

Persistence Tracking in a Retro-commissioning Program

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Synopsis

The persistence of energy savings and electrical demand reductions created by retro-commissioning programs can easily be eroded if the beneficial changes are reversed or eliminated by building operators or by service personnel. This happens most often when tenants complain about space temperatures or air flows, and operators look for a quick fix without adequately investigating the extent of the problems or fully understanding what may be causing them. These situations were anticipated when a utility retro-commissioning program was planned and a persistence tracking activity was developed to improve the persistence of savings. Persistence tracking is rarely done in utility-sponsored retro-commissioning programs. Monitoring for retro-commissioning has traditionally been accomplished by portable equipment for short-term monitoring or by utilizing the trending function of the building automation system (BAS). Disadvantages of these approaches include memory and downloading limitations for portable monitoring equipment and that fact that BAS trends reside in the same system that the building operator uses to control the building, resulting in trends that may be unintentionally or intentionally deleted. Neither of these methods is suitable for reliable, long-term persistence tracking.

A data acquisition approach has been developed for persistence tracking and implemented on two buildings participating in the utility retro-commissioning program. This system utilizes the same sensors and calculations of the BAS, but the control points are temporarily stored and automatically archived to a remote site through the Internet on a daily basis for future analysis. This paper discusses the persistence tracking equipment and methods that have been implemented in the utility retro-commissioning program. Preliminary results of the persistence tracking are presented, reasons why some measures have not held over time are discussed, and challenges that arose in implementing the tracking system are noted.

About the Author

Mike Eardley, P.E. holds a B.S. and M.S. in engineering and is a member of Architectural Energy Corporation's building commissioning team. His background in HVAC design engineering led to his current work in building systems commissioning, with representative commissioning projects including office building, university, military, mixed-use, and tenant fit-out. System types commissioned include ground source heat pump, underfloor air distribution, building envelope, and daylight dimming. In addition to his commissioning work, Mr. Eardley also serves as project manager for Architectural Energy Corporation's multiple sustainable design services on projects, which include measurement and verification, energy modeling, and daylighting analysis. He is currently exploring automated fault detection and diagnostics as a means of ensuring the persistence of energy savings and maintained system functionality.

Retro-commissioning and Persistence

Retro-commissioning of building heating, ventilating and air-conditioning (HVAC) systems is a proven benefit to existing buildings, both from an energy savings and maintenance perspective. If a building has not been initially commissioned, control sequences that have not been correctly implemented or mechanical components that are not fully functional are more likely than in a building that has had its mechanical systems fully commissioned. For building HVAC systems that have never been commissioned, retro-commissioning can be very beneficial to the building operator and owner.

Retro-commissioning Purpose

Retro-commissioning involves a detailed study of building system operation. Faults in building systems are identified for resolution (e.g. fans not operating according to schedule, inoperable or leaky valves/dampers) and control changes may be recommended that increase energy efficiency, such as changes in system setpoints or operating schedules. Retro-commissioning reports often include economic analysis that calculates energy savings. A simple payback may be determined by comparing calculated energy savings to the estimated cost of implementing the recommended measure. This simple payback calculation is often used to rank which measures from the retro-commissioning report to implement.

Value of Persistence

A vital piece that is missing from the traditional retro-commissioning practice is the follow-up of building operation to verify that accepted measures have been maintained. Persistence tracking is defined here as the verification that accepted retro-commissioning measures have been correctly implemented, and continue to hold over time. This verification ensures persistence in energy savings and other anticipated benefits over future operation of the building.

Short term monitoring of building system operation has traditionally been performed for retro-commissioning follow-up (as well as new building commissioning) using portable data logger equipment or the trending function of the building automation system (BAS). This type of monitoring is typically done over a matter of weeks, because of limited data logger memory and the fact that trending the BAS may conflict with normal building operation. What is desired for persistence tracking is a continuous monitoring system that will identify deviation from recommended measures, and do so in a minimally invasive way that will not require continual site visits or affect building operation.

If a measure has not held over time, it is likely that either implementation was not understood or the building operator made a conscious decision to abandon that measure. Persistence tracking will identify when measures have not held over a substantial period of time. Issues may then be brought back to the building owner to determine the reason that measures have not been maintained.

