Cost-Effective Commissioning: Getting the Job Done Within Utility Guidelines

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When Pacific and Utah Power began to develop a DSM program for new commercial buildings, commissioning was a key element in the program design. The Energy FinAnswer program was launched in 1991, and program management was given the freedom to test initial commissioning ideas on early projects, with the assumption that insights gained would lead to process improvements. Beginning in 1993, the development directive has been to streamline the commissioning process.

The data from 50 completed projects strongly support the value of commissioning as a vital part of the program. Program streamlining efforts cannot seriously consider dropping the commissioning component; rather, program managers must look for ways to reduce costs without losing the effectiveness. Streamlining will also improve customers' perceptions of commissioning as it enables the program to respond more promptly to their needs.

The Energy FinAnswer commissioning process includes technical, administrative, and communication components, Technical expertise is needed for ensuring that equipment and building systems operate as intended. Several changes have been made in the field testing and documentation procedures since 1991, keeping program costs down and quality up. Administrative tasks range from assigning a commissioning agent to each job, to maintaining project and program documentation. Experience has shown the value of ongoing informal process evaluation and making program adjustments before management systems get overloaded. Communicating the value of commission is vital to the success of the process. In addition, both utility staff and customers need to understand the roles they play.

Introduction

When Pacific and Utah Power began to develop a DSM program for new commercial buildings, commissioning was part of the package of customer services. The Energy FinAnswer (EF) program was launched in May of 1991, and program management was given the freedom to test initial commissioning ideas on early projects. (See Yoder and Kaplan 1992 for a description of the Energy FinAnswer program.) Lessons learned from those projects led to a number of process improvements. Beginning in 1993, the development directive has been to streamline the commissioning process.

Having commissioned approximately 50 projects, with another 30 under way, we have ample evidence that commissioning can have a significant impact on energy use and the proper operation of building systems. Building owners and occupants as well as the utility's DSM effort benefit from commissioning.

Because of the recognized value of commissioning, the primary goal of the streamlining effort is finding ways to continue high-quality commissioning at a reduced cost to the DSM program. Commissioning must contribute its share to any cost cutting effort necessary to help the overall program meet utility cost-effectiveness criteria.

A second goal of streamlining is more efficient utilization of commissioning resources, thereby keeping pace with the volume of work. Simplified commissioning procedures also help us to respond promptly to customer needs, thereby gaining greater acceptance for the commissioning process. This paper discusses the technical, administrative, and communication components of one commissioning program. Technical expertise is needed for ensuring that equipment and building systems operate as intended. Currently most technical tasks are the responsibility of the commissioning technical coordinator and 25-30

commissioning agents who are on contract with the utility. Administrative tasks range from assigning a commissioning agent to each job, to maintaining project and program documentation. Primary responsibility for administrative tasks falls to two program managers and a clerical assistant with a full-time commissioning focus; a third program manager divides his time between the sales and commissioning aspects of the Energy FinAnswer program. Communication is vital to the success of the program. Tasks include informing both utility personnel and potential customers about the commissioning process and the results from completed jobs. It is also important to listen and respond to concerns voiced by program managers, the utility sales staff, and customers.

Technical Improvements

We have seen numerous technical improvements in the Energy FinAnswer commissioning process. Most of these improvements fall under the areas of increased commissioning agent expertise, a growing library of test procedures, more standardization of test procedures, and directing our commissioning efforts towards equipment and systems where commissioning is most cost-effective.

Commissioning Agent Expertise

It is natural to expect that commissioning agents would ride the learning curve to greater effectiveness. This is an inevitable result of applying a well-defined set of procedures to a series of projects. In fact this is what happened in the Energy FinAnswer program. In addition to the accumulated field experience, the review of all commissioning technical documentation by the commissioning technical coordinator has helped instill in the commissioning agents better understanding of specific EF program requirements.

We have also found that training commissioning agents must be an ongoing process. Every new commissioning agent goes through a two day training session. These sessions start with the presumption of adequate technical background on the part of all commissioning agent candidates. Most of the two days is spent not on equipment-oriented technical matters, but on explaining the commissioning process, how to write test plans, and how to fulfill EF documentation requirements.

