



PROCESS
VFD FOR GLYCOL PUMP MOTOR
SWPR002-02

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MEASURE NAME

VFD for Glycol Pump Motor

STATEWIDE MEASURE ID

SWPR002-02

TECHNOLOGY SUMMARY

Wineries use refrigeration systems throughout the year to keep wine at storage temperatures, to perform cold stabilization, and to remove heat created internally during the fermentation process. These systems are typically designed to meet the maximum required loads during the “crush” season. During “crush”, the tanks and barrels are typically full, and the chiller is running at near full capacity. However, during “non-crush” season, the load on the refrigeration system is typically less than the design capacity.

This measure is defined as the installation of a variable frequency drive (VFD) on a glycol pump motor for process cooling end-use applications. The glycol circulation pumps are running at a constant speed even though glycol is being bypassed from the wine tanks and returning right back to the glycol storage tank. Installing a VFD on the pump motors will decrease the glycol flow to reflect the actual load on the system. This will reduce the energy required to pump the glycol through the system by adjusting the speed of the pump to the actual demand from the wine tanks.

MEASURE CASE DESCRIPTION

The measure case is defined as the installation of a new variable frequency drive (VFD) on a constant speed glycol circulation pump. The installation of a new VFD on a constant speed glycol pump is intended to achieve energy savings during process load cooling of winery production. Measure offerings are tiered by pump size, as specified below.

Measure Case Specification

Measure Offering	Pump Size (hp)
Glycol pump VFD	3.0
	5.0
	7.5
	10.0
	15.0
	20.0
	25.0

BASE CASE DESCRIPTION

The base case is defined as an existing glycol circulation pump operating at a constant speed, without a variable frequency drive (VFD).

Base Case Specification

Base Case	Pump Size (hp)
Glycol pump, constant speed	3.0
	5.0
	7.5
	10.0
	15.0
	20.0
	25.0

CODE REQUIREMENTS

Because this is for a process application, there are no applicable codes or standards that govern this application of adding a variable frequency drive to a glycol circulation pump motor; this measure is a process application and does not trigger state or federal codes.

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	None	n/a
Federal Standards	None	n/a

NORMALIZING UNIT

Each

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	DnDeemed	Ag



Eligible Products

This measure involves the installation of a variable frequency drive (VFD) on an existing glycol pump motor. Chilled fluid, other than glycol, can be considered only if the unit energy savings (UES) is equal to or exceeds the UES of this measure.

Application of this measure is for the addition of a VFD on an *existing* glycol pump motor.

The existing glycol pump(s) must operate at constant speed.

The VFD must have automated controls based on pressure feedback, fluid temperature feedback, and/or flow rate feedback.

Rebates are based on the motor horsepower.

The customer must provide documentation that the VFD is not installed on a back-up pump or redundant pump.

Eligible Building Types and Vintages

This measure is only applicable to the winery industry for process end-use applications.

Eligible Climate Zones

This measure is applicable in all California climate zones.

PROGRAM EXCLUSIONS

This measure is not eligible for a back-up pump or a redundant pump.

DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

USE CATEGORY

Process

ELECTRIC SAVINGS (kWh)

Methodology

Energy savings from the use of a VFD are a result of the affinity laws. The affinity laws for pumping state that the motor horsepower required to pump a volume of fluid varies based on the following expressions:

$$\frac{HP_2}{HP_1} = \left(\frac{n_2}{n_1}\right)^3$$

HP_2 = Motor operating horsepower

HP_1 = Motor nameplate horsepower

n_2 = New speed of the pump / motor

n_1 = Original speed of the pump / motor



$$\frac{Q_2}{Q_1} = \left(\frac{n_2}{n_1}\right) \quad \frac{H_2}{H_1} = \left(\frac{n_2}{n_1}\right)^2$$

Q2 = New volumetric flow rate of the pump

Q1 = Original volumetric flow rate of the pump

H2 = New total developed head of the pump

H1 = Original total developed head of the pump

Thus, reducing the speed of the pump results in a reduction of the required horsepower by the cube root.

In practice, the energy savings do not usually match this theoretical maximum due to friction losses and other inefficiencies of the system.

The unit energy savings (UES) was calculated as the different between the unit energy consumption (UEC) of the baseline pump motor (constant speed) and the measure case pump motor with the VSD (variable speed).¹ The UEC and UES calculations and all inputs are presented below.

