**Work Paper PGE3PHVC150**

**Enhanced Time Delay Relay**

**Revision 4**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**Enhanced Time Delay**

**Measure Code H796**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Applicable Measure Codes:** | **H796** |
| **Measure Description:** | Enhanced Fan Time Delay – Residential |
| **Energy Impact Common Units:** | Per ton |
| **Base Case Description:** | Air-conditioner with fan cycling off at the same time as the compressor. |
| **Base Case Energy Consumption:** | HVAC end use for appropriate climate zone and building type, PG&E existing vintage weighted |
| **Measure Energy Consumption:** | Building type, climate zone, fan usage dependent |
| **Energy Savings**  **(Base Case – Measure):** | Building type and climate zone dependent |
| **Costs Common Units:** | Per ton |
| **Base Case Equipment Cost ($/unit):** | $0 |
| **Measure Equipment Cost ($/unit):** | Source: SCE ET Report  $13.32 Material Cost |
| **Gross Measure Cost ($/unit)** | Source: SCE ET Report  $13.32 Material per ton  $63.44 Labor per ton  $76.76 Total per ton |
| **Measure Incremental Cost ($/unit):** | $76.76 Total per ton |
| **Effective Useful Life (years):** | 5 years (1/3 EUL for HV-ResAC) |
| **Measure Application Type:** | REA |
| **Net-to-Gross Ratios:** | 0.55; Res-Default>2 |
| **Important Comments:** |  |

**PGE3PHVC150 Enhanced Time Delay Relay R4**

PG&E is using the SCE work paper Work Paper SCE13HC0521 ex-ante values for PG&E measure code H79.

The measure mapping is as follows:

PG&E Measure code H796 = SCE code AC-48754

# Document Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision #** | **Date** | **Section-by-Section Description of Revisions** | **Author (Company)** |
| Revision 1 | Aug. 29, 2014 | SCE WP used 2.123 Tons/System for building type DMO.  New DEER number is 3.4977 Tons/System for DMO.  DMO energy savings (kW & kWh) are revised with the new number 3.4977 Tons/System. | Tai Voong (PG&E) |
| Revision 2 | December 1, 2014 | Impacts are now reported as per tonnage. | Jia Huang (PG&E) |
| Revision 3 | March 1, 2016 | Updated to new ex ante template. | Jia Huang (PG&E) |
| Revision 4 | September 19, 2016 | Added downstream delivery channel to implementation table. | Jia Huang (PG&E) |

# At-a-Glance Summary

|  |  |
| --- | --- |
| ****Applicable Measure Codes:**** | AC-48754 – Air Conditioner – Efficient Fan Control |
| **Measure Description:** | Fan controller device using built-in logic to delay the evaporator fan cycle off time. |
| **Base Case Description:** | Split-system air-conditioner with fan cycling off at the same time as the compressor. |
| **Energy Impact Common Units:** | Per unit (PG&E)  Per ton (SCE) |
| **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):** | 5 years (1/3 EUL for HV-ResAC) |
| **Measure Application Type:** | REA |
| **Net-to-Gross Ratios:** | 0.85; ET-Default |
| **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 |
| SCE13HC052.0 | Yes | 08/24/12 | Brian James/SCE | Original work paper |
| SCE13HC052.1 | Yes | 04/01/14 | Ray Phillips/PECI | -Update using the latest DEER eQUEST prototypes (via MASControl).   * Update to include all 16 CA climate zones * Update kW and kWh savings   -Work paper updated for the reporting period, effective 7/1/14 – 12/31/14. |

# Section 1. General Measure & Baseline Data

## Measure Description & Background

This work paper outlines the retrofit add-on of an efficient fan controller (EFC) device onto a residential single-family, multi-family or double-wide mobile home split-system air conditioner. The base case is a 14 SEER AC unit without an EFC.

Table 1 Measure Names

|  |  |
| --- | --- |
| Solution Code | Measure name |
| AC-48754 | Air Conditioner - Efficient Fan Control |

### Measure Requirements

**Eligibility Requirements**

This measure only applies to residential split-system air conditioning units with an indoor evaporator coil. The baseline air conditioning system cannot have built-in delay.

**Implementation Requirements**

This work paper only allows the installation of an automated fan controller, unless the manually-set time-delay fan controller is set and commissioned by a trained contractor. This measure can be installed in single family, multi-family, and double-wide mobile homes in all SCE climate zones.

