HEATING, VENTILATION AND AIR CONDITIONING (HVAC) – CONTROL

ADAPTIVE PHOTONIC CONTROL FOR HVAC FAN MOTORS

Measure Description

This measure covers the installation of adaptive photonic control systems applied to HVAC fan motors. Adaptive photonic control involves integration with an HVAC system's motors including PTACs, PTHPs, mini-splits, central air units and furnace distribution system supply fans. It enables adaptive speed control for single-speed AC fan motors using sensors by continuously adapting to end-user requirements. The controller uses photonic (opto-electronic) transducers and graphical apertures that are integrated into intelligent, signal and vector processors enabling their use as analog power controllers [1123, 1124]. It provides an adaptive airflow solution by tracking air temperature and optimizing operation based on climate conditions. Savings accrue not only from the reduction of fan speed to match thermal delivery rates, but also through better air mixing in the space and more effective heat transfer on the coils when the system is in operation. By adjusting airflow to improve heat transfer, the controller improves whole system operating efficiency and significantly reduces compressor run times.

This measure is only applicable to adaptive photonic control integrated into single-speed AC induction fan motors rated up to 5 horsepower (HP) that do not have speed variability restriction (e.g., via centrifugal speed switch).[1125, 1126] Savings estimated per this methodology may be claimed in retrofit applications as well as in new construction applications where electronically commutated (EC) motors are not otherwise required by federal, state, local or municipal codes or standards.

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating} + \Delta kWh_{fan}$$

$$\Delta kWh_{cooling} = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times hrs_{cooling}$$

$$\Delta kWh_{heating} = units \times \frac{(W_{heating} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

$$\Delta kWh_{fan} = units \times \frac{(W_{blowerfan} \times ESF)}{1{,}000} \times LF \times hrs_{fan}$$

Note: ΔkWh_{fan} is only applicable if fan is set to on position during occupancy

[1123] IEEE Transactions on Industrial Electronics, 'A novel switched reluctance motor drive with optical graphical programming technology', 2000.
[1124] ACHR News, Fan Coil Units Get VSD, 2005
[1125] San Diego Gas & Electric, Work Paper WPSDGENRHC1051, Revision 1, Sept 2016
[1126] Comfort-Plus Drive™, Variable Speed Drive for Fan Coil Units, 2005

Summer Peak Coincident Demand Savings

$$\Delta kW = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times CF$$

Annual Fossil Fuel Energy Savings

$$\Delta MMBtu = units \times \frac{(kBtu/h_{in} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

where:

$$W_{cooling} = W_{evaporator} + W_{compressor} + W_{condenser}$$

$$W_{heating} = W_{evaporator} + W_{ElecHeat}$$

$$W_{evaporator} = V_{evaporator} \times A_{evaporator} \times PF$$

$$W_{compressor} = V_{compressor} \times A_{compressor} \times PF$$

$$W_{condenser} = V_{condenser} \times A_{condenser} \times PF$$

$$hrs_{fan} = hrs - (hrs_{cooling} + hrs_{heating})$$

where:

ΔkWh = Annual electric energy savings
ΔkW = Peak coincident demand electric savings
$\Delta MMBtu$ = Annual fossil fuel energy savings
$\Delta kWh_{cooling}$ = Annual electric energy savings in cooling mode
$\Delta kWh_{heating}$ = Annual electric energy savings in heating mode
ΔkWh_{fan} = Annual electric energy savings in fan only mode
units = Number of measures installed under the program
$W_{cooling}$ = Retrofitted system peak wattage in cooling mode
$W_{heating}$ = Retrofitted system peak wattage in heating mode
$W_{evaporator}$ = Retrofitted system evaporator wattage, based on nameplate specifications
$W_{compressor}$ = Retrofitted system compressor wattage, based on nameplate specifications
$W_{condenser}$ = Retrofitted system condenser wattage, based on nameplate specifications
$W_{blowerfan}$ = Retrofitted system blower fan wattage, based on nameplate specifications
$W_{ElecHeat}$ = Retrofitted system electric resistance heating element wattage, based on nameplate specifications, where applicable
$V_{evaporator}$ = Retrofitted system evaporator voltage
$V_{compressor}$ = Retrofitted system compressor voltage
$V_{condenser}$ = Retrofitted system condenser voltage
$A_{evaporator}$ = Retrofitted system evaporator amps
$A_{compressor}$ = Retrofitted system compressor amps

$A_{condenser}$ = Retrofitted system condenser amps
PF = Power factor
$kBtu/h_{in}$ = Retrofitted system space heating input fuel rating (kBtu/h)
ESF = Energy savings factor
LF = Motor load factor
$hrs_{cooling}$ = Retrofitted system annual operating hours in cooling mode
$hrs_{heating}$ = Retrofitted system annual operating hours in heating mode
hrs_{fan} = Retrofitted system annual operating hours in fan only mode
hrs = Retrofitted system annual operating hours
CF = Coincidence factor
1,000 = Conversion factor, one kW equals 1,000 watts