Baseline Unit Energy Consumption

The baseline system is a glycol pump that operates at constant speed without a VFD. The baseline UEC is a function of the motor rated power (hp) and annual hours of operation. Power is a function of the assumed load factor and motor efficiency rating.

The baseline UEC was calculated as:

$$UEC_{Base} = \frac{HP \times Misc_Load}{HPEff \times CFac_hp_kw} \times OpHours_base$$

HP = *Motor rated horsepower, (hp)*

Misc_Load = *Motor load factor, (ratio)*

OpHours_base = *Annual operating hours, baseline (hours/yr)* *HPEff* = *Motor efficiency, (ratio)*

CFac_hp_kw = *Conversion constant, 1.341 hp/kW*

Measure Case Unit Energy Consumption

The measure case UEC is calculated as the sum of the energy use of the motor when it operates at full speed and the energy use of the motor when it operates at reduced speed. The calculation of each is similar to the baseline UEC calculation above, but accounts for increased efficiency due to the VFD during hours of motor operation at reduced speed.

The measure case UEC calculations for hours at full speed and reduced speed are below. The annual measure case UEC is equal to the sum of the UECs at full and reduced speeds.

¹ Pacific Gas & Electric (PG&E). (n.d.) "PGE3PPr01018r2 Sample VFD Calc.xls"

$$UEC_{Meas_FullSpeed} = \left(\frac{HP \times Misc_Load}{HPEff\ Ratio \times CFac_hp_kw} \times OpHours_{FullSpeed} \right) \times \left(\frac{1}{VFDEff} \right)$$

$$UEC_{Meas_ReducedSpeed} = \left(\frac{HP \times Misc_Load}{HPEff\ Ratio \times CFac_hp_kw} \times OpHours_{ReducedSpeed} \right) \times \left(\frac{MotorSpeedRatio^{MotorSpeedExp}}{VFDEff} \right)$$

$$UEC_{Meas} = UEC_{Meas_FullSpeed} + UEC_{Meas_ReducedSpeed}$$

<i>HP</i>	=	<i>Motor rated horsepower (hp)</i>
<i>Misc_Load</i>	=	<i>Motor load factor (ratio)</i>
<i>OpHours_{FullSpeed}</i>	=	<i>Annual operating hours at full speed (hour/yr.)</i>
<i>OpHours_{ReduceSpeed}</i>	=	<i>Annual operating hours at reduced speed (hours/yr)</i>
<i>HPEffRatio</i>	=	<i>Motor efficiency (ratio)</i>
<i>CFac_hp_kw</i>	=	<i>Conversion constant, 1.341 hp/kW</i>
<i>MotorSpeedRatio</i>	=	<i>Motor speed reduction with VFD (ratio) taken as an annual average from multiple customer sites</i>
<i>MotorSpeedExp</i>	=	<i>Motor speed exponent for the relationship between the pump speed reduction and required motor horsepower (also known as the "affinity factor") (ratio)</i>
<i>VFDEff</i>	=	<i>VFD efficiency, (ratio)</i>
<i>UEC_{Meas_FullSpeed}</i>	=	<i>Annual unit energy consumption during the hours when the VFD is running at full speed, measure case (kWh/yr)</i>
<i>UEC_{Meas_ReduceSpeed}</i>	=	<i>Annual unit energy consumption during the hours when the VFD is running at reduced speed, measure case (kWh/yr)</i>

Annual Unit Energy Savings

The annual UES was calculated as the different between the UEC of the baseline pump motor (constant speed) and the UEC of the measure case pump motor with the VFD (variable speed).

$$UES = UEC_{Base} - UEC_{Meas}$$

UEC_{Base} = Annual unit energy consumption, baseline (kWh)

UEC_{Meas} = Annual unit energy consumption, measure case (kWh)

Inputs and Assumptions

Many baseline assumptions were derived by actual glycol VFD projects installed through the Wine Industry Efficiency Solutions (WIES) program.²

Motor efficiency is based on standard efficiencies³ according to EPA Act 1992⁴

$$Motor \frac{kWh}{HP} = Motor_{kW} \times Hours$$



Motor Efficiency, by Motor Size (hp)

Horsepower (hp)	Motor Efficiency
1	82.5%
1.5	84.0%
2	84.0%
3	87.5%
5	87.5%
7.5	89.5%
10	89.5%
15	91.0%
20	91.0%
25	91.7%
30	92.4%
40	93.0%
50	93.0%
60	93.6%
75	94.1%
100	94.1%
125	94.5%

Motor load is assumed to be 80% based upon the design conditions of the pump, which is a typical value documented in the field.