Benefits of persistence tracking include:

- Verifying that building operation indicates retro-commissioning measures have been correctly implemented
- Verifying that anticipated savings continue over time and are not overridden by changes in building control, schedule changes, or other building maintenance
- Ensuring that measures are compatible with actual building operation (do modified setpoints allow comfort conditions to be maintained?)

Utility Retro-commissioning Program

A utility retro-commissioning program offered incentives and technical assistance to building owners for retro-commissioning services. Different phases of this program included:

- Preliminary scoping of a building to determine the potential for energy savings
- In-depth retro-commissioning investigation
- Assistance for implementation of favorable retro-commissioning measures

Two buildings (referred to here as Building 1 and Building 2) participated in the utility retro-commissioning program and retro-commissioning reports were created that demonstrated savings if measures were implemented. These buildings were also selected to participate in persistence tracking, to ensure that accepted energy saving measures remain in place.

Building Descriptions

In order to verify the persistence of energy saving measures, the HVAC system at each building has been monitored. Each building has central hot water heating, chilled water cooling, evaporative condensing plant, and central air handling units. Both buildings are also equipped with a central BAS.

Building 1

Building 1 is a ~400,000 square foot, 20-story office building. The HVAC system is composed of one 3600 MBH gas-fired hot water boiler, one chiller at 550 tons, one chiller at 525 tons, and one cooling tower rated at 785 tons. A flat plate heat exchanger is provided for chilled water economizer when outside air conditions are cool. The air handling system consists of one hot deck fan and one cold deck fan per floor. Each fan is provided with the associated heating/cooling coil.

Building 2

Building 2 is a ~600,000 square foot, 30-story office building. The HVAC system is composed of two 2400 MBH gas-fired hot water boilers, two chillers at 550 tons, and one cooling tower rated at 1220 tons. Four variable air volume air handling units serve multiple floors.

Recommended Measures

Measures from the respective retro-commissioning reports were accepted for implementation in these buildings. The majority of measures involve programming changes to the sequences of operation at the BAS. These measures and the air handling unit (AHU) affected are summarized below.

Building 1

- Revise lobby AHU cold deck fan schedule from 24/7 operation to an occupied start/stop
- Reduce all AHU cold deck static pressure setpoints from 0.9 in.wg. (inches water gauge) to 0.6 in.wg.
- Change cold deck supply temperature setpoint from variable 55°F-70°F to 50°F on digitally controlled floors and 55°F on pneumatically controlled floors
- Modify free chilled water cooling schedule so that mechanical cooling is enabled before chilled water system is too far out of range, which has resulted in electrical demand spikes
- Reduce chiller plant condenser water supply temperature setpoint from 75°F to 60°F

Building 2

- Correct unbalanced cooling tower water distribution, which has caused a portion of the tower media to dry out and reduced evaporative cooling efficiency
- Change chiller sequencing from parallel operation to serial operation
- Reduce chiller plant condenser water supply temperature setpoint from 70°F to 60°F
- Increase chilled water supply temperature setpoint from 40°F to 45°F
- Tune chilled water valve control on one of four AHUs to prevent excessive cycling
- Reset supply air static pressure setpoint based on fan speed for one of four AHUs

Persistence Tracking System

The utility retro-commissioning program elected to follow-up measure implementation with persistence tracking. The method of persistence tracking presented here is automatic archival of BAS control points for future analysis. A tracking system was installed at both Building 1 and Building 2. This tracking system communicates with the BAS to create a continually updated database of control point data, beginning when the system was installed. Using this archived history of control point data, determining whether or not measures have held over time can be done by inspection.

Approach

The persistence tracking system is composed of building controls equipment that continuously polls the BAS at each building, temporarily storing the multiple control points required to verify measure implementation. The tracking equipment stores one day's worth of control point data (in 5-minute intervals). Once per day this control point data is transferred via the Internet to a remote server, where the historical data is stored for future analysis. In this way the tracking system continuously monitors the BAS while providing an archive that is separate from each BAS. The trending is not subject to deletion or termination by anybody else interfacing with the BAS. Memory limitations are not a concern at the server where historical data is stored. Figure A shows a representation of the different components in this system.

