Application Note:
Measurement and Verification of Energy Retrofit Projects

Description of application: Meters and sensors are installed in a facility to monitor the energy savings from energy retrofit projects on systems such as lighting and HVAC (heating, ventilating and air conditioning). The sensors are connected to a data acquisition server (DAS) or building control system (BCS) and the run times or energy consumption are measured and compared to energy usage prior to the installation.

Background: Facility managers in commercial and retail buildings are tasked with operating the buildings as efficiently as possible in order to maintain (or improve) the operating margins and profits for the owners. In many industries (e.g., retail) margins tend to be small and savings in energy use translate into significant bottom line impacts, but energy savings have to be realized with little or no impact on temperatures, lighting levels, etc. There is no shortage of potentially energy reducing technologies such as higher efficiency lights, variable speed motors, high efficiency compressors, etc., but it is very challenging for facility managers in a dynamic environment to determine the benefits of these technologies.

Consider the following example: a retail store facility manager attends a trade show and learns about a new, low cost technology for lighting in areas such as storage and warehouse space. Savings of 30% and more are projected and it looks like a logical program for all the manager's 100 stores, but he wisely decides to do a pilot program in one store to evaluate the results. He hires a lighting contractor who does the retrofit and after a commissioning session and a training program for local staff, he waits for the next month's lower electric bill. When the bill arrives, he finds that the bill is actually higher than the previous month and the prior year. Certain that the contractor made a mistake, he calls the lighting contractor who goes to the job site and assures that after significant review and testing, the system is working as specified and should be producing savings.

What went wrong? The facility manager calls the local store manager to find out if there were any changes to operations or other factors that might have influenced energy usage. He finds out the following from the local store manager:

- It "…seemed a lot hotter this year than last year"
- Sales were up 3% from last year and the receiving area was "busier than usual"
- "Our 'Midnight Madness' sales promotion on a couple of weekends added a fair number of hours to our normal operation."

To make a long story short, it's virtually impossible for the facility manager to determine whether the lighting retrofit fell short, met or exceeded the energy savings expectations. It's budget time, and the facility manager needs to decide whether to plug in a capital item to do all 100 stores, but he has no way of knowing whether the test site was a success or not. A clearly defined measurement and verification (M&V) program that provides definitive proof of the savings from this retrofit would have prevented this dilemma. This application note provides some guidelines for getting a solid M&V program for energy retrofits.

How does it work: The owner and the energy management contractor must agree in advance about the desire to measure and verify the energy savings because it is important in many cases to establish a "benchmark" for performance before changes are made. The M&V system may have to be in place and operational for anything from several days to several months in advance to establish a sound baseline for comparison. The key to the ultimate success or failure of the M&V program is the ability to isolate the specific systems being modified (e.g., lighting) from the rest of the energy consuming equipment in the building. The steps required in a typical M&V program are:

1. Pre-retrofit – Before any systems changes are made, sensors and an acquisition server are installed to determine how much energy is being used by the system to be modified. The amount of time required to establish a baseline will depend on a number of factors, such as seasonal changes, operational complexity, etc. If the building has been part of an accountability metering program (see Application Note # 1 – Accountability Metering), this baseline data may already be available. The purpose of this baselining exercise is to verify the expected savings and to adjust the payback estimates to reflect the actual usage.

2. During installation – If possible, the sensors and data acquisition server (DAS) installed during the baseline period should remain in place during and after the installation to provide consistency in measurement. The information from the DAS can be valuable in commissioning the new system as this data provides 24 hour, 7 day a week measurement to ensure that systems are operating to the proper setpoint and times. Many commissioning and acceptance programs focus on a "snapshot" view of system performance that may or may not be reflective of the longer term operation. Reports at this period are invaluable for fine-tuning system operation for the maximum return on investment for the contractor and owner.