**Documentation Requirements**

There are no documentation requirements at this time.

## Technical Description

EFC devices delay the evaporator fan cycle off time to take advantage of the residual liquid refrigerant remaining in the evaporator after the compressor cycles off. The controller can delay the fan cycle off time either by allowing the user to set the time delay period, or by using built-in logic to delay the fan cycle off time based on the compressor run time. This work paper only allows the installation of a fan controller with built-in logic, heretofore after referred to as “automated fan controller,” unless the manually set time delay is set and commissioned by a trained contractor.

## 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.

**Delivery Mechanism** for this measure is Financial Support / Down-Stream Incentive – Deemed and Financial Support / Direct Install.

**Program Type/Install Type** of this measure is RET – Add-on (REA).

## 1.4 Measure and Base Case Cost Effectiveness Data

### 1.4.1 DEER Measure and Base Case Analysis

DEER building prototypes for all vintages were used to establish the baseline energy consumption of the single family, multi-family, and double-wide mobile home of a SEER 14 split-system AC. The 03 vintage was selected as an un-weighted representative for the average residence. DEER prototypes assume the system type to be Packaged Variable Volume Variable Temperature (PVVT) systems. This was changed to Packaged Single Zone to reflect a typical residential building with a single zone because there is no built-in system for Split Single Zone units in eQuest. It is assumed variances in simulation results between split and packaged systems would be insignificant.

*At the time the analysis was performed the current version of MASControl (version 3.00.019 and 3.00.20) were not able to generate a prototype for the double-wide mobile home type of residential building. The SFM prototype was substituted for the DMO for this workpaper to provide savings for the DMO type of building.*

Table 2 DEER Difference Summary

|  |  |
| --- | --- |
| DEER Difference Summary Table | |
| Modified DEER Methodology | Yes |
| Scaled DEER Measure | No |
| DEER Building Prototypes Used | Yes |
| Deviation from DEER | DEER assumed different baseline systems of packaged variable-volume units. Changed to packaged single zone. |
| DEER Version | DEER 14 |
| DEER Run ID and Measure Name (Sample) | RSFm1405RSA14 |

**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\* |
| Res-Default>2 | All other EEM with no evaluated NTGR; existing EEM with same delivery mechanism for more than 2 years | Residentail | Any | Any | 0.55 |

\*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 | 1.0 |

**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.

Table 5 READi Tech IDs

|  |  |
| --- | --- |
| READi Field Name | Values included in this workpaper |
| Measure Case UseCategory | HVAC |
| Measure Case UseSubCats | Space Cooling (SpaceCool) |
| Measure Case TechGroups | dX AC Equipment (dxAC\_equip) |
| Measure Case TechTypes | Non-DEER (NonDEER) |
| Base Case TechGroups | dX AC Equipment (dxAC\_equip) |
| Base Case TechTypes | SEER Rated Split System AC (spltSEER) |

### 1.4.2 Codes and Standards Analysis

There are currently no federal, state, or regional codes that impact efficient fan controllers for residential AC. However, starting in 2015 federal code requires a residential AC unit installed in California to have a SEER (Seasonal Energy Efficiency Ratio) rating of at least 1 [B]. This efficiency rating was used to establish the baseline AC unit for this measure. For application in 2014 programs the savings are slightly conservative as the 2014 code requires SEER 13.

Table 6 Code Summary

|  |  |  |
| --- | --- | --- |
| Code | Applicable Code Reference | Effective Dates |
| Title 24 (2013) | N/A | N/A |
| Title 20 (2014) | N/A | N/A |
| N/A | N/A | N/A |

### 1.4.3 Non-DEER Study Review

ET11SCE1130 tested a nominal 3-ton split air-conditioning unit in a laboratory setting where the unit was equipped with an air-cooled condenser and a single speed compressor. This combination of components is representative of one of the most common configurations of air-conditioning units found in residential applications. The measure evaluation portion of the testing included the installation of the two types of commercially available add-on delay controllers. The two fan controllers allowed the fans to run after the compressor was shut off, but one ran for a prescribed period of time while the other had a built-in logic to delay for a period of time based off of the compressor’s run time. The projects findings were used for subsequent analysis using eQuest to perform multiple simulations across California climate zones. The full report can be viewed in the attached file “ET11SCE1130\_Evap Fan Delay\_Final.pdf” found below.