Regular half-day and full-day “refresher sessions” are held at least once a year. All commissioning agents are required to attend if they wish to remain on the contractor list. These sessions focus on a presentation of any program changes, discussion of program problem areas, and often a presentation of some unfamiliar commissioning technique or system commissioning procedure. In past sessions we have presented data logging instrumentation and techniques, power quality analysis procedures, and VSD commissioning procedures.

Recently we began faxing occasional technical bulletins to all commissioning agents. These cover subjects such as safety procedures around electrical equipment, motor testing techniques, and use of energy management systems for commissioning. The purpose of these bulletins is not only to impart useful information, but also to remind the commissioning agents that they are on our team, that this is a technically challenging process, and that they have resources they can draw on. The fax format allows more timely dispersal of information than our semi-annual newsletter, and may in the end replace the newsletter entirely.

The quality of our commissioning agents is increasing also because we have dropped the least effective commissioning agents from the contractor list. When we make a mistake in selecting a commissioning contractor, it usually takes only one project to identify the problem and take corrective action. Problems have included inadequate technical knowledge, tardiness in completing field work or documentation, and disregard for program procedures. In addition to dropping the least effective commissioning agents, we have also tended to assign the majority of new projects to those commissioning agents who proved themselves most effective. “Effective” does not necessarily mean “cheap.” Rather, it implies that they provide comprehensive work at a fair price. We are currently considering guaranteeing a minimum volume of work to our two or three most effective commissioning agents. The purpose of this would be to assist them in planning manpower requirements so they can be more responsive to EF project schedules.

Test Plan Resources

When the Energy FinAnswer program began, we had few resources for test plans for the equipment and systems whose performance we were to verify. We resisted efforts to develop standard test plans since we felt that the infinite variation among different models and manufacturers of equipment would defeat any efforts to standardize. Strictly speaking, we still believe that. However, we have gained respect for the similarities between different manufacturers and models of equipment types. We have also seen a greater conformity among energy efficiency measure types than we expected. But conformity breaks down where control sequences are concerned. It is difficult to write standardized test plans around control sequences. However, standard approaches are possible. As an example, it may be difficult to predefine the exact strategy to be used for supply air temperature reset control. However, it is relatively straight forward to recommend trending or monitoring of the supply air temperature versus the

expected independent (driving) variables such as outdoor air temperature, zone temperatures, and so forth.

We have also found that the static installation, or pre-commissioning, tests are more readily standardized than the functional performance tests. All mechanical equipment can be checked for proper mounting, proper ducting or piping, proper electrical service, and so on. To this end, we have developed pre-commissioning checklists for a wide range of equipment and systems including various types of heat pumps and air conditioning units, variable speed motor drives, energy management systems, lighting controls, and so forth. It is a rare project where the technical coordinator is not able to send some sample test plans to the commissioning agent for use as a starting point.

In addition to having collected a sizable library of representative test plans, we have begun two other efforts towards test standardization. The first builds on the network of heat pump installation contractors that the utility has trained and certified. We now assign any small projects whose commissionable measures include only heat pumps, programmable thermostats, and small economizers to a utility-certified heat pump contractor who is located near the project site.

The deliverables required for these simpler projects are also less complicated than full commissioning deliverables. A standard five-page test procedure and reporting form can be applied to commissioning all air-to-air heat pump installations. This procedure expands only slightly on these contractors' normal scope of installation check-out, and thus can be applied quite cost-effectively, This has driven the commissioning cost for such projects from a minimum of about $3000 when commissioning agents were doing the work, to a typical range of $500 to $1000 when heat pump contractors do the work. Given that many of our projects are remotely located, and include perhaps four or five heat pumps with economizers, this represents large program savings.