Summary of Variables and Data Sources

Variable	Value	Notes
$W_{ElecHeat}$		From application.
$W_{blowerfan}$		From application.
$V_{evaporator}$		From application.
$V_{compressor}$		From application.
$V_{condenser}$		From application.
$A_{evaporator}$		From application.
$A_{compressor}$		From application.
$A_{condenser}$		From application.
PF	0.85	From Standard Handbook of Electrical Engineers[1127] and the Engineering Toolbox.[1128]
$kBtu/h_{in}$		From application.
ESF	0.30	Average of multiple validation tests.[1129]
LF	0.9	Assumed value to reflect that motors do not typically run at 100% of rated power.
$hrs_{cooling}$		From application. If unknown, see Operating Hours section below.
$hrs_{heating}$		From application. If unknown, see Operating Hours section below.
hrs		From application. If unknown, see Operating Hours section below.
CF	0.8	

Coincidence Factor (CF)

The prescribed value for the coincidence factor is 0.8.[1130]

[1127] Standard Handbook for Electrical Engineers (McGraw-Hill Handbooks), Donald G. Fink, ISBN 10: 0070220050 / ISBN 13: 9780070220058, Published by McGraw-Hill Publishing Co., 1999
[1128] Engineering Tool Box, Power Factors for Inductive Loads, https://www.engineeringtoolbox.com/power-factor-electrical-motor-d_654.html
[1129] Aclectic, Adaptive Control Technologies, Validation Tests
[1130] *No source specified – update pending availability and review of applicable references*

Baseline Efficiencies from which Savings are Calculated

The baseline condition is a standard efficiency, single-speed AC induction motor in a direct-drive HVAC circulation (blower) fan application. Baseline wattage shall be derived from the nameplate rating of existing system components.

Compliance Efficiency from which Incentives are Calculated

The compliance condition is a single-speed AC induction motor with adaptive photonic control as described in the Measure Description section above in a direct-drive HVAC circulation (blower) fan application.

Operating Hours

Annual cooling mode, heating mode and total system operating hours shall be taken from application. If the operating hours are unknown, look up cooling and heating mode operating hours from Appendix G (i.e., cooling and heating equivalent load full hours shall be used as proxy values for annual cooling mode and annual heating mode hours, respectively). If the circulation fan is set to on during facility operation, look up total system operating hours by building type from the table below.

Facility Type	Hours (hrs/yr)	HVAC Int	Facility Type	Hours (hrs/yr)	HVAC Int
Auto Related*	2,810	AR	Manufacturing Facility	2,857	Ind
Automotive / Transportation Service or Repair Facility (24/7)	8,760	AR	Medical Offices	3,748	SOfc
Bakery	2,854	FS	Motion Picture Theatre	1,954	Asy
Banks	3,748	SOfc	Multi-Family (Common Areas)	7,665	MFL
Church	1,955	Rel	Museum	3,748	Asy
College – Cafeteria**	2,713	FS	Nursing Homes	5,840	MFL
College – Classes	2,586	CC	Office (General Office Types)**	3,013	SOfc/ LOfc
College - Dormitory	3,066	Dorm	Parking Garages	4,368	None
Commercial Condos***	3,100	SOfc	Parking Garages (24/7)	7,717	None
Convenience Stores	6,376	SRet	Parking Lots	4,100	None
Convention Center	1,954	Asy	Penitentiary	5,477	MFL
Court House	3,748	LOfc	Performing Arts Theatre	2,586	Asy
Dining: Bar Lounge/Leisure	4,182	FS	Police / Fire Stations (24 Hr)	7,665	Asy
Dining: Cafeteria / Fast Food	6,456	FF	Post Office	3,748	SRet
Dining: Family	4,182	FS	Pump Stations	1,949	Ind
Entertainment	1,952	Asy	Refrigerated Warehouse	2,602	RWH
Exercise Center	5,836	SRet	Religious Building	1,955	Rel
Fast Food Restaurants	6,376	FF	Restaurants	4,182	FS

Facility Type	Hours (hrs/yr)	HVAC Int	Facility Type	Hours (hrs/yr)	HVAC Int
Fire Station (Unmanned)	1,953	Asy	Retail	3,463	SRet/ LRet
Food Stores	4,055	Gro	School / University	2,187	Univ
Gymnasium	2,586	Asy	Schools (Jr./Sr. High)	2,187	HS
Hospitals	7,674	Hosp	Schools (Preschool/Elementary)	2,187	Sch
Hospitals / Health Care	7,666	Hosp	Schools (Technical/Vocational)	2,187	CC
Industrial - 1 Shift	2,857	Ind	Small Services	3,750	SOfc
Industrial - 2 Shift	4,730	Ind	Sports Arena	1,954	Asy
Industrial - 3 Shift	6,631	Ind	Town Hall	3,748	Asy
Laundromats	4,056	SRet	Transportation	6,456	Asy
Library	3,748	LOfc	Warehouse (Not Refrigerated)	2,602	WH
Light Manufacturers**	2,613	Ind	Waste Water Treatment Plant	6,631	Ind
Lodging (Hotels/Motels)	3,064	Hotel/ Motel	Workshop	3,750	Ind
Mall Concourse	4,833	LRet			