3. Post retrofit – Many energy retrofits perform well initially, but the ROI is never realized because system efficiency degrades over time due to calibration drift, manual overrides, etc. Post-retrofit M&V will not only serve as a warning system for loss of efficiency, but can also provide valuable insight to the total cost of installing and maintaining energy efficiency. For example, assume that a package unit retrofit costs $10,000 and saves $1,000 per month, providing a payback period of 10 months. If post-retrofit monitoring shows that the new system requires quarterly calibration visits (at $250 per quarter) to maintain efficiency, the actual payback period is 11 months, or 10% longer. If this particular retrofit is being used as a model project for multiple locations, determining the total cost of the project is crucial prior to a wider rollout.

Benefits: The facility manager evaluating the success of a particular project can move forward with a much greater degree of certainty about the energy and dollars saved from the project if he or she is looking at actual data from the data acquisition system rather than projections and calculations. In addition, the manager actually improves the likelihood of a successful project if the proper tools are in place for M&V as real time feedback becomes available to the manager and the contractor.

Drawbacks: Adding real M&V to an energy retrofit project adds costs in the form of hardware and software and the manpower needed to review the reports and track the project's success. Establishment of a baseline for measurement can delay the implementation of the project for a few weeks, stretching the payback time.

Installation requirements: The specific hardware required for M&V will, obviously, be dependent on the systems being retrofitted and the expected outcome. Consider the following examples for general guidelines:

1. Chiller retrofits – chiller retrofits generally are designed to improve the efficiency of the chiller system in producing cooling (typically measured in kW/ton). The benefits and savings from most chiller retrofits can be determined using the following:

- AcquiSuite™ DAS – gathers the data on user-specified intervals and stores it till it is sent to the remote server
- Electrical sub-meter – provides data on the power (kW) consumed by the chiller system to produce cooling (tons)
- Chilled water supply and return temperature sensors – used to measure the temperature differential between supply and return temps (DT)
- Flowmeter – used to determine how many gallons of chilled water move through the chiller; when combined with DT, the amount of cooling produced (in tons) can be calculated
- Software to calculate chiller efficiency (in kW/ton) to provide comparison to before and after retrofit and to fine tune performance

2. Variable speed drives – great savings can be realized from converting constant volume fans and pumps to variable speed as the load on the fan or pump can be reduced during non-peak load periods, but if the system is not properly sized and calibrated, the savings can be lost. There are several options for monitoring the performance of VSD's:

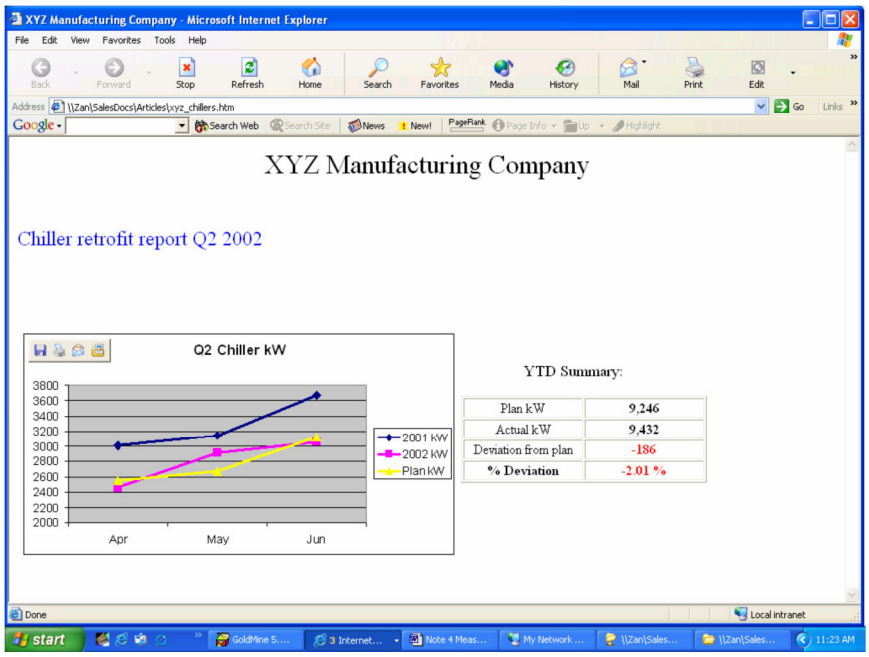
- AcquiSuite™ DAS – gathers the data on user-specified intervals and stores it till it is sent to the remote server
- *[Option 1]* Electrical sub-meter – provides data on the power (kW) consumed by the motor; most accurate and most expensive
- *[Option 2]* Analog current sensor – connected to one leg of the motor electrical supply, the current sensor measures amps which can be used as a measure of the load on the motor
- *[Option 3]* Analog output from the drive – many VSD's provide an analog output signal proportional to the load. For example, a 4 to 20 mA output signal would read 12 mA at 50% of full load. This is usually the least expensive option if the analog signal is available from the drive