The second effort is the development of a CSI-format commissioning specification that can be integrated into construction specifications. The primary intent of this specification is to inform all parties of any commissioning-related responsibilities they have throughout the design and construction process. When use of this commissioning specification has been approved by program management, field sales representatives will be responsible for giving it to customers for inclusion in their construction documents. In order to give all contractors a firm basis for bidding their work, this commissioning specification includes a large number of generic test plans, both static and functional performance, and states criteria for test acceptance.

Focusing on Energy Measures Where Commissioning is Cost-Effective

As we have gained experience with commissioning many different types of measures, we have been struck with the fact that the level of effort required for commissioning certain measures far outweighs the potential energy savings.[1] The total cost of a measure, including the cost to make sure it operates properly (i.e. commissioning), should meet the EF program cost guidelines.

This can mean that some measures save too little and cost too much to commission to warrant their funding, even though they may appear to be cost-effective when commissioning costs are not included.[2] Other measures may generally perform properly without commissioning, and the utility can accept the risk of funding them without performance testing. We have been attempting to sort funded measures and related equipment into three categories: 1) measures that fail without commissioning, but whose commissioning costs outweigh the potential measure savings, 2) measures and equipment that fail without commissioning, and whose commissioning costs are justified by the potential measure savings, and 3) measures and equipment that generally perform properly with little or no commissioning.

Table 1 shows a number of the measures and types of equipment that we commission, and assigns each to one of the three categories. Note that at this time this is semi-intuitive categorization, based on our close observation of many commissioning projects and on a preliminary case study analysis of measure-specific predicted savings, deficiencies identified during commissioning, and documented commissioning costs.

Though much of our evidence is anecdotal, we can offer some analytical evidence to support the placement of energy efficiency measures in these three categories. (See also Kaplan 1994.)

Dehumidification heat pump systems for enclosed swimming pools clearly belong in the first category-those energy efficiency measures and systems that fail without commissioning but whose commissioning costs outweigh the potential measure savings. (The utility's avoided cost considers only electrical savings, and these systems have their greatest savings in natural gas.) These systems require extensive commissioning, and have very low electrical savings. One project had a predicted savings of 108 kWh for this measure, and a commissioning cost of $4600!

Turning our attention to economizers, we believe this measure also belongs in the first category. (The code

Table 1. The Effectiveness of Commissioning Specific Energy Efficiency Measures

Measure, Equipment, or Function	Commissioning (cx) Category: Fails Without cx, but cx Cost Too High	Fails Without cx, but cx Cost Justified	Generally Works Without cx
Lighting Controls . . .			
Daylighting controls	?		
Sweep controls		X	
Grocery Refrigeration . . .			
Basic compressor operation			X
Maintenance of case temperature			X
Evaporator defrost			X
Floating head pressure control		X	
Anti-condensate heater control		X	
Energy management system control of store environment		X	
HVAC . . .			
Economizers	X		
High-efficiency mechanical refrigeration[4]			X
Heat pump backup heat staging		X	
Variable speed drives		X	
Ventilation air control		X	
Building pressurization control		X	
VAV terminal unit dampers			X[5]
VAV terminal unit valves & coils		X	
Fan-powered terminal unit staging		?	
Unoccupied setback, override, & optimal start/stop controls		X	
Dehumidification heat pumps	X		
Through-the-wall heat pumps	X		
Pump and cooling tower controls		X	

baseline requires economizers for air handling units greater than 3500 CFM in capacity. The utility funds economizers on smaller units only.) We've found that economizers have a very high rate of failure when they are not commissioned. The dollar value of annual energy savings for a properly performing small system economizer in the Northwest generally falls in the range of $40-$160, based on an integrated kWh and kW cost of $.04/kWh. Since it has usually taken between two and 12 hours to commission an economizer, at a cost of about $150 to $750, it becomes doubtful that it is still a cost-effective measure when the commissioning cost is included. (The cost of commissioning includes preparation of test plans, submittal of required reports, and administration of the utility contract. A project with only one or two economizers might therefore have a very high commissioning cost per unit.)

