Technology Focus

An update on technologies for energy and resource management prepared by the New Technology Demonstration Program

Duty Cycling Controllers Revisited

A look at energy management controllers and their Federal sector potential

Introduction

The primary objective of this Technology Focus is to provide an overview of the results of a study (see Reference 1) that was conducted to evaluate recent offerings of products that belong to the class of energy management controllers known as "duty cyclers" or "cyclers," and to determine if there is significant potential for this technology in Federal facilities. Appendix A contains an overview of the findings from the study.

The duty cycling technique evolved from demand side management (DSM) and energy conservation technology developments explored in the 1970s and 80s, where the primary goal was peak load reduction. A secondary claim was that these controllers produced a reduction in energy use by cycling equipment off for various periods of time and under certain conditions, and appears to have evolved from the notion that when equipment is off it is not using energy. In fact, the use of duty cyclers for energy savings was a controversial subject that ultimately became the focus of a Federal Trade Commission investigation [2] about unreasonable claims made by some of the manufacturers at that time. The use of duty cycling for the purpose of reducing energy consumption subsequently fell out of favor for about a decade. However, duty cycling continues to be used extensively for load shifting and peak demand curtailment by utilities under DSM direct load control programs.

Although duty cycling is still offered in various energy management system products and utility direct load control programs, the focus of this study was on standalone controllers suitable for retrofit to existing installations of residential and light commercial unitary heating and cooling equipment for the purpose of saving energy.

Technology Description

Duty cycling means to change or control the duty cycle (i.e., the ratio of on-period to total cycle time) of on/off controlled equipment (generally, unitary air conditioners and furnaces). In the past, a variety of methods were used to implement duty cycling on heating and cooling equipment. These ranged from simple fixed-time-based strategies to sophisticated optimization methods. In all of these methods it is ultimately the off-period that is either fixed or adjusted in either a given reference period (typically 15 or 30 minutes), or dynamically based on temperature measurements. This results in the imposition of an equipment duty cycle that is primarily under the control of the cycler; i.e., it overrides the "natural" duty cycle of the thermostat. In most cases the circulating fan is controlled by the thermostat so it would be cycled off only when the thermostat was satisfied (unless set at the "on" or continuous circulation fan setting). While recent versions of these controllers implement duty cycling in a slightly different way (e.g., use rate of change of return air temperature) than in the past, the net effect on operation is the same.

Potential of Applications

Although there are no significant performance benefits from duty cycling when a comparison is made at equivalent load conditions, if duty cycling is judiciously applied so that the comfort impacts are tolerable or unnoticed (e.g., hotel room or residence where occupants are gone most of the day), then both energy and demand savings may be achieved. Direct load control studies have shown that comfort can be compromised to some extent without upsetting the occupants (especially if they are being compensated for it).

Disregarding whether or not there are other more cost effective means to attain the same benefits that duty cycling controllers offer (e.g., much the same result can be attained by simply lowering the thermostat setpoint), it appears that these controllers are best utilized in the following situations:

- All situations where comfort impacts can be tolerated or are unnoticed.
- Large open architecture retail and offices where multiple units operate such that duty cycling of one unit is made up by fully loading another and discomfort of one unit is made up partially by another.
- Where demand charges are a significant part of energy costs.

Limitations

The following precautions and limitations should be born in mind when these controllers are being considered for use:

- Check first to see that existing controls are maintained, are adjusted correctly, and operating properly.
- Apply duty cycling only after a thorough analysis has been made of the operational and comfort needs of the prospective building occupants. Find out which times of the day or year comfort can be compromised so that it can be tolerated or go unnoticed.
- Avoid assumptions about energy savings based on operation in other facilities that may or may not reflect the application in question.
- Avoid making estimates of annual savings based on limited test data and testing done without metered energy input. Beware of "apples-to-oranges" performance claims that equate changes in duty cycle to efficiency improvements.
- Avoid in situations where tight comfort conditions are required.
- Avoid use with undersized equipment; capacity will be further reduced such that the comfort will be significantly impaired even on non-peak days.
- Avoid high humidity cooling applications.
- Avoid use on older, natural draft heating equipment.
- Consider alternative, less expensive controls solutions.

Federal Sector Potential

The outlook for this technology as a means of saving energy in Federal facilities is mixed for the following reasons:

- Testing is based on limited data so that results to date are inconclusive.
- Product literature does not present an adequate thermodynamic explanation about how energy savings are derived.
- Past studies of similar technology concluded that duty cycling for air conditioning and furnaces results in little or no energy savings.
- The limited use of this technique in the private sector as a means of saving energy attests to its lack of endorsement by the HVAC controls industry. Current vendors for these products appear to be limited to two who market primarily to the Federal sector.
- Simple time or adaptive strategies are widely accepted in utility DSM/direct load control programs for their effectiveness in shifting peak demand, although no energy savings are expected.

As an energy saving technique for Federal facilities, these controllers should be used only under certain circumstances (see Limitations above) and with caution until performance can be verified.

