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| HVAC  VSD for Central Plant System  SWHC008-01 |

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Measure Name

Variable Speed Drive for a Central Plant System

Statewide Measure ID

SWHC008-01

Technology Summary

A central plant system provides space cooling to a building by cooling water in a chiller and circulating this chilled water through a chilled water coil in an air handler or throughout the building zones. A chiller is either air-cooled or water-cooled; in a water-cooled chiller a separate water loop absorbs heat from the chiller which is then rejected by a cooling tower. A significant amount of energy is required for the pumps to circulate water in these types systems.

A chilled water pump (CHWP) circulates water cooled by the chiller and a condenser water pump (CWP) circulates the water that transfers heat between the chiller and the cooling tower. These pumps are designed to meet peak load conditions, when the equipment must operate at approximately 100% of the system design capacity. However, most of the time the demand for cooling is less than the peak design capacity.

Energy savings and demand reduction result from varying the pump speed to meet actual load. A variable speed drive (VSD) controls the motor speed by varying the frequency and voltage of the pump motor. A VSD can be programmed to reduce pump speed to meet actual load; reducing pump speed when the load drops below design conditions will yield significant pump energy savings throughout the year.

Measure Case Description

The measure case is defined as the installation of a variable speed drive (VSD) on a chilled water pump (CHWP) or on a condenser water pump (CWP) in a water-cooled central plant with existing condition not provided with a VSD and controls. The measure offerings are available as add-on equipment and for new construction application types.

Measure Offerings

| **Statewide Measure Offering ID** | **Application Type** | **Measure Offering Description** |
| --- | --- | --- |
| SWHC008A | Add-on equipment | Variable speed drive on chilled water pump (CHWP) |
| SWHC008B | Variable speed drive on condenser water pump (CWP) |
| SWHC008C | New construction | Variable speed drive on condenser water pump (CWP) |

**Base, Standard, and Measure Cases**

| **Case** | **Description of Typical Scenario** |
| --- | --- |
| Measure | Variable Speed Drive on Chilled Water Pump (CHWP)  Variable Speed Drive on Condenser Water Pump (CWP) |
| Existing Condition | CHWP Control – Single speed for add-on equipment  CWP Control – Single speed for add-on equipment and new construction |
| Code/Standard | CHWP Control – Single speed or variable speed based on the vintage and building type  CWP Control – Single speed for add-on equipment and new construction |
| Industry Standard Practice (ISP) | No explicit industry standard practice (ISP) study exists but this equipment is addressed in 2019 California Building Energy Efficiency Standards (Title 24)[[1]](#footnote-1) as discussed in the Code Requirements section below. |

Base Case Description

The base case is defined as the existing customer equipment or applicable California Building Energy Efficiency Standards (Title 24) based on building vintage. The analysis of this measure assumed single-speed pumps as the base case for both chilled water pump (CHWP) and a condenser water pump (CWP) control measure offerings.

Decision 16-08-019[[2]](#footnote-2) by the California Public Utilities Commission (CPUC) formally adopted a policy of existing conditions as the basis for estimating ex-ante savings of deemed energy efficiency measures. Resolution E-4818[[3]](#footnote-3) was approved by the CPUC on March 2, 2017 and directed Commission staff to update the Database of Energy Efficient Resources (DEER) to reflect revised baseline policies.

The existing baseline conditions for this measure were evaluated using the measure expected useful life (EUL) relative to the Title 24 code update cycles in which the measures have been required.

| **Measure Offering** | **Analysis** |
| --- | --- |
| Variable Speed Drive on  Condenser Water Pump (CWP) Control | Title 24 does not require VSDs on CWPs. Hence, it is highly likely for the measure NOT to have been fully adopted by industry. Therefore, this measure has savings potential above current industry standard practice. |
| Variable Speed Drive on  Chilled Water Pump (CHWP) Control | A VSD on a CHWP has been a code requirement since Title 24 2005[[4]](#footnote-4). CHWP retrofit is deemed as alteration in Title 24 and triggers mandatory and prescriptive requirements. Hence, this measure is only eligible for CHWP vintages before 2005 including prof of existing condition. |

Code Requirements

Applicable state and federal codes are specified below.