Similarly, we have a long list of daylighting control systems that were inoperative prior to our commissioning

efforts. Two recent projects are typical. All classrooms in a northern California high school were retrofit with efficient lighting fixtures and daylighting controls. Miscalibration of the controls resulted in no dimming of lights under any conditions, and zero savings from this energy efficiency measure investment. The predicted savings of the combination occupancy/daylighting controls were 75,000 kWh. Assuming half of these savings are directly due to the daylighting controls, and again assuming a $.04/kWh cost, the predicted annual value of the energy savings is $1400. The cost of commissioning this measure was about $1000. A second project, a 100,000 square foot government office building in Portland, Oregon, has very similar data. In this case, an estimated 30,000 kWh would have been lost annually if not for commissioning, which cost about $1000.

Since the cost and savings of daylighting controls are typically combined with the cost and savings of related lighting measures, we can't say definitively whether such controls are cost-effective in the northwest when commissioning costs are considered. But we can say that daylighting control systems should not be funded or installed if commissioning is not done.

Moving to the second category, energy efficiency measures and systems that fail without commissioning and whose commissioning costs are justified by the potential measure savings, we look first at a case study of lighting sweep controls. In the same Portland government office building we used for the daylighting case study, lighting sweep control was predicted to save about 100,000 kWh annually. At $.04/kWh, this amounts to an annual cost savings of about $4000. At the time of commissioning, the sweep control was inoperable due to inappropriate zoning, incorrect programming, and several other deficiencies. All savings were being defeated. The estimated commissioning cost for this measure was $1200.

This case study is representative of every lighting sweep control system we've commissioned. Each one has had deficiencies that either partially or wholly defeated the potential energy savings. Predicted savings from lighting sweep controls are generally high, and it is relatively straightforward to commission these systems. Preliminary data suggest that lighting sweep controls fall in our second category-energy efficiency measures that fail without commissioning, and whose commissioning costs are justified by the savings.

Another measure that generally falls into this category is the variable speed drive (VSD). In over half of the program experiences with VSDs, our commissioning agents have found deficiencies that often wholly defeat the predicted savings. Most of these deficiencies aren't directly related to the actual VSD hardware, but rather to the control of the systems that the VSDs serve. Since the predicted savings are an effect of the operation of the systems served, these deficiencies are devastating from a utility perspective.

In one project, a school in eastern Washington, two-position valves on individual heat pumps in a water-loop heat pump system were to close when the heat pump compressors weren't operating. However, a deficiency in the wiring of the valves permitted them to stay in the open position at all times. Until this was corrected, it defeated all savings from the 40 horsepower loop pump VSD. Though there are some discrepancies between the computer simulation and engineering calculations for this measure, we estimate that the annual savings are between 50,000 and 100,000 kWh. At the $.04/kWh cost, this amounts to an annual cost savings of between $2000 and $4000. The commissioning cost for this measure was approximately $3000.

We have also seen numerous instances of lost savings on fan VSD installations where the static pressure set-point for fan operation was set so high that the fan had to operate at full speed at all times in a futile effort to reach set-point. As was the case with lighting sweep controls, we have much anecdotal evidence that the cost of commissioning VSD installations is generally justified by the predicted measure savings, and that these measures have an unacceptable failure rate if they are not commissioned.

Turning to commercial refrigeration, we have generally found that the floating head pressure control of the compressor racks and control of the anti-condensate heaters on the doors of the frozen food cases both have a high failure rate if not commissioned. The greatest portion of the predicted savings in refrigeration system improvements in the Energy FinAnswer program is due to the floating head pressure control. Commissioning of 14 groceries revealed that the head pressure control was either not adjusted at all, or adjusted with an overly conservative setting in almost half of the projects in which this was funded. This would have led to the loss of over 1 million kWh in predicted savings had these deficiencies not been corrected as a result of commissioning.

Looking at one typical grocery, we saw the defeat of about 375,000 kWh in annual savings due to incomplete installation of the anti-condensate heater controls and overly conservative adjustment of the head pressure controls. At $.04/kWh, this amounts to an annual cost savings of about $15,000, all of which was at risk without commissioning-which cost about $1000 for these measures.