3. Lighting retrofits – most simple lighting retrofits (e.g., ballast and tube replacements) are the easiest to measure since the amount of energy saved (in watts) per fixture is nearly constant and the only variable that needs to be monitored is the run time. Typical requirements are:

- AcquiSuite™ DAS – measures the total runtime on user-specified intervals and stores it till it is sent to the remote server
- On/off current sensor – this sensor is similar to the analog current sensor described above, but the current sensor simply uses current flow to determine whether the lights are on and the DAS calculates the run time to verify that the hours of operation are the same as the baseline period
- *[Optional]* Analog current sensor – the analog sensor can be used to measure the actual current draw and verify not only that the hours of operation are consistent, but that the equipment is functioning properly
- *[Optional]* Ambient light sensor – If there is concern that the retrofit will have a negative effect on light levels, one or more ambient light sensors can be installed to verify that the lighting levels are acceptable

Reports: The reports for M&V can be relatively simple (baseline energy use vs. actual) or can involve a great deal of post-processing. For example, analysis of a chiller retrofit would likely have to include some "normalization" of energy use to include temperature differences from the baseline period to the M&V period to account for higher temperatures that might impact the load on the chiller.

A simple example showing plan vs actual savings for a chiller retrofit might look like the following:



Analysis/Actions: A targeted M&V program can greatly accelerate an energy program because the facility manager (and contractor) can:

- React more quickly to correct problems that are identified in the M&V audit. Many retrofits are installed or operated incorrectly and the problems are not identified until weeks or months later when the utility bills are analyzed. In many cases, it is difficult if not impossible to determine the root cause of poor performance months later.
- Quickly determine the success (or lack thereof) of a particular energy retrofit and make better decisions about wider implementations to more locations
- Provide measurable proof for owners and executives of the impact of energy retrofits on the bottom line, greatly improving the chances of getting additional program support

Costs: As with all the application notes in this series, it is very difficult to estimate costs due to a variety of factors (wiring distances, communications issues, scheduled shutdowns, etc.), but some general guidelines for costs (hardware and installation) are*:

- AcquiSuite™ or AcquiSuite EMB data acquisition server - $1,000 to $2,200
- Electrical sub-meter (3 phase) - $600 to $1,000
- Current sensor (digital or analog) - $100 to $200
- Data storage and reports - $20 per month per AcquiSuite™

** General figures based on available information; contact Obvius for the latest pricing*

Notes/miscellaneous: Historically, energy contractors and building owners have been reluctant to add equipment for measurement and verification, choosing instead to rely on calculations (aka, stipulated savings), snapshot studies and utility bill analysis to verify savings from energy retrofits. This view has resulted in many projects that may not have any return being accepted as successful and has also almost certainly caused projects with good returns to be deemed as failures because extraneous factors masked real savings. The simple fact is that a good M&V program (using new cost-effective technologies from companies like Obvius) pays for itself both in the near term and over the long haul as managers are assured that the retrofits they invest in continue to provide the expected returns for many years to come.

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