### 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 “DEER2014-EUL-table-update\_2014-02-05.xlsx” 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.

To obtain the EUL value the DEER14 update documentation, “DEER2014-EUL-table-update\_2014-02-05.xlsx” [436], was consulted. Table 7 below identifies the value/methodology used for the measures in this work paper. The EUL of the measure is capped at the remaining useful life of split and package equipment, or a third of 15 years, as it is assumed that the controller would be removed with the equipment once it reaches its remaining useful life.

Table 7 DEER14 EUL Value/Methodology

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| READi EUL ID | Market | Enduse | Measure | EUL (Years) | RUL (Years) |
| HV-ResAC | Residential | HVAC - Miscellaneous | High Efficiency Air Conditioner (package and split systems) | 5 | N/A |

# Section 2. Energy Savings & Demand Reduction Calculations

Energy savings was calculated using eQuest v3.64 to establish the baseline energy consumption then applying the part load ratio curve fit equation from the ET report [A]. The eQuest simulations used a minimally above-code SEER 14 split-AC system to be slightly conservative. The cooling capacity varied by building type and climate zone based on the DEER building prototypes for double-wide mobile home, multi-family, and single family residential buildings. The DEER building prototypes are the most recent updates to include the Title 24 2008 [208] and Title 24 2013 [355] code based vintages. These new prototypes were the models that were used in conjunction with revised weather data files to provide the energy savings for the measure. Four hourly variables were captured from the eQuest simulations for a year: total cooling load (Btu/hr), condensing unit energy (kWh), supply (indoor) fan energy (kWh), and AC total cooling capacity (Btu/hr). The total AC energy usage was calculated by equation 1:

**Equation 1**

The part load ratio was determined by equation 2:

**Equation 2**

Once the Part Load Ratio (PLR) is obtained, equation 3 applies the logarithmic curve fit of percentage of energy savings versus part load ratio determined from laboratory testing. See Figure 11 on page 15 of the attached report [A].

**Equation 3**

The result from equation 3 is AC energy savings per hour. This number is summed for all hours of the year to obtain the total energy savings. Results were obtained for each zone (each with a separate split-AC system) as specified in the DEER building prototypes. There were 2 systems (N-S, E-W orientations) in double-wide mobile homes (however this was represented by the SFM), 4 systems in single-family homes (single-story, two-story, two orientations), and 24 systems in multi-family homes (two-story buildings with 12 units, two orientations). The results obtained for each of the building prototypes were averaged to obtain one representative savings number per building type.

For a sample calculation, consider a double-wide mobile home in climate zone 13 with a N-S orientation at 5:00 PM on July 8th per the calculation spreadsheet in Attachment 2 [F]. First solve equation 1:

Next, solve for the PLR with equation 2:

Lastly, solve for the AC energy savings for that hour with equation 3:

This process is repeated for all 8,760 hours in the year and summed to obtain the total annual energy savings for the EFC controller of each DEER building prototype. The annual energy savings were then normalized by cooling capacity using actual tonnage for each unit examined within each prototype for SCE. For PG&E, the savings are normalized to a “per unit” value using tonnages for each building type extracted from the MASControl tool. These tonnages are 3.184, 2.123, and 1.122 for single family, double wide mobile home, and multi-family, respectively. Results for all zones or systems were simple averages for each building type and orientation. As an example of the energy savings, for a double-wide mobile home in CZ 13, the calculated energy savings were 113.63 kWh/ton annually. (The mobile home energy savings is currently being represented by the single family home savings until DEER mobile family prototypes are available with post 2008-2013 Title 24 Code updates.) The savings are converted to a per unit basis as follows for PG&E:

**Demand Reduction Calculations**

Since hourly values of AC energy savings were available for one full year, demand reduction was calculated by summing the total energy consumed during the peak demand period for the specific summer weekday periods delineated by climate zone, 2:00 PM to 5:00 PM as set forth in CPUC Decision D06-06-063. The total energy consumption during this period was then divided by nine, the number of peak hours, as shown in equation 4. The AC Energy Savings During Peak Period was normalized by cooling capacity using actual tonnage from the DEER prototypes:

**Equation 4**

Using the previous example of a double-wide mobile home in CZ 13, whose peak period falls between 2:00 PM and 5:00 PM, July 8-10 we obtain the following results after applying equation 4:

This value is averaged with the E-W orientation to obtain a final peak demand reduction of 0.0687 kW.