As we learn to better identify which measures belong in each of these categories, we direct the commissioning

agents to focus their efforts on the measures and equipment in the second category-those measures that fail without commissioning, and for which the cost of commissioning is justified by the predicted savings. We are also slowly eliminating any new funding for measures in the first category.

Operations and Maintenance

We have always recognized that the persistence of measure savings in a building depends as much on the quality of ongoing operation and maintenance (O&M) as on commissioning. But we have struggled to find effective ways to assist the building operators to do their jobs. When the Energy FinAnswer program began, we directed the commissioning agents to (1) review the O&M manuals, (2) write O&M manuals when this was not covered by the construction documents, (3) write O&M training plans for execution by the contractors, and (4) present the O&M training when this was not covered by the construction documents.

We are currently considering whether any of these activities have actually been effective. Although our commissioning agents have reviewed many O&M manuals, it is rare that a contractor will respond to requests for revisions. When our commissioning agents have actually written O&M manuals, covering the funded measures, it is not clear that these manuals have been used by the persons responsible for building O&M. [3]

Our original intent in having commissioning agents write O&M training plans was to assist the contractors in planning and delivering effective training. This was based on our belief that most contractors are not well versed in the concepts of training by objectives, suiting training media to learning styles, proper staging of topics, and so forth. But we found that even when the commissioning agent was well versed in these concepts, the contractors would rarely listen to the commissioning agent's advice. However, it is likely that if the training plan were included in the contract specification as a responsibility of both the commissioning agent and the contractor, it could be a valuable addition to facility O&M preparation.

We have moved away from some of the original O&M tasks. At this time we are ensuring that O&M manuals have been prepared and delivered, but we are doing little or no quality control review of these manuals. We are no longer writing training plans unless the contractor has expressed an interest in this service. We do, though, offer to videotape the contractor-delivered training, and sometimes use this as a pretext to discuss the "script" for filming with the contractor.

Like many utilities, we are looking for ways to encourage the building staff to follow good operations and maintenance practices.

Administrative Improvements

The administrative side of commissioning in the Energy FinAnswer program includes assigning jobs to commissioning contractors, releasing payment to customers for measures that comply with the customers' EF contracts, resolving payment issues for measures that do not comply, and maintaining accurate project records.

Assigning Commissioning Jobs

Some additional data gathering is almost always necessary before a new EF project can be given to a commissioning agent. Key information includes the project construction schedule, the names of primary designers and contractors, and most importantly, a clear description of the energy efficiency measures to be installed. Although the customer has signed a contract which includes measure descriptions, we find that these description are often inadequate to guide the commissioning process.

Energy efficiency measure descriptions, written by the EF design modeler, were not originally intended to serve as commissioning guidelines. Rather, they focused on describing measure benefits to the customer or on the modeling approach used to predict energy savings. As such they often contained little detail to support verifying the installation and operation of efficient systems. Clarifying the intended specifics became the job of commissioning program management. We are working with the design modelers to change the focus of their energy efficiency measure descriptions, with the goal of freeing ourselves from the need to gather additional information.

Commissioning jobs are usually assigned to a contractor whose home base is near the building site. This helps reduce the commissioning job cost and improves the timeliness of field work. It also facilitates the commissioning agent collecting drawings and specifications from the construction office or architect. When the program began we collected such information and distributed it to commissioning agents as needed. However, waiting for plans and specs became a serious bottle neck. Now we provide only basic energy efficiency measure information and the commissioning agent is responsible for the system details. A second advantage of assigning jobs locally is that informal site visits are possible; and the not uncommon trips to check out repairs that don't materialize have less impact on the project budget.

An exception to this local commissioning agent rule is the assignment of a single refrigeration specialist to most grocery store jobs. He has been able to limit travel to just one or two site visits per project, however. The rest of his systems check-out work is done through a modem link to the refrigeration system controller.

Data Management

Project tracking and data management needs will differ from one program to another. Our objective here is to point out the issues that became significant for us as the number of projects increased. It has been a challenge to maintain accurate project status records that are accessible to the field sales staff as well as to program management. While management staff is located in two corporate offices in Portland and Salt Lake City, the field sales staff is located in district offices scattered across seven states. Only the utility's mainframe computer links all offices electronically.