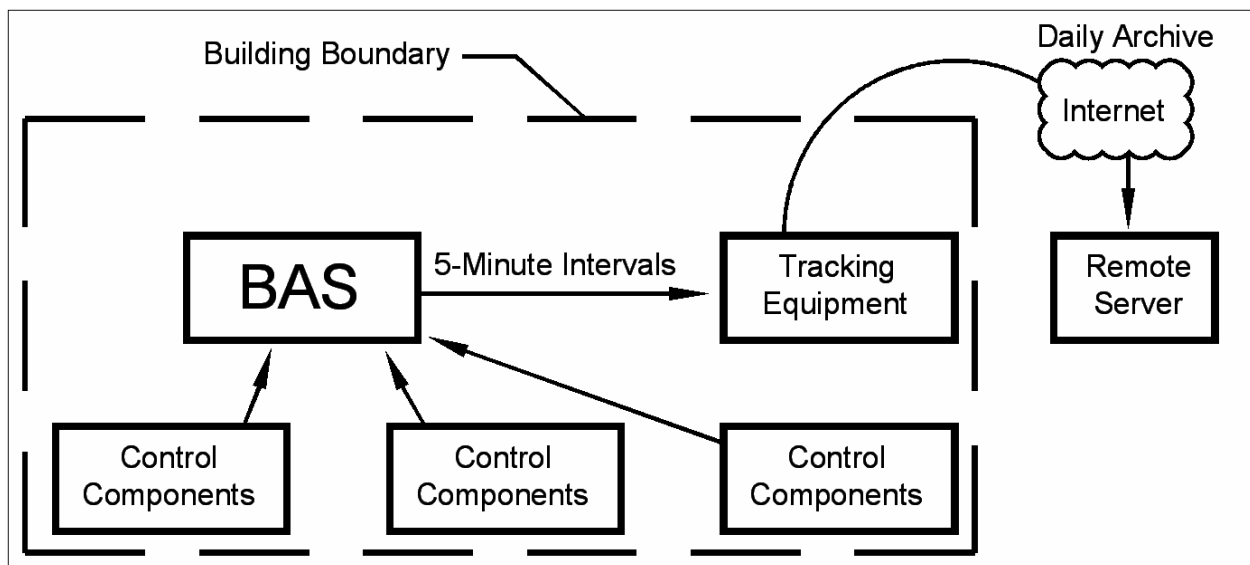


Figure A: Persistence Tracking System Diagram

Challenges and Lessons Learned

Once initialized, this tracking system has data archived on a daily basis, creating a history of building operation data. However, system setup has proved challenging. Issues that have delayed the initiation of tracking include:

- Coordinating with multiple parties in building controls maintenance to provide the necessary access, passwords, and firewall workarounds to allow outside communication with the BAS
- Unintentional resetting of some setpoints at the BAS during tracking, due to a higher priority designation of the control points residing on the tracking equipment
- A perceived conflict in communication at the BAS due to the tracking equipment, resulting in expected schedules failing to initiate

During this case study, this last issue as been discussed at length. Controllability issues (such as AHUs not shutting down according to schedule or free chilled water cooling mode not initiating)

would be identified by building maintenance personnel. At this time, the tracking equipment would be disconnected and the building controller reset. It is not clear if it was resetting the building controller that corrected the problem, whether the tracking equipment was causing communication issues, or some programming was done at the BAS to fix a separate problem that was the cause of the issue. Regardless, once the tracking system was disconnected, the remote connection to the equipment was lost as well and no remote diagnosis was possible. Ongoing coordination between all parties involved finally resolved these issues and allowed for continuous monitoring.

Tracking Results

Persistence of the recommended retro-commissioning measures has been verified by inspection of data archived using the tracking system. This analysis process is not calculation intensive, but is simply comparing expected BAS data (duct static pressure, supply air temperature, etc.) to actual building data. If the values of the associated control points for a measure are outside the expected range, the measure has not held over time. The results presented in this paper cover the time periods of 1/3/07-3/2/07 for Building 1 and 1/24/07-3/2/07 for Building 2. Verification of maintained energy saving measures is presented below.

