7	7.98	37,319.0	7.77
40 HP	100,585.9	20.93	50,676.0	10.54	49,909.8	10.38
50 HP	125,200.1	26.05	84,051.5	17.49	41,148.6	8.56

4 The proposed operating speed is a weighted average based on the expected minimum speeds for various agricultural customers. The operating speed used would be conservative or comparable for industrial customers

5 https://www.energy.gov/sites/prod/files/2014/04/f15/motor_tip_sheet11.pdf

SECTION 3. LOAD SHAPES

The ideal load shape for net benefits estimates would represent the difference between the base case and measure case. The closest load shapes that are applicable to the measures in this work paper are listed in the table below.

Building Types and Load Shapes

Building Type	Load Shape	E3 Alternate Building Type
Agricultural	14 = Agricultural	PGE:AGRICULTURAL:14 = Agricultural

SECTION 4. COSTS

4.1 BASE CASE COST

The measure outlined in this workpaper is classified as AOE measure type. Therefore, there is no base case cost associated with this measure since the fan motor is already existing.

4.2 MEASURE CASE COST AND INCREMENTAL COST

The full measure cost is used for AOE measure application type. The equipment requirements for this measure are the material and labor for the installation of the VSD with commissioning. The costs for the VSD were collected using 2019 RS Means[6] and are summarized by motor size in HP below:

Measure Cost and Incremental Measure Cost

Fan Motor (HP)	VSD Material Cost ($)	VSD Installation Cost ($)	Total Project Cost ($)
10 HP	$2,716	$ 875	$3,591
15 HP	$3,516	$1,316	$4,832
20 HP	$4,317	$1,316	$5,632
25 HP	$5,093	$1,744	$6,837
30 HP	$6,354	$1,744	$8,098
40 HP	$7,324	$1,744	$9,068
50 HP	$9,797	$2,224	$12,021

[6] RS Means 2019 data was collected from Gordan's online database portal for RS Means. For additional details on the line items #s please reference the Excel Calculation file sheet 'Measure Cost"

ATTACHMENTS

Calculations for PGECOPRO115 R1.xlsx

Fan Project Data for PGECOPRO115 R1.xlsx

PGECOPRO115 R1 AGR Customer Survey.xlsx

Determining Electric Motor Load and Efficiency.pdf