When the Energy FinAnswer program was launched, project tracking was established on the mainframe. An existing data base, already familiar to the field sales staff, was expanded to include DSM projects. However, this data base was not suited to daily project management, so we did not try to add in any commissioning detail. Instead a local area network data base was chosen. Unlike the mainframe, we had very good access to programming support for the network. This gave us more flexibility to modify data tables and reports as we fine-tuned the administrative side of our commissioning program. The drawback was that field staff did not have access to the network data. To further complicate matters, program managers responsible for other aspects of the EF program had their own stand-alone data bases. Multiple data bases in a variety of formats led to redundant data entry, the likelihood that information for a single project would not be consistent across all data bases, and confusion about who is responsible for tracking program performance. We are currently developing a single system which tracks all phases of the Energy FinAnswer projects. This system will also include other DSM programs with structures similar to the program discussed in this paper.

Our next data crisis is likely to be the vast amount of paper we collect to document the planning and completion of Energy FinAnswer projects. Proposals to convert the paper-based system to an electronic format are not likely to be realized soon. As a result, we need to be more careful to keep only essential documents and final copies of reports. With six persons adding information to project files, we would benefit from a set of guidelines about information retention. We have no system in place for policing ourselves, but the need is there.

Conservation Payments to Customers

Release of energy efficiency measure payments to customers has become a commissioning issue because payment is made after the commissioning agent reports that a measure is installed and operating correctly. This approach gives the customer maximum incentive to promptly correct any identified deficiencies. But it can also work against the commissioning agent because he is seen as responsible for holding up funding. Several alternatives to our current approach to making customer payments have been proposed, but no decisions have been made. The best approach may be one that removes the program's reference to "up front funding. " We could then require that measures operate correctly before any payment is made. Commissioning could be positioned as a service to help ensure correct operation, rather than a barrier to receiving payment. Commissioning should be viewed as a process that includes both the utility-funded diagnostics work and the customer-funded correction of deficiencies. Diagnostics alone do not ensure efficient system performance.

Communication Improvements

The ease with which a commissioning program can be managed is highly dependent on the extent to which it is a valued and accepted component of the larger DSM program. The importance of getting upper management and field sales staff acceptance for commissioning should not be underestimated. Upper management will make budget decisions that determine whether commissioning can go forward. Field sales staff who value commissioning will present it to their customers in a positive way, thereby establishing an atmosphere of cooperation between the commissioning agent and the owner's design and construction team. Field staff who do not value commissioning fail to communicate clearly that successful commissioning requires involvement by the owner's team.

We have found that most resistance to the commissioning process stems from a perception that building commissioning is either redundant, extravagant, or futile. Those who feel it is redundant assume that the owner's contractors are already carrying out sufficiently detailed performance testing and that our commissioning agent is repeating those tests. They give typical construction practice more credit than it deserves. Others argue that optimum performance is an ideal we should not strive to attain because it is not worth the price of commissioning. Finally, there are those who feel the diagnostics provided by our commissioning agents are wasted. Deficiencies that are identified may be ignored by the customer, whose primary concern is not energy efficiency. From this perspective commissioning is futile. Commissioning imposes a standard of quality on all jobs that exceeds current common

practice. Therefore its value must be promoted both inside the utility and among customers.

Among the steps we have taken to promote the value of commissioning are participation in a research study which seeks to quantify the costs and benefits of commissioning for a sample of EF projects; development of an informational brochure; support of ASHRAE and other efforts to move commissioning towards standard practice in the construction industry; and preparation and distribution of commissioning case studies.

Conclusion

In the four years since initial development began for the commissioning program described in this paper, the DSM program it supports as well as the utility have undergone many changes. We are committed to continuing with commissioning, but expect that the program aspects of the process will change dramatically over the next year. The primary driver of change right now is reducing program costs. One way to do this is to be more selective about the systems we commission, eliminating those where