Persistence of Energy Saving Measures

Table 1 and Table 2 summarize whether or not each measure has held over the observed period.

Table 1: Building 1 Measure Tracking

Measure	Measure held?	
	Yes	No
Revise lobby AHU schedule	√	
Revise AHU cold deck pressure setpoint		√
Revise AHU cold deck temperature setpoint		√
Revise free chilled water cooling schedule		√
Reduce chiller plant condenser water setpoint		√

Table 2: Building 2 Measure Tracking

Measure	Measure held?	
	Yes	No
Correct uneven cooling tower flow	√	
Sequence chillers for serial operation	√	
Reduce chiller plant condenser water setpoint	√	
Increase chiller plant supply temperature setpoint		√
Reduce AHU-1 chilled water valve cycling		√
Implement AHU-4 duct static pressure reset		√

Measures Held

Measures that have held were verified as follows:

- Building 1 lobby AHU shows fan operation during occupied hours only
- Building 2 condenser water temperature difference between inlet and outlet is constant for a given outside air wet bulb temperature
- Building 2 secondary chiller is observed to operate only at the beginning or ending of primary chiller operation, indicating serial scheduling
- Building 2 condenser water supply temperature is observed to fall to as low as 60°F during cooling tower operation, as recommended

Measures Not Held

Table 3 shows the results of tracking for the recommended cold deck static pressure reset at Building 1. The retro-commissioning report recommends that the duct pressure setpoint be 0.6 in.wg. This has been determined to provide insufficient airflow to satisfy some zone temperature setpoints and has been overridden in some cases.

Table 3: Building 1 – Cold Deck Static Pressure Setpoint

Unit	Maximum Pressure Setpoint (in. wc.)	% Time Above Recommendation
AHU-2	1.0	14%
AHU-6	1.2	56%
AHU-7	1.2	56%
AHU-10	0.9	70%
AHU-11	1.0	79%
AHU-13	1.0	9%
AHU-14	1.0	100%
AHU-15	0.9	59%
AHU-16	1.5	77%
AHU-17	0.9	78%
AHU-19	1.5	20%
AHU-20	1.5	94%

For 12 out of 20 AHUs observed the static pressure setpoint has been increased at some point during the observed period, to as high as 1.5 in.wg. in some cases. This results in a reduction of energy savings assumed in the retro-commissioning report, but has been viewed as necessary by the building operator in order to meet zone setpoint.

Figure B shows how Building 2 chilled water supply temperature setpoint varies during chiller operation. The retro-commissioning report recommends that the setpoint be a constant 45°F.