* New car showrooms and Big Box retail stores with evening and/or weekend hours should use the Facility Type "Retail" for lighting operating hours.
** Lighting operating hours data from the 2008 California DEER Update study
*** Lighting operating hours data for offices used

Example Calculation *(Not to be used as default)*

An adaptive photonic control system is installed on a central air conditioning and 150 kBTU/h gas heating system in a small office building. The system's compressor is rated at 230 V and 28.2 amps, the condenser is rated at 230 V and 2.4 amps and the evaporator is rated at 230 V and 12 amps. The blower fan has a rated wattage of 2.25 kW. The system runs in cooling mode for approximately 600 hours per year, in heating mode for approximately 1,600 hours per year and in fan only mode for approximately 1,500 hours per year, for a total of 3,700 hours annually. Annual Electric Energy Savings, Summer Peak Coincident Demand Savings and Annual Fossil Fuel Energy Savings are calculated as below.

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating} + \Delta kWh_{fan}$$

$$\Delta kWh_{cooling} = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times hrs_{cooling}$$

$$\Delta kWh_{heating} = units \times \frac{(W_{heating} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

$$\Delta kWh_{fan} = units \times \frac{(W_{blowerfan} \times ESF)}{1{,}000} \times LF \times hrs_{fan}$$

$$\Delta kW = units \times \frac{(W_{cooling} \times ESF)}{1{,}000} \times LF \times CF$$

$$\Delta MMBtu = units \times \frac{(kBtu/h_{in} \times ESF)}{1{,}000} \times LF \times hrs_{heating}$$

units = 1, from application
$W_{cooling} = W_{evaporator} + W_{compressor} + W_{condensor} = 2{,}346 + 5{,}513 + 469 = 8{,}328$ W
$W_{cooling}$ equation from 'where' section
$W_{evaporator} = V_{evaporator} \times A_{evaporator} \times PF = 230 \times 12 \times 0.85 = 2{,}346$ W
$W_{evaporator}$ equation from 'where' section
$V_{evaporator}$ from application
$A_{evaporator}$ from application
PF from Summary of Variables and Data Sources table
$W_{compressor} = V_{compressor} \times A_{compressor} \times PF = 230 \times 28.2 \times 0.85 = 5{,}513$ W
$W_{compressor}$ equation from 'where' section
$V_{compressor}$ from application
$A_{compressor}$ from application
$W_{condensor} = V_{condensor} \times A_{condensor} \times PF = 230 \times 2.4 \times 0.85 = 469$ W
$W_{condensor}$ equation from 'where' section
$V_{condensor}$ from application
$A_{condensor}$ from application
ESF = 0.3 from Summary of Variables and Data Sources table
LF = 0.9 from Summary of Variables and Data Sources table
$hrs_{cooling} = 600$, from application
$W_{heating} = 0$, from application
$W_{blowerfan} = 2{,}250$, from application
$hrs_{fan} = hrs - (hrs_{cooling} + hrs_{heating}) = 3{,}700 - (600 + 1{,}600) = 1{,}500$
hrs from application
$hrs_{heating}$ from application
CF = 0.69, from Summary of Variables and Data Sources table
$kBtu/h_{in} = 150$, from application

$$\Delta kWh_{cooling} = 1 \times \frac{(8{,}328 \times 0.3)}{1{,}000} \times 0.9 \times 600 = 1{,}349\ kWh$$

$$\Delta kWh_{fan} = 1 \times \frac{(2{,}250 \times 0.3)}{1{,}000} \times 0.9 \times 1{,}500 = 911\ kWh$$

$$\Delta kWh = 1{,}349 + 0 + 911 = 2{,}260\ kWh$$

$$\Delta kW = 1 \times \frac{(8{,}328 \times 0.3)}{1{,}000} \times 0.9 \times 0.69 = 1.55\ kW$$

$$\Delta MMBtu = 1 \times \frac{(150 \times 0.3)}{1{,}000} \times 0.9 \times 1{,}600 = 64.8\ MMBtu$$

Effective Useful Life (EUL)

See Appendix P.

Ancillary Fossil Fuel Savings Impacts

HVAC circulation fans with adaptive photonic controlled AC motors generate less heat during operation, resulting in decreased cooling loads and increased heating loads. These effects are captured in the prescribed methodology detailed above. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

Ancillary Electric Savings Impacts

HVAC circulation fan with adaptive photonic controlled AC motors generate less heat during operation, resulting in decreased cooling loads and increased heating loads. These effects are captured in the prescribed methodology detailed above. The HVAC interaction factors calculated from the prototypical building DOE-2 models as a function of the building and HVAC system type are shown in Appendix D.

References

1. A novel switched reluctance motor drive with optical graphical programming technology, Clarkson University, P. Pillay; Yaguang Liu; O.G. Durham, IEEE Transactions on Industrial Electronics (Volume: 47, Issue: 4, Aug 2000).
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