

Continuous Commissioning Through an Operations and Maintenance Contract

Jonathan Soper, P.E.

Enovity, Inc.

Synopsis

Every facility regardless of size or complexity requires the services of an operations and maintenance (O&M) contractor. The basic scope of an operations and maintenance contract includes responding to the every day needs of building occupants, keeping building systems operational and maintaining the electrical, mechanical, structural and architectural components that make up the facility. Larger facilities will have technicians on site full time while smaller facilities may have crews that respond on an as-needed basis. In many instances the O&M contractor restricts themselves to performing the basic tasks of service call response, keeping systems operational, minor equipment repairs and preventative maintenance. Professional engineering and commissioning services, larger repair projects and facility infrastructure projects are normally handled by entities other than the O&M contractor. The O&M contractor is often consulted on larger project work, but most times does not play a major role. The O&M contractor or building owner will also usually call in outside consultants or engineers to help troubleshoot and optimize systems. The O&M contractor is however the party that is most familiar with a facility and is in a great position to perform a much more active role in all aspects of a facility's operation including design assistance, commissioning, general contractor, energy consultant and project manager. This paper describes a much more comprehensive role for the O&M contractor and through a real example at the Phillip Burton Federal building in San Francisco shows how an empowered O&M contractor with the right skill sets on staff can really improve the operation of a facility. The paper describes how the O&M contractor has taken a pro-active role in retrocommissioning, continuous commissioning and in the implementation of ongoing facility upgrade projects.

About the Author

Jonathan Soper, P.E. is co-principal and co-founder of Enovity, Inc., a San Francisco-based commissioning and energy engineering firm and provider of operations, maintenance and repair (OM&R) services to the Federal Government. The firm is a leading provider of new building commissioning, retro-commissioning and continuous commissioning services. Recent commissioning work has focused on projects for federal and local government, university campuses and private sectors.

Mr. Soper has given professional seminars on a diverse range of topics related to commissioning, operations and maintenance topics and energy evaluations, throughout his more than 13 years of experience in the construction industry. He is a member of ASHRAE. Enovity is a member of the Building Commissioning Association.

Background

Enovity, Inc. was awarded a full service operations and maintenance contract for the Phillip Burton building in January 2004. The Phillip Burton building is a 1.4 million sq. ft facility with twenty floors and two basement levels. It is the largest federal building west of the Mississippi and is the General Services Administration (GSA) Region 9 Headquarters building. Enovity staffs the building with thirteen full time stationary engineers, electricians, maintenance technicians and administration staff. Enovity is responsible for all of the electrical, HVAC, fire life safety, structural and architectural systems. The building has a primary 12.5 kV electrical supply with seven main substations. The HVAC systems include a central cooling plant with three centrifugal chillers and a primary variable flow chilled water loop, a central heating plant with three gas fired boilers and a primary variable flow hot water loop, eight large dual duct VAV air handlers serving over 1200 VAV boxes, and many smaller single zone and multi-zone air handlers and AC Units. The building's main control system is an Alerton Envision DDC Building Automation System (BAS). Three floors of VAV boxes have ALC Webctrl DDC control and the two DDC control systems are fully interoperable using the BACnet protocol.

Retrocommissioning Projects

About six months into the operations and contract Enovity began the process of retrocommissioning all the HVAC and controls systems in the building. Soon after award of the operations and maintenance contract the Chief Engineer and one of the stationary engineers were sent to be factory trained on the Alerton BAS. Enovity performs all controls work in house and no longer requires the services of the local controls contractor. Having qualified controls engineers on site means that controls related HVAC problems can be solved right away by qualified technicians and 'quick fixes', that often waste energy and result in less than optimal system operation, are minimized.