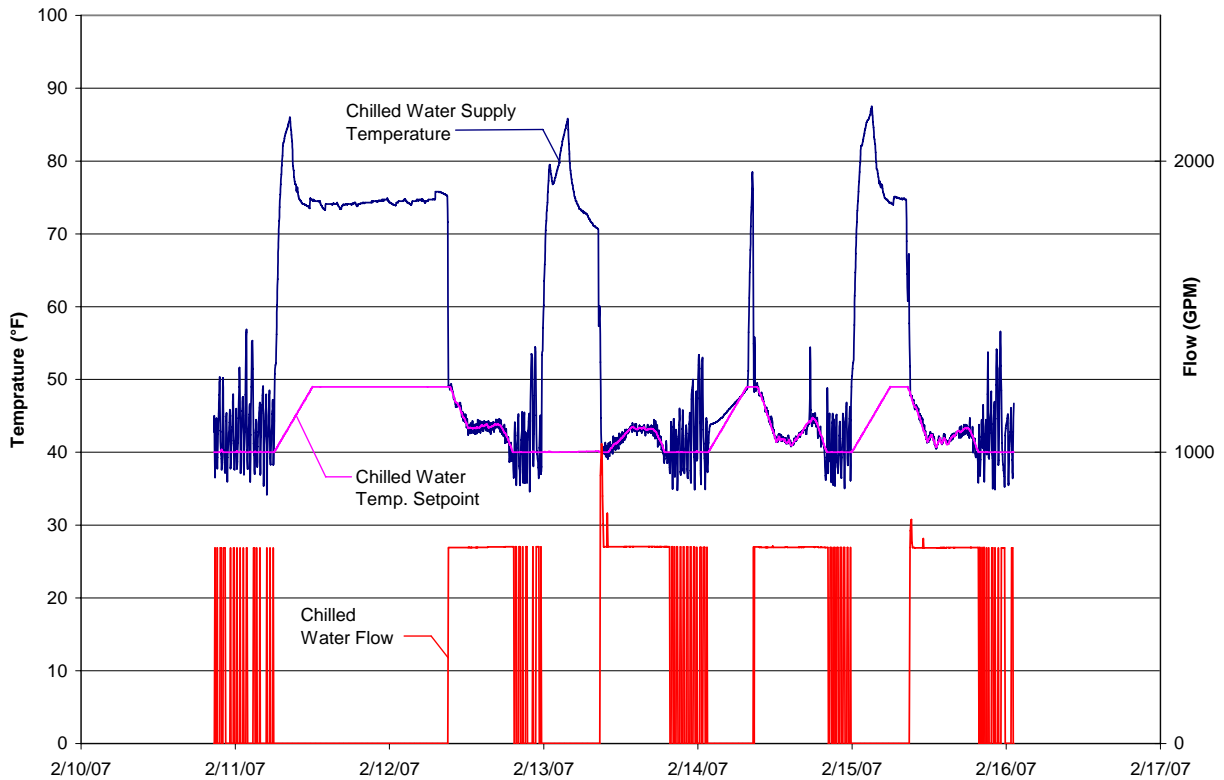


Figure B: Building 2 – Chilled Water Supply Temperature

During chiller operation, the chilled water supply temperature resets between 40°F and 49°F. A reset strategy (although not mentioned in the retro-commissioning report) would be favorable for mechanical cooling energy savings. However the reset schedule provides chilled water as low as 40°F, which has been noted in the retro-commissioning report to be unfavorable from an energy perspective.

Figure C shows the tracking results for chilled water cycling in one AHU at Building 2. Chilled water cycling may go unnoticed by building operators as this condition will not necessarily result in comfort complaints and setpoints may still be maintained. However, excessive valve cycling results in system instability and may increase the maintenance required for valve and/or actuator.