Motor speed is assumed to run less than 100% throughout the year during “non-crush” months and at full speed (100%) during “crush” months. The assumption is reasonable since a good correlation exists between refrigeration load and glycol pumping requirements while considering that wineries typically utilize less than 70% of their tank capacity on average throughout the year.⁵

UEC Calculation Inputs

Estimated Load Ratio	VFD Efficiency	Motor Speed Exponent (“Affinity Factor”)	Motor Speed Ratio
0.80	0.98	2	0.70

The baseline and measure case hours of operation were derived from an average of runtime hours based on actual past projects.⁶

² Pacific Gas & Electric (PG&E). 2009. “PGE3PPPr01018r2 Actual glycol pump VFD data from projects.xls”.

³ Port of Stockton. 2014. *2014 Energy Efficiency Program Offering Procedures Manual. Appendix C: California Statewide Manual Baseline Efficiencies.*

⁴ H.R.776 – 102nd Congress. Energy Policy Act of 1992. Pub. L. 102-486.

Annual Hours of Operation

Baseline	Measure Case – Full Speed	Measure Case – Reduced Speed
7,163	1,490	5,673

PEAK ELECTRIC DEMAND REDUCTION (kW)

Because the pump is assumed to run at full speed during the peak period of 4 p.m. to 9 p.m., there is no demand reduction from this measure.

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.”⁷ This approach provides a reasonable RUL estimate without the requiring any a priori knowledge about the age of the equipment being replaced.⁸ Further, as per Resolution E-4807, the California Public Utilities Commission (CPUC) revised add-on 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.”⁹

The EUL and RUL specified for glycol pump motor VFD, specified below, are based upon several retention studies. The RUL is based upon the EUL of the host equipment, a pump motor.

⁵ Pacific Gas & Electric (PG&E). 2012. “PGE3PPR0108r2 Survey of winery process cooling loads - tank usage during the year.xlsx”.

⁶ Pacific Gas & Electric (PG&E). 2009. “PGE3PPr01018r2 Actual glycol pump VFD data from projects.xls”.

⁷ California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 32.

Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs) – measure	15.0	<p>San Diego Gas & Electric. 2004. <i>1994 & 1995 Commercial Energy Efficiency Incentives – Ninth Year Retention Evaluation</i>. Study ID Nos. 925 & 961.</p> <p>Southern California Edison Company. 2006. <i>Southern California Edison Commercial/ Industrial/ Agricultural Energy Efficiency Incentives Program Ninth Year Retention Study</i>. CEC Study ID #558 Calmac Study ID: SCE 0243.01.</p> <p>Southern California Edison Company. 2004. <i>Southern California Edison Commercial/Industrial/Agricultural Energy Efficiency Incentives Program Retention Study Ninth Year Report for Program Years 1993/1994 Commercial Measures</i>. CEC Study ID #547.</p> <p>Southern California Edison Company. 2003. <i>Southern California Edison Commercial/Industrial/Agricultural Energy Efficiency Incentives Program Retention Study Sixth Year Report for Program Years 1993-1997 Industrial and Agriculture Measures</i>. CEC Study ID #547 B,C and 558 B, C.</p> <p>San Diego Gas & Electric. 2006. <i>1996 & 1997 Nonresidential New Construction Program Ninth Year Retention Evaluation</i>. Study ID No. 1006.</p> <p>San Diego Gas & Electric. 2003. <i>1996 & 1997 Agricultural Energy Efficiency Incentives Sixth Year Retention Evaluation</i>. Study ID Nos. 1000 & 1024.</p>
EUL (yrs) – host pump motor	15.0	<p>San Diego Gas & Electric (SDG&E). 2003. <i>1996 & 1997 Agricultural Energy Efficiency Incentives Sixth Year Retention Evaluation</i>. Study ID Nos. 1000 & 1024.</p> <p>ADM Associates, Inc. 2003. <i>Southern California Edison Commercial/Industrial/Agricultural Energy Efficiency Incentives Program Retention Study</i>. Prepared for Southern California Edison Company.</p> <p>San Diego Gas & Electric (SDG&E), Marketing Programs & Planning. 2004. <i>1994 & 1995 Commercial Energy Efficiency Incentives Ninth Year Retention Evaluation</i>. Study ID Nos. 925 & 961.</p> <p>California Public Utilities Commission (CPUC). 2008. "EUL_Summary_10-1-08.xls."</p>
RUL (yrs) – host pump motor	5.0	<p>California Public Utilities Commission (CPUC), Energy Division. 2013. <i>Energy Efficiency Policy Manual, Version 5</i>. Page 32.</p>