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) | Sections 140.4(k)1 and 140.4(k)6 | January 1, 2020 |
| Federal Standards | None | n/a |

The 2019 California Building Energy Efficiency Standards (Title 24)[[5]](#footnote-5), stipulates the following:

*“HVAC chilled and hot water pumping shall be designed for variable fluid flow and shall be capable of reducing pump flow rates to no more than the larger of: a) 50 percent or less of the design flow rate; or b) the minimum flow required by the equipment manufacturer for the proper operation of equipment served by the system”. (Section 140.4(k)1, page 220)*

The exception to this requirement is systems that include no more than three control valves and total pumping power less than or equal to 1.5 hp.

Section 140.4(k)6A of Title 24, specifies requirements for variable flow controls:

*“Individual pumps serving variable flow systems and having a motor horsepower exceeding 5 hp shall have controls or devices (such as variable speed control) that will result in pump motor demand of no more than 30 percent of design wattage at 50 percent of design water flow. The pumps shall be controlled as a function of required differential pressure.”*

Additionally, Section 140.4(k)6B, provides requirements for pressure sensor location and setpoint. The exceptions to Section 140.4(k)6 are heating hot water pumps and condenser water pumps (CWPs) serving only water-cooled chillers.

Normalizing Unit

Nominal 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** |
| CWP Control - New construction | DnDeemDI | Com |
| CWP Control - New construction | DnDeemed | Com |
| CWP Control – Add-on equipment | DnDeemDI | Com |
| CWP Control – Add-on equipment | DnDeemed | Com |
| CHWP Control - Add-on equipment | DnDeemDI | Com |

Eligible Products

All new variable speed drives (VSDs) and motor equipment must be UL Listed and specifically rated for the application.

For building types not listed in this workpaper but use water-cooled central plant systems, measure savings will be mapped under “Office Small,” which has relatively lower savings. Program will track all building types incentivized under the measures.

Constant speed Condenser Water Pump (CWP) and Chilled Water Pumps (CHWP) not already equipped with a variable speed drive (VSD) are eligible.

**For CHWP VSD Incentives.** CHWP VSD measure is only eligible if the host equipment (CHWP) was installed before 2005 and the chilled water coils are controlled by three-way valves.

This measure is only eligible for delivery through downstream direct install for which the installation contractor must verify the type of existing controls. Specifically, the installation contractor must:

* Verify and document central plant vintage via “as-built” drawings or similar
* Verify and document that existing incentivized pump operates at constant volume excluding modulating speed controls.
* Verify and document that zone distribution system (e.g., fan coil and/or air handler unit) is controlled by 3-way-CHW valves.

The simultaneous operation of the two measure offerings has interactive effects and impacts energy savings. If both measures are implemented for vintages 96 and 03, then the measures must be cascaded, and the total (aggregated) estimated savings will be slightly less than sum of the savings of the individual measure offerings. Given the vintage restrictions on the CHWP VSD measure offering, it is expected that this measure primarily will support CWP VSD implementation.

**Implementation and Installation Requirements.** Successful implementation of this measure will depend greatly on the characteristics of the installed system. For a VSD addition to the CWP special attention must be given to the condenser water flow turndown capabilities of the existing chiller(s). It is imperative that chiller manufacturer selection data and retrofit information be reviewed carefully to ensure that the existing chiller(s) is (are) rated to operate at the selected minimum condenser water flow, and that the control strategy includes capability to increase the flow as needed to keep the leaving condenser temperature from exceeding an upper limit dependent on the existing chiller.

For a CHWP, the designers should evaluate the flow control at the cooling/heating coil in the air-handling units and should consider a potential retrofit from 3-way to 2-way valve and/or pressure differential sensors and controls that may be needed to adequately complete the measure.

In all cases, measure installation must meet all applicable regulations including but not limited to the current California Building Energy Efficiency Standards (Title 24) and the National Electrical Code®.

Eligible Building Types and Vintages

This measure is applicable for the following building types that use water-cooled central plant systems.

|  |  |
| --- | --- |
| **Eligible Building Types** | |
| Education – Community College (ECC) | Health/Medical - Nursing Home (Nrs) |
| Education – Secondary School (ESe) | Office Large (OfL) |
| Education – University (EUn) | Office Small (OfS) |
| Health/Medical – Hospital (Hsp) | Retail - Multistory Large (Rt3) |
| Lodging – Hotel (Htl) |  |

The CWP measure offering is eligible for buildings of all vintages (“existing/ median”, and “new”)

The CHWP measure offering is ONLY eligible for “old” vintage buildings with proof of verification of existing condition.

Eligible Climate Zones

This measure is applicable in all California climate zones.