Enovity's professional mechanical engineers teamed with the Enovity technicians on site and conducted a thorough review of all the sequences of operation. The Building Tune Up program, managed by Quantum Consulting, provided the funding for this retrocommissioning effort. Facility Dynamics Engineering (FDE) had completed a retrocommissioning project prior to the start of Enovity's operations and maintenance contract and their findings provided valuable input into Enovity's retrocommissioning effort. A summary of the main projects completed during Enovity's retrocommissioning effort are as follows:

1. **Static Pressure and Temperature Reset on the Main Air Handlers:** The original sequence called for a constant static pressure setpoint on the eight main dual duct VAV air handlers. With no means to control static pressure independently on each deck a constant static pressure setpoint was causing over-pressurization of either the hot deck or cold deck. A customized static pressure and temperature reset sequence were programmed.
2. **Chiller Staging:** The chilled water plant has two 1050-ton chillers and one 550-ton chiller. The design sequence called for a small chiller as the lead then staged up to a large chiller and from there to two large chillers. The sequence was changed so that the plant staged from one large chiller to a large and a small

- chiller rather than two large chillers. This saved pump energy and also allowed the chillers to operate at better part load efficiencies.
3. **Return Fan Control:** The return fan VFDs were originally programmed to maintain a building static pressure setpoint; this sequence was causing unstable building static pressure and fan speeds were often too high. The sequence was changed to run the return fans at 80% of the supply fan speed. The new sequence has saved significant fan energy and stabilized building static pressure.
 4. **Economizer Controls on Smaller Air Handlers:** Many of the smaller single zone and multi-zone air handlers were found to have no air side economizer control. A standard integrated differential temperature economizer sequence was programmed for the all the single and multi-zone air handlers. Outside air supply and exhaust fans were installed in the Penthouse mechanical room to bring more cool outside air into the mechanical room and improve the economizer cycle on the air handlers.
 5. **Program Optimum Start:** An optimum start routine was programmed for all the building's eight (8) main dual duct air handlers.
 6. **Re-evaluate VAV Box Minimum Settings:** The turn down ratio of many of the building's 1200 VAV boxes was found to be high. A survey was performed of all the building zones and new minimum air flows were determined. The revised minimums were programmed into the VAV boxes.
 7. **Re-evaluate Schedules for Exhaust Fans:** Many of the building's smaller exhaust fans serving bathrooms and special purpose areas were found to be running 24/7. Separate schedules were set up for these fans.
 8. **Install CO Sensors for the Garage Exhaust Fans:** The garage exhaust fans were running 24/7. CO sensors were installed in the garage and VFDs installed on the fans. The VFD speed on the fans modulate to maintain CO levels below a fixed setpoint.

Enovity, as the O&M contractor was in the perfect position to both identify and implement the projects described above. Enovity was intimately familiar with the systems being commissioned and therefore in a good position to understand control strategies that could work. With trained controls engineers on staff at the building Enovity was able to fine tune new sequences over time and continuously evaluate them using trend data. Being the O&M contractor, contracting mechanisms for implementing projects with the owner were very straightforward and the work could be implemented and completed in a very timely and cost effective manner. Enovity's contractor's license and staff of professional engineers and on-site electricians and mechanics allowed for implementation through a design/build turnkey contract and it was one of the first retrocommissioning projects to be completed under the Quantum program.

The implementation of optimization strategies like the projects described above clearly results in energy savings and increased levels of building comfort. Retrocommissioning services targeted to HVAC systems' optimization and energy efficiency are now a proven strategy and retrocommissioning programs offered recently in California have resulted in significant energy savings. A recent measurement and evaluation (M&E) study titled: "Evaluation of Retrocommissioning Persistence in Large Commercial Buildings" by N.J. Bourassa, M.A. Piette, and N. Motege from the Lawrence Berkeley National Laboratory (LBNL) evaluated the persistence of energy savings for eight buildings that were retro-

commissioned as part of the Sacramento Municipal Utility District (SMUD) Retro-commissioning program. The study included both measure status and whole-building energy analysis. The energy analysis was conducted in three phases and included obtaining local weather data, producing weather normalized whole building energy consumption data and comparison of consumption data to a pre-retrocommissioning baseline year. The LBNL energy analysis showed an average whole-building electric energy savings of 7.3% per year for the eight buildings. The analysis also showed that the savings increased during years one and two as expected, since measures were implemented over time. After the second year, the savings flattened out and then degraded slightly in year four. LBNL concluded that their findings are similar to previous research suggesting that most of the savings persist beyond three-years. LBNL also stated that additional tools and methods are needed to allow building engineers and operators to obtain feedback on the ongoing performance of the building and retro-commissioning activities.