See attachments 2, 3, and 4 for detailed energy savings and demand reduction calculations [D, E, F].

# 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 DEER:HVAC\_EFF\_AC 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 |
| Residential – Double-Wide Mobile Home | RES | DEER:HVAC\_EFF\_AC |
| Residential – Multi-Family | RES | DEER:HVAC\_EFF\_AC |
| Residential – Single Family | RES | DEER:HVAC\_EFF\_AC |

# Section 4. Base Case & Measure Costs

## 4.1 Base Case Cost

For REA measures, there is no base case cost as the measure is being added onto the existing equipment.

## 4.2 Measure Case Cost

The measure equipment material cost was determined by reviewing the purchased price for two fan delay controllers tested in the ET laboratory report [A]. The price paid was $25 per controller, plus $3.50 for shipping and handling. The price was cross-referenced with Southern California Gas Company’s work paper SCG0077.0 California HVAC Upgrade: Efficient Fan Controller (EFC) – Residential, which listed the material equipment cost at $25. The controller cost is also normalized on a per-ton basis using the average rated capacities of the HVAC systems in the DEER eQuest models for DMO, MFM, and SFM. The average rated capacities for DMO, MFM, and SFM are 2.123, 1.122, and 3.184 tons, respectively. The combined average rated capacity used to calculate the average cost per ton is 2.14 tons. This results in an average equipment cost of $13.32 per ton.

The measure labor cost was determined from “Revised DEER Measure Cost Summary (05\_30\_2008) Revised (06\_02\_2008).xls.” DEER labor costs have remained the same as of DEER 2016. The base labor rate is $67.88 per hour for the residential sector for downstream prescriptive rebates/incentives. Installation of the fan controller takes 1-2 hours, so the labor cost is estimated at $135.76. Normalized per ton, the measure labor cost is $63.44. Refer to Attachment 5 for the cost calculation [G].

Measure Case Cost= Measure Equipment Cost + Measure Labor Cost

= $28.50+ $135.76

= $164.26/unit

Measure Case Cost= Measure Equipment Cost + Measure Labor Cost

= $13.32+ $63.44

= $76.76/ton

## 4.3 Gross and Incremental Measure Cost

### 4.3.1 Gross Measure Cost

For REA measures, the gross measure cost (GMC) is the measure equipment material costs plus installation labor. From section 4.2 above, the GMC is equal to $164.26/unit and $76.76/ton.

### 4.3.2 Incremental Measure Cost

For REA measures, Incremental Measure Cost is the same as Gross Measure Cost.

# Attachments

1. Efficient Fan Controller for Residential Air Conditioners\_Final.xlsm
2. Efficient\_Fan\_Controller\_for\_Residential\_Air\_Conditioners\_SFM\_Results\_v4.xlsb (**available upon request due to size**)
3. Efficient\_Fan\_Controller\_for\_Residential\_Air\_Conditioners\_MFM\_Results\_v4.xlsb (**available upon request due to size**)
4. Efficient\_Fan\_Controller\_for\_Residential\_Air\_Conditioners\_DMO\_Results\_v4.xlsb (**available upon request due to size**)
5. Cost Calc.xlsx
6. ET11SCE1130\_Evap Fan Delay\_Final.pdf

# References

Reference List\_06\_10\_2014.xlsx

[31]

[208]

[351]

[355]

[436]

1. Effects of Delaying Evaporator Fan Cycle Off Time for Residential Air-Conditioning Units. Design and Engineering Services, Emerging Technologies Program. March 20, 2012. - Attachment
2. Energy Conservation Standards for Residential Central Air Conditioners and Heat Pumps http://www1.eere.energy.gov/buildings/appliance\_standards/residential/residential\_cac\_hp.html
3. Attachment 1. Calculation Template 2015 v4.xlsm
4. Attachment 2. Efficient\_Fan\_Controller\_for\_Residential\_Air\_Conditioners\_SFM\_Results\_v4.xlsb
5. Attachment 3. Efficient\_Fan\_Controller\_for\_Residential\_Air\_Conditioners\_MFM\_Results\_v4.xlsb
6. Attachment 4. Efficient\_Fan\_Controller\_for\_Residential\_Air\_Conditioners\_DMO\_Results\_v4.xlsb
7. Attachment 5. Cost Calcs.xlsx

# 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 |