⁸ KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc.

⁹ California Public Utilities Commission (CPUC). 2016. Resolution E-4807. December 16. Page 13.

BASE CASE MATERIAL COST (\$/UNIT)

This measure is classified as add-on equipment and the base case is a motor without a VFD. Thus, the base case material cost is equal to \$0.

MEASURE CASE MATERIAL COST (\$/UNIT)

The measure case equipment costs for VFDs were derived from data obtained for various motor sizes from the RSMMeans Online Data (Electrical Costs) released for the 4th quarter of 2020.¹⁰

BASE CASE LABOR COST (\$/UNIT)

This measure is classified as add-on equipment and the base case is a motor without a VFD. Thus, the base case labor cost is equal to \$0.

MEASURE CASE LABOR COST (\$/UNIT)

The measure case labor costs for VFDs were derived from data obtained for various motor sizes from the RSMMeans Online Data (Electrical Costs) released for the 4th quarter of 2020.¹¹

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. From Resolution E-5082, the NTG ratio for Process Pumping VFD measures is 0.40.

Net-to-Gross Ratios

Parameter	Value	Source
NonRes-sAll-mProcPumpVFD	0.40	CPUC, August 27, 2020 <i>Resolution E-5082</i> , Page 19

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. This GSIA rate is the current

¹⁰ Gordian. 2020. *RS Means Data Online*. Electrical Costs, Year 2020, Quarter 4, National Average Location, Line Number: 262923100100 – 262923100160.

¹¹ Gordian. 2020. *RS Means Data Online*. Electrical Costs, Year 2020, Quarter 4, National Average Location, Line Number: 262923100100 – 262923100160.

“default” rate specified for measures for which an alternative GSIA has not been estimated and approved.¹²

Gross Savings Installation Adjustment

Parameter	GSIA	Source
GSIA - Default	1.00	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 DEER-based inputs and methods, and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

DEER Item	Comment
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 eQUEST Prototypes	No
DEER Version	No
Reason for Deviation from DEER	This measure is not in DEER
DEER Measure IDs Used	No
NTG	Source: DEER READI v2.5.1. The NTG of 0.4 is associated with NTG ID: <i>NonRes-sAll-mProcPumpVFD</i>
GSIA	The GSIA of 1.0 is associated with GSIA ID: <i>Def-GSIA</i>
EUL/RUL	Source: DEER READI v 2.5.1. The value of 15 years is associated with EUL ID: <i>HVAC-VSD-pump</i> . RUL is equal to 1/3 of the pump EUL (<i>Motors-Pump</i>).

¹² California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 31.

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision
01	6/30/2018	Jennifer Holmes, Cal TF Staff	Draft of consolidated text for this statewide measure is based upon: PGE3PPR01018, Revision 2 (January 1, 2016) Consensus reached among Cal TF members.
	03/29/2019	Jennifer Holmes, Cal TF Staff	Updates for submission of version 01.
	07/03/2019	Randy Kwok PG&E	Corrected mistakes per Kerri-Ann’s review comment: Added 25 hp offering to both “Measure Case Specification” and “Base Case Specification” tables. Changed Measure case-Full Speed value from 11,773 to 1,773 in the Annual Hours of Operation table.
02	12/15/2020	Danielle Dragon, PE, CEM, CDSM PG&E	Updated NTG from 0.60 to 0.40 as required by Resolution E-5082. NTG update to take effect in 2022. Material and labor cost update using RSMeans 2020
	09/17/2021	Adan Rosillo PG&E	Updated annual hour of operation. Energy savings will change according to the new runtime.