Continuous Commissioning Diagnostic Tools

Other than operator training and good documentation, there are rarely protocols in place to ensure that the energy efficiency measures (EEMs) identified and recommended during the retro-commissioning process remain implemented over time. For example, there is no reporting mechanism in place which would notify a building owner or operator when a recommended energy measure such as optimum start or supply air reset had been over-ridden. A continuous commissioning program can provide the necessary data to improve the persistence of implemented retro-commissioning measures as well as provide ongoing, monitoring-based retro-commissioning within the building, resulting in sustainable energy efficiency. Retrocommissioning may begin to degrade in time due to a variety of factors that include:

1. Inability of operation and maintenance (O&M) staff to continually monitor building performance and correct deficiencies as they arise;
2. Degradation and/or failure of equipment components and control devices;
3. Changes made to controls without regard to energy efficiency or design intent;
4. Attrition of O&M staff trained to ensure persistent energy savings;
5. Changing priorities of the building owner and O&M staff.

At the Phillip Burton Federal Building two continuous commissioning tools have been implemented. The first is the PACRAT (Performance and Re-commissioning Analysis Tool) diagnostic tool. PACRAT was developed by Facility Dynamics Engineering (FDE) and was the first comprehensive automated diagnostic tool for HVAC system performance. PACRAT is being used to diagnose operations of the main air handlers and chillers. The second is the Fault Detection and Diagnostic (FDD) Algorithm developed by National Institute for Standards and Technology (NIST). The FDD Algorithm is being used to diagnose problems with the building's 1200 VAV boxes. An agreement was made between Enovity and the building owner GSA to curtail regular VAV box annual maintenance and instead to run the FDD algorithm on all the VAV boxes so that problems could be identified as they happen rather than waiting for a scheduled PM.

PACRAT accesses trend data recorded on the Alerton Building Automation System (BAS). PACRAT captures the trend data, analyzes the data and produces an anomaly

report for any defined and independent system. At the Phillip Burton Building PACRAT is running on twelve (12) independent systems: the eight (8) main air handlers, each of the three (3) chillers and the chilled water distribution system. The anomaly reports are generated every quarter for each of the twelve systems. Through review of these anomaly reports Enovity works with Facility Dynamics to ensure that optimization strategies remain implemented. PACRAT also identifies new problems/failures as they happen which may include sensors out of calibration or failed, leaking valves, unstable control loops, excessive outside air or economizers not functioning and deviations from setpoint. An example printout of the 2005 4th quarter anomalies for one of the main dual duct air handlers; S20E1 is provided below.

| Fault Type | Fault Description | Sensor | Report Date | Anomaly Period |
|---------------------------------|---|---------|-------------|------------------------|
| Suspect Sensor Readings | The OA_Enth sensor was suspect from 10/2/2005 6:15:00 AM to 12/31/2005 11:45:00 PM 21% of the time. It showed an average value of 20.2. | OA_Enth | 1/3/2006 | 10/1/2005 - 12/31/2005 |
| Suspect Sensor Readings | The RA_Enth sensor was suspect from 10/1/2005 2:00:00 PM to 12/22/2005 7:00:00 AM 15% of the time. It showed an average value of 21.7. | RA_Enth | 1/3/2006 | 10/1/2005 - 12/31/2005 |
| Valve Leaking or Miscalibration | CC_VPct appears to be leaking. An average temperature difference of 2.4°F was sensed while it was closed and the unit was running. | CC_VPct | 1/3/2006 | 10/1/2005 - 12/31/2005 |

It was found that the enthalpy sensors needed to be replaced and that the temperature difference across the cooling coil was the result of an inaccurate mixed air temperature sensor.