Costs

Current listed unit prices for commercial controllers marketed as energy savers are in the range of $500 to $2200, not including installation. Duty cyclers used for peak load control are near $100. Since the performance improvement at constant load has not been proven, the cost effectiveness of commercial energy saver controllers is questionable.

Summary and Conclusions

There is a common thread in all of the duty cycling studies conducted to date. Independent of how duty cycling is implemented, and whether a particular implementation increases or decreases cycling rate, the technique always results in a lowered duty cycle (i.e., less on-time per cycle) and energy output of the equipment. Although more sophisticated in implementation, newer controllers accomplish basically the same result as those of the past.

Extensive research and testing was conducted on these types of controls in the past. A review of the studies and recent product literature and test reports on the use of these controls with unitary heating and cooling equipment supports the following conclusions:

1. There are no significant energy savings to be derived from duty cycling technology if constant load and comfort conditions are maintained.
2. Duty cycling always results in a change in operating point characterized by reduced output (which in turn produces a corresponding reduction in energy consumption).
3. Performance of new versions of these controllers does not appear to be significantly different from past versions.
4. More recent test results for new versions of these controllers are not adequate to verify manufacturers' claims for energy savings at constant output so performance is, at best, inconclusive.

Appendix A: Technology Description & Performance

A number of studies (see citations listed in Reference 1) document the results of field and laboratory testing conducted to determine energy savings associated with duty cycling. Two noteworthy papers present an overview and analysis of many of the studies relevant to this subject. Goldschmidt [3] reviews (and refutes the results of) a number of the duty cycling performance studies that were conducted in the 1980s. Likewise, Greenberg [4] reported that, overall, the studies were either inconclusive or showed negligible savings. Two additional studies definitively document that duty cycling results in negligible savings for unitary heating (Wise and Kweller [5]) and cooling (Mulroy [6]) equipment.

Recent vendor sponsored testing was, likewise, found to be inconclusive for the following reasons:

1. Test data is limited and samples are not large or complete enough so that before and after performance at equivalent load conditions can be compared via statistical analysis.
2. Tests conducted over short periods of time have been used to extrapolate to annual performance. Accurate annual performance cannot be computed without employing performance vs. load profiles for duty cycling.
3. Explanations in product literature for performance improvements are misleading or inadequate in terms of their thermodynamic basis.

Product literature and manufacturers test reports, both past and present, indicate annual savings in the range of 15% to 40% using duty cycling products. To explain these savings, it has been claimed that duty cycling saves energy by interrupting the thermostatic call cycles to periodically recover or "harvest" stored energy and to deliver it to the space via the continued operation of the circulating fan. Other explanations have been offered based on improvements in heat transfer and reduced losses associated with lower (heating) or higher (cooling) temperatures. For boilers, savings are purported to be derived from longer but less frequent on-periods that result from the imposed lengthened off-periods.

In virtually all research studies, and the manufacturers' test reports, it is clear that all duty cycling techniques result in lowered output (and thus potentially lower input energy) relative to normal control. It is the misunderstanding (and misrepresentation) of this fact that creates considerable confusion about the efficacy of duty cycling.

Appendix B: Vendors

Based on the results of the vendor search, the following appear to be the major manufacturers of duty cycling controllers for the purposes indicated.

Energy Savings

The Pentech Companies
6048 Cornerstone Court West,
Suite A
San Diego, CA 92121
619-550-8228

Microtherm, Inc.
1929 18th St. NW, Suite 1132
Washington, DC 20009
202-588-2201

Peak Load Curtailment

Dencor
1450 West Evans
Denver, CO 80223
303-922-1888

RELM Communications, Inc.
7707 Records St.
Indianapolis, IN 46226
317-545-4281

Scientific Atlanta, Inc.
4261 Communications Dr.
Norcross, GA 30093
770-903-5000

Appendix C: References

1. T.L. Webster and P. Benenson, "Technology Assessment Report: Duty Cycling Controllers Revisited," LBNL Report 41754, Lawrence Berkeley National Laboratory, 1999.
2. "FTC Alleges Duty Cycler Marketers are Making Fake Claims," Air Conditioning, Heating and Refrigeration News, December 23, 1985, p. 1.
3. V.W. Goldschmidt, "On the use of Duty Cyclers in Residential HVAC Systems," ASHRAE Proceedings, # NY 87-19-2, ASHRAE, Atlanta, 1987.
4. S. Greenberg, "Duty Cyclers for Furnaces and Air Conditioners: Energy Savers or Energy Wasters?," Energy Auditor & Retrofitter, May/June 1987, p. 25.
5. R.A. Wise and E.R. Kweller, "Part-load, Seasonal Efficiency Test Procedure Evaluation of Furnace Cycle Controllers," ASHRAE Proceedings, #PO-86-13 No. 3, ASHRAE, Atlanta, 1986.
6. W.J. Mulroy, "The Effect of Short Cycling and Fan Delay on the Efficiency of a Modified Residential Heat Pump," ASHRAE Proceedings, #SF-86-17 No. 1, ASHRAE, Atlanta, 1986.

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