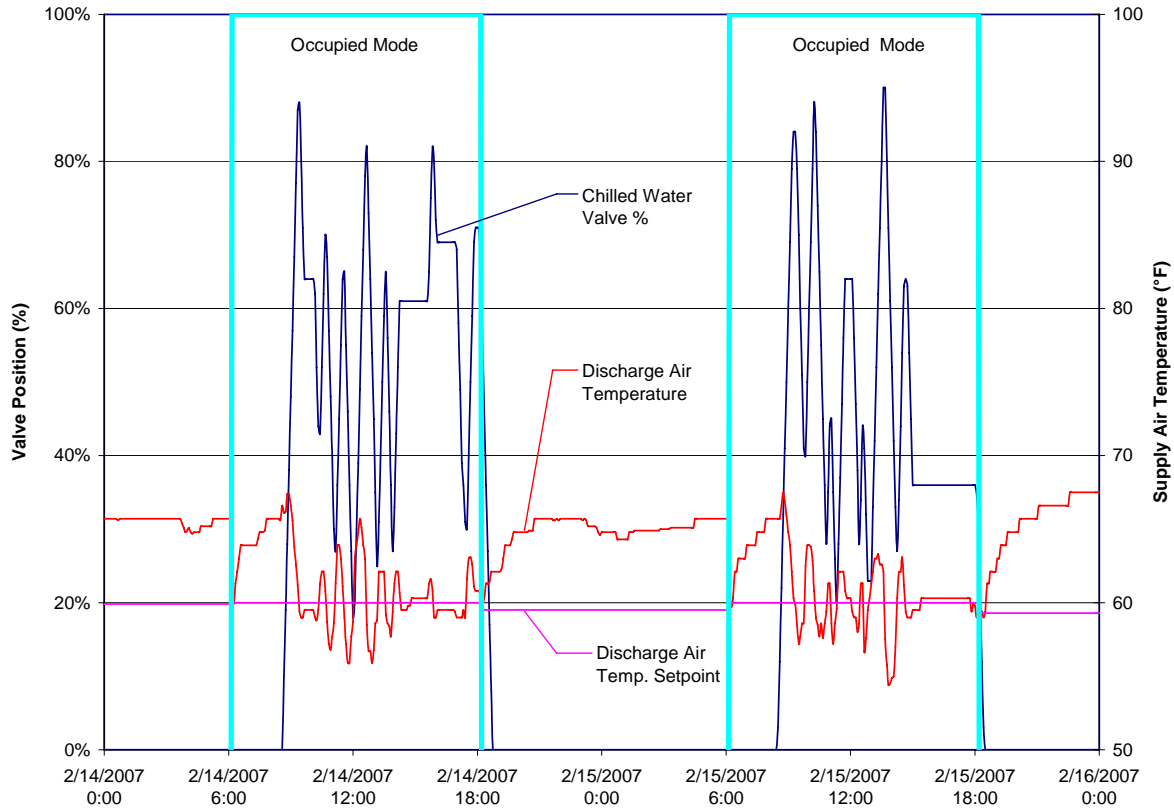


Figure C: Building 2 – Chilled Water Valve Cycling

This chilled water valve modulates excessively between 20% and 80%, resulting in a supply air temperature that modulates excessively as well. A finely tuned control algorithm should maintain a relatively constant chilled water control signal around 50% during this period with slight modulation. This would eliminate overshooting of valve position and supply air temperature.

A summary of other measures that have not held are as follows:

- Building 1 AHU cold deck supply temperature setpoint is observed to reset between 55°F and 65°F, instead of the constant 50°F or 55°F setpoint recommended.
- Building 1 AHU chilled water valve position is observed to go full open consistently during free chilled water cooling. This indicates insufficient cooling from the chilled water system, resulting in chilled water loop temperature being out of range and a demand spike in mechanical cooling when chillers are enabled.
- Building 1 condenser water temperature setpoint is observed to remain constant at 75°F instead of the recommended 60°F.
- Duct static pressure setpoint at a particular AHU in Building 2 is observed to remain constant, instead of the reset strategy recommended based on fan speed.

Overall, many measures in this study have not been maintained over time. Without follow-up study of a building to determine if measures are maintained, whether or not calculated savings

persist year after year is unknown. Payback periods will be affected and anticipated annual savings will not be realized if measures are not maintained. Ideally, follow-up will not be a snapshot of building operation, but will be continuous and extend over a long period of time. The persistence tracking system described here accomplishes these goals by archiving building control data in 5-minute intervals and storing data remote from the BAS. Once this archive is created, verification of recommended measures is simply a matter of inspection to compare expected and actual operation.

Conclusions

There is great potential for energy savings and operational improvement in the existing building market. Detailed study is required to identify the areas with the greatest potential impact. The identified measures, if implemented, will reduce operational cost and may have very attractive payback periods. However, follow-up is required to verify that measures have been correctly implemented, and that measures have held over time. Ideally, monitoring will be continuous and extend over a substantial period of time (more than a few weeks). This will ensure the persistence of savings anticipated when the recommendations from retro-commissioning study are accepted.

The tracking system presented in this paper meets these desired traits, in that it provides continuous monitoring and is in place for the long term. Although less than two months of preliminary results of the tracking are presented here, this system is continuously archiving data and may continue to do so indefinitely. Access to data is not limited by installing and retrieving data loggers or setting up and downloading trends at the BAS. Data from this tracking system is available by connecting to a remote server (separate from the BAS) via the Internet and control point histories are available from the date that tracking began.

As shown in the case study presented, over half the measures at two buildings studied have been shown here to not hold during the observed period. This is not thought to be an uncommon scenario after retro-commissioning study and measure implementation, which is why the utility retro-commissioning program has elected to undertake persistence tracking. Further study of additional buildings will confirm the energy savings that have been realized by building owners over time. Continuous, long term tracking systems like the one presented in this paper will allow this analysis to take place.