The NIST FDD algorithm is embedded in the Alerton DDC code on the VAV box controller and can identify up to seven different faults that include unstable air flow, high or low space temperature and low air flow. The algorithm continuously monitors the VAV boxes and generates alarms in real time. A few examples of actual alarms and the resulting problem resolution are provided below.

| NIST Alarm Description | Problem Resolution |
|--|--|
| Nist Alarm Code : 12051 PV:40 Unstable hot deck airflow alarm, high hot deck airflow alarm | Hot deck actuator was not responding correctly, gearing inside actuator was bad, replaced actuator and observed operation |
| Nist Alarm Code : 7088 PV:64. High zone temperature alarm | MSK for LC 8/5/05 - Looking into air handler situation. MSK 8/5/05 Problems due to air handler program. Sequences being updated. |
| Nist Alarm Code : 11009 PV:4 Unstable cold deck airflow alarm | LC- lowered zero velocity cutoff to 2. operation is now stable at low cfms |

Enovity is now in the process of working with NIST to implement the FDD algorithm on some of the building's smaller air handlers.

Integration of Diagnostic Tools with a Computerized Maintenance Management System

The Phillip Burton Building is on the GSA Region 9 Government Energy and Maintenance Network (GEMnet). GEMnet is a web based application that provides a common Computerized Maintenance Management System (CMMS) called Maxweb. All the Region 9 (California, Nevada, Arizona & Hawaii) GSA buildings use the same web based CMMS which allows the GSA to keep track of preventative maintenance, service call and equipment repair work orders across all their buildings. GEMnet also serves up web pages for energy use and cost in Region 9 buildings and connects directly to the Building Automation Systems of several Region 9 buildings allowing for real time remote monitoring of a building's HVAC systems.

For the Phillip Burton building both PACRAT and the NIST FDD are integrated with the Maxweb CMMS program. When PACRAT produces a quarterly anomaly report a work order is generated on Maxweb. The work order tags the specific piece of equipment from the Maxweb database and lists the anomalies generated for that piece of equipment in the remarks section of the work order. The work order then remains open until the Enovity O&M staff has addressed each of the anomalies. When the NIST FDD generates a VAV box alarm a Maxweb work order is also generated. The work order identifies the VAV box and the type of fault; the work order remains open until an Enovity maintenance technician has resolved the VAV box problem.

Facility Upgrade Projects

Prior to the award of the operations and maintenance contract, Enovity principals were involved in several large HVAC, controls and electrical upgrade projects in the capacity of project manager and construction administrator and were therefore already very familiar with the building. At the start of the operations and maintenance contract Enovity developed a full project prospectus for additional facility upgrade projects which included project descriptions and budget costs. The GSA applied for funding and is now in the process of completing projects as funding becomes available. Enovity has provided design assistance, construction administration, commissioning and inspection services for all of the projects that have been completed to date. Enovity can also provide these services to the GSA at a very competitive rate because:

1. No time is needed to get up to speed with unfamiliar systems.
2. Enovity has staff on site and there is little or no travel time.
3. Enovity can leverage staff who are working on other activities in the building.

Examples of projects completed to date include:

Cooling Coil Replacement: All the cooling coils on the eight main dual duct air handlers were replaced. Enovity provided inspection and commissioning services and coordinated contractor activities.

Substation 7 Retrofit: Enovity was awarded the design contract for the reconfiguration of one of the main electrical substations; Enovity also commissioned the project. The re-configuration proved successful and now the GSA has decided to re-configure all the remaining electrical substations.

Elevator Standby Power: Enovity was awarded the design contract for the installation of new standby control power for the twenty five elevators in the building. Prior to this project none of the elevators would function on emergency power. Enovity recently completed the testing and commissioning of the project.

Fire Life Safety Upgrade: Enovity was asked to review the simplex fire life safety system and make recommendations for required upgrades. Enovity is generating as built drawings where the originals were found missing, networking individual panels, repairing the fireman’s override panel and developing a fire life system specification.