Program Exclusions

This measure excludes central plant equipment under any type of plant optimization and/or retro-commissioning at both the central plant and/or system HVAC levels; and/or central plants supporting “process” load; and/or industrial applications serving non-HVAC “space comfort” loads; and/or central plant operating with thermal energy storage. All non-standard central plant applications shall be incentivized under custom programs.

Data Collection Requirements

The chilled water pumping system effective useful life (EUL) is approaching the number of years since variable flow on chilled water pumps became a code requirement. Hence, the CHWP variable speed drive (VSD) measure may warrant an industry standard practice (ISP) evaluation.

Use Category

HVAC

Electric Savings (kWh)

The unit energy savings (UES) of this measure were derived from building energy use energy simulations of variable speed drives (VSDs) that serve central plant chilled water (distribution) and condenser water pumps. MASControl3, the analysis software for the 2020 version of the Database of Energy Efficient Resources (DEER2020) was used to generate UES values for all measure offerings.[[6]](#footnote-6) MASControl3 uses the DOE‑2.3/ eQuest 3.65 simulation engine and generates the energy usage and peak demand reduction.

Baseline and Measure Case Energy Use Simulations

**Measure Definition.** DEER does not have a measure for variable flow chilled water pump (CHWP) or a condenser water pump (CWP). Hence, an existing measure “WtrCldCentChlr-Cpnv-0.748kwpton” was replicated and modified as follows:

The existing measure in DEER has chiller efficiency at 0.748 kW/ton for all capacities of chillers. This efficiency is less than the Title 24 stipulated values. Hence, the efficiency of the chillers was revised based on requirements specified in Table 112-D of Title 24 2005. It is assumed that this efficiency is representative of existing chiller efficiency.

The existing measure in DEER has already variable flow controls on the secondary chilled water loop for the following building types: Education – Community College (ECC), Education – University (EUn), Health/Medical – Hospital (Hsp), and Lodging – Hotel (Htl). However, these controls are revised to constant speed controls for the evaluation of savings potentials.

**Vintages.** For the CWP VSD measure offering, the models corresponding to vintages listed below were considered. For CHWP VSD measure, only the vintages 2003 and 1996 were considered since this measure is not eligible for vintages after 2005. For building vintages before 1993, the condenser and chilled water pumping system are past its effective useful life and assumed to have been replaced with newer systems.

* 1993 – 2001 (1996)
* 2001 – 2005 (2003)
* 2005 – 2009 (2007)
* 2009 – 2013 (2011)
* 2014 – 2016 (2015)
* 2017 - 2019 (2017)
* After 2019 (2020)

The following table summarizes the eQuest keywords used for the baseline and measure case.

**eQUEST Keyword Modifications**

| **Vintage(s)** | **Keyword** | **Baseline Design Value** | **Measure Design Value** |
| --- | --- | --- | --- |
| **Chilled Water Loop Pump (CHWP)** | | | |
| 96,03 | PUMP:CAP-CTRL | ONE-SPEED-PUMP | VAR-SPEED-PUMP |
| 96,03 | SYSTEM:CHW-VALVE-TYPE | THREE-WAY | TWO-WAY |
| **Condenser Water Loop Pump (CWP)** | | | |
| 96,03,07,11,15,17,20 | PUMP:CAP-CTRL | N/A | VAR-SPEED-PUMP |
| 96,03,07,11,15,17,20 | CHILLER:CW-FLOW-CTRL | CONSTANT-FLOW | VARIABLE-FLOW |
| 96,03,07,11,15,17,20 | CHILLER:CW-MIN-FLOW | N/A | 0.70 (ratio) |
| 96,03,07,11,15,17,20 | CHILLER:MAX-COND-T | N/A | 85.0 (degF) |

For the CWP VSD measure offering, it is important to define a minimum condenser water flow rate and a maximum allowable leaving condenser temperature:

* *Minimum flow rate:* The determinants are the minimum flow required by the chiller and the minimum flow required by the tower. A conservative estimate of 70% achievable flow turndown was specified for the measure case, based upon secondary research.[[7]](#footnote-7)
* *Maximum leaving condenser temperature:* The limit was set to 85 °F, the condenser temperature at the rated conditions for the modeled chiller.

With the above modifications and selections, batch processing was run in MASControl3 for all climate zones. The output file included unit energy and demand values for baseline, measure, and savings.

Unit Energy Savings Calculation

To calculate the UES (per horsepower), the pump demand was extracted from MASControl3 and was converted to horsepower by dividing by 0.746. The nominal horsepower for the motors was determined by comparing with the industry standard motor sizes available from 2018 RSMeans Electrical Costs.[[8]](#footnote-8) [[9]](#footnote-9)

The UES from the above steps for vintages defined by year ranges were transformed into the era vintages using a weighted average approach with the DEER2020 building weights.[[10]](#footnote-10)  For CWP the “old,” “median/recent” were combined into “Ex” using the DEER2020 building weights.

For CWP while the kWh savings for New are always lower than Ex, the normalized savings kWh/hp for New may be slightly higher compared to Ex in some cases. This is because the nominal motor horsepower (normalizing unit) value decreases for New vintage.

Peak Electric Demand Reduction (kW)

The approach to derive electric unit energy savings was followed to calculate the peak demand reduction. See Electric Savings.

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.”[[11]](#footnote-11) This approach provides a reasonable RUL estimate without the requiring any a priori knowledge about the age of the equipment being replaced.[[12]](#footnote-12) 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. [[13]](#footnote-13)

The EUL and RUL established for this measure are specified below. The EUL was established for a variable flow water loop pump for the 2008 update of the Database of Energy Efficient Resources (DEER) and was based upon results of several retention studies conducted in California.

Effective Useful Life and Remaining Useful Life

| **Parameter** | **Value** | **Source** |
| --- | --- | --- |
| *New application types– New application types for variable flow water loop, VSD pump  (used for the VSD on condenser water pump)* | | |
| EUL (yrs) | 15.0 | San Diego Gas & Electric (SDG&E). 2003. 1996 & 1997 Agricultural Energy Efficiency Incentives Sixth Year Retention Evaluation. Study ID Nos. 1000 & 1024.  San Diego Gas & Electric (SDG&E), Marketing Programs & Planning. 2004. 1994 & 1995 Commercial Energy Efficiency Incentives Ninth Year Retention Evaluation. Study ID Nos. 925 & 961.  San Diego Gas & Electric (SDG&E), Marketing Programs & Planning. 2006. *1996 & 1997 Nonresidential New Construction Program Ninth Year Retention Evaluation.* Study ID No 1006.  ADM Associates, Inc. 2003. Southern California Edison Commercial/Industrial/Agricultural Energy Efficiency Incentives Program Retention Study. Prepared for Southern California Edison Company. |
| RUL (yrs) - | 5.0 |  |
| *Add-on equipment application types for variable flow water loop, VSD pump  (used for the VSD on chilled water pump and VSD on condenser water pump)* | | |
| EUL (yrs) | 5.0 |  |

Base Case Material Cost ($/unit)

The base case cost is assumed to be $0 for add-on equipment application types because these measure offerings are considered discretionary modifications to the customer existing equipment. The customer’s alternative is to make no changes to the existing system.

The base case cost is assumed to be $0 for new construction application types because the base case is defined as the existing equipment, which does not require replacement.

Measure Case Material Cost ($/unit)

The measure case material cost and labor were derived from the 2018 RSMeans Electrical Costs.[[14]](#footnote-14) The installed equipment is a new variable speed drive (VSD), 3-Phase, 460 volts, with enclosed (NEMA 1) or a custom engineered VSD.

The average total cost of a VSD per nominal horsepower for CHWP and CWP motors was calculated as the average cost per horsepower for motors 3 hp to 200 hp for enclosed and custom engineered VSDs.[[15]](#footnote-15)

Base Case Labor Cost ($/unit)

The base case labor cost is assumed to be $0 for add-on equipment application types because these measure offerings are considered discretionary modifications to the customer existing equipment. The customer’s alternative is to make no changes to the existing system.

The base case labor cost is assumed to be $0 for new construction application types because the base case is defined as the existing equipment, which does not require replacement.

Measure Case Labor Cost ($/unit)

See Measure Case Material Cost.

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 NTG value is based upon the average of all NTG ratios for all evaluated 2006 – 2008 commercial programs, as documented in the 2011 DEER Update Study conducted by Itron, Inc. 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.

Net-to-Gross Ratios

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Source** |
| NTG – Commercial | 0.60 | Itron, Inc. 2011. *DEER Database 2011 Update Documentation.* 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. This GSIA rate is the current “default” rate specified for measures for which an alternative GSIA has not been estimated and approved.

Gross Savings Installation Adjustment Rates

|  |  |  |
| --- | --- | --- |
| **Parameter** | **GSIA** | **Source** |
| GSIA | 1.0 | California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 31. |

Non-Energy Impacts

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

DEER Differences Analysis

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

DEER2020 does not support these measures. The DEER2017 includes the related measure offerings from DEER2005 – variable speed drive (VSD) on CHWPs as a combination of two measures but only for certain building types. D03-046 specified three-way valves and a single-speed pump in the base case, and two-way valves and a single-speed pump in the measure case. D03-047 defined two-way valves and a single-speed pump in the base case, and two-way valves and a variable-speed pump in the measure case.

DEER does not support measure savings on CWP VSD, and DEER2020 provides latest updated chiller models; hence, savings estimates were derived based on the DEER2020 chiller models.

DEER Difference Summary

| **DEER Item** | **Comment / Used for Workpaper** |
| --- | --- |
| Modified DEER methodology | No |
| Scaled DEER measure | No |
| DEER Base Case | Yes (DEER2020 model with modifications) |
| DEER Measure Case | No |
| DEER Building Types | Yes |
| DEER Operating Hours | Yes |
| DEER eQUEST Prototypes | Yes |
| DEER Version | 2020 |
| Reason for Deviation from DEER | CWP and CHWP measure offerings are not in DEER2020 |
| DEER Measure IDs Used | N/A |
| NTG | Source: DEER2019. The NTG of 0.60 is associated with NTG ID: *Com-Default>2yrs* |
| GSIA | Source: DEER2011. The GSIA of 1.0 is associated with GSIA ID: *Def-GSIA* |
| EUL/RUL | Source: DEER2014. The value of 15 years is associated with EUL ID and RUL ID: *HVAC-VSD-pump*. |

Revision History

Measure Characterization Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision Number** | **Revision Complete Date** | **Primary Author, Title, Organization** | **Revision Summary and Rationale for Revision**  **Effective Date and Approved By** |
| 01 | 09/30/2018 | Jennifer Holmes  Cal TF Staff | Draft of consolidated text for this statewide measure is based upon:  SCE17HC039, Revision 2 (August 17, 2018)  Consensus reached among Cal TF members. |
|  | 06/05/2019 | Akhilesh Reddy Endurthy & Nicholas Fette  Solaris-Technical, LLC. | DEER2020 updates |
|  | 06/26/2019 | Jennifer Holmes  Cal TF Staff | Revisions for submittal of version 01. |

1. California Energy Commission (CEC). 2018. *2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* CEC-400-2018-020-CMF. [↑](#footnote-ref-1)
2. California Public Utilities Commission (CPUC). 2016. Decision 16-08-019 in the Order Instituting Rulemaking Concerning Energy Efficiency Rolling Portfolios, Policies, Programs, Evaluation, and Related Issues (R.13-11-005). August 18. [↑](#footnote-ref-2)
3. California Public Utilities Commission (CPUC). 2017. Resolution E-4818. March 2.  [↑](#footnote-ref-3)
4. California Energy Commission (CEC). September 2006. *2005 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* CEC-400-2006-015. [↑](#footnote-ref-4)
5. California Energy Commission (CEC). 2018. *2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* CEC-400-2018-020-CMF. [↑](#footnote-ref-5)
6. Southern California Edison (SCE). 2019. “SWHC008-01 BES Files.zip” [↑](#footnote-ref-6)
7. ASHRAE Journal, June 2012. Optimizing Design & Control of Chilled Water Plants. Steven T. Taylor. [↑](#footnote-ref-7)
8. Gordian. 2018. *Electrical Costs with RSMeans data. 2018.* 41st Annual Edition. [↑](#footnote-ref-8)
9. Southern California Edison (SCE). 2019. “SWHC008-01 Energy Impact Calcs.xlsx.” [↑](#footnote-ref-9)
10. California Public Utilities Commission (CPUC), Energy Division. (n.d.) “DEER2020-Building-Weights.xlsx.” [↑](#footnote-ref-10)
11. California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 32. [↑](#footnote-ref-11)
12. KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc. [↑](#footnote-ref-12)
13. California Public Utilities Commission (CPUC). 2016. *Resolution E-4807.* December 16. Page 13.   [↑](#footnote-ref-13)
14. Gordian. 2018. RSMeans Online - Electrical Cost Data. [↑](#footnote-ref-14)
15. Southern California Edison (SCE). 2019. “SWHC008-01 MeasureCost.xlsx” [↑](#footnote-ref-15)