Improvements in Building Performance

The retrocommissioning, continuous commissioning and project work described above together with a rigorous preventative maintenance program has resulted in significantly lower energy costs, a more comfortable work environment and fewer tenant calls at the Phillip Burton Federal building. Figures 1 and 2 compare monthly electricity and gas consumption for Years 2004 and 2005. Electricity consumption was 18% lower for 2005 compared with 2004 and gas consumption was 15% lower. Figure 3 shows the number of service calls per month between May 2004 and December 2005 and illustrates that service calls from tenants have reduced significantly.

Figure 1 Monthly Electricity Consumption: Year 2004 compared to Year 2005

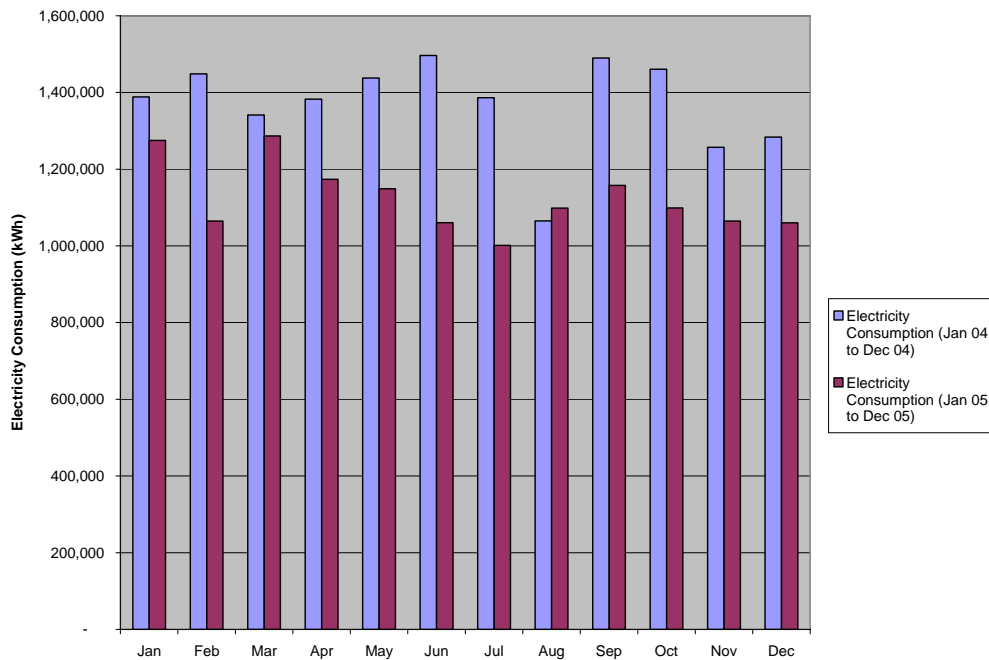


Figure 2 Monthly Gas Consumption: Year 2004 compared to Year 2005

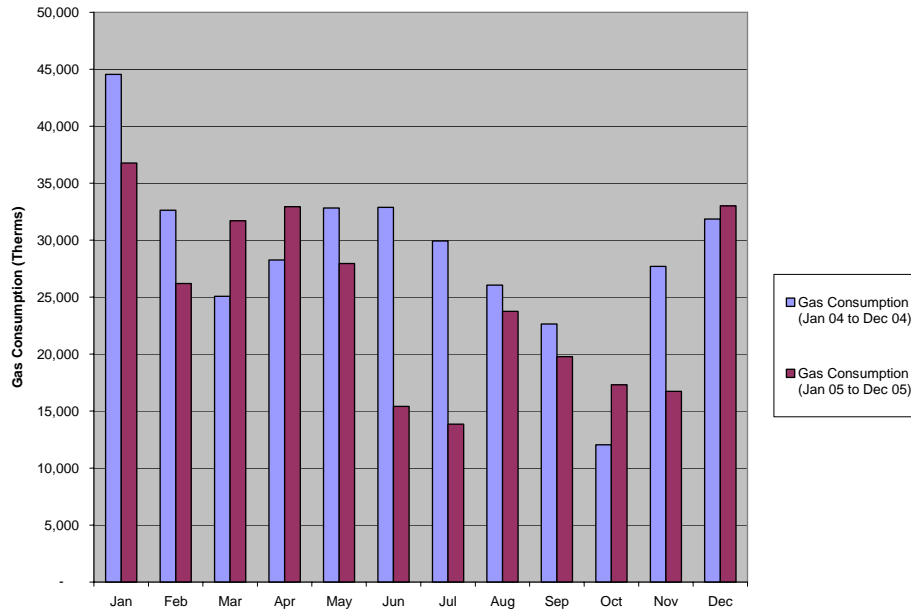
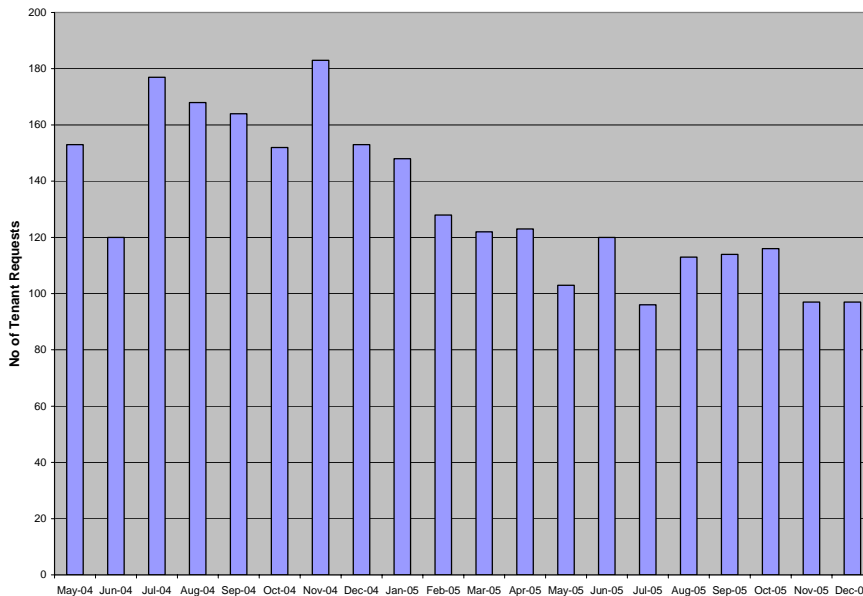


Figure 3 Monthly Service Calls May 2004 through December 2005



Future Projects

A comprehensive Square D PowerLogic electrical monitoring system was recently installed at the Phillip Burton building. The system includes over 50 sub-meters which measure the electrical load and status of all the 480 volt main feeder breakers. This allows for fault diagnosis when breakers trip and also enables the owner to keep track of different electrical loads in the building. Enovity is in the process of working with the owner to automate the generation of monthly energy reports. The monthly energy reports

will identify an energy breakdown for: lighting & plug loads, chillers, fan, pump and other motor loads and will identify exactly where night time and weekend electrical loads are being used. The more detailed energy data will help Enovity and the GSA to further reduce energy costs. The PowerLogic system will be integrated with the CMMS Maxweb program so that the energy reports can be served up on a web page each month.

Other energy projects that have been funded and are under way include the installation of a 500 kW co-generation plant, lighting upgrades on floors sub-basement through 5 from older generation T8 fixtures to new generation T8 fixtures and the replacement of all the old and leaking outside air dampers on the main air handlers. Enovity is actively involved in all of these new energy projects.

Conclusion

The business model described above for an operations and maintenance contract offers great benefits to the building owner. A pro-active and engaged O&M contractor with well trained technicians, professional engineers and project managers can provide the owner with extremely cost effective services for systems troubleshooting and optimization, commissioning, project concept design and budgeting and project/construction management. As illustrated at the Phillip Burton building the O&M contractor is in the best position to identify and implement low cost projects that will reduce energy costs and improve building comfort. And then through continuous commissioning the O&M contractor can make sure that systems remain optimized.

It is also in the O&M contractor's interest to make sure that systems operate in an optimal manner as there will be less time and resources expended on repair work, answering tenant calls and working with outside contractors/consultants that need to get on a learning curve before they can provide really useful solutions to building problems. A fully engaged and involved O&M contractor should therefore provide a win/win situation for both the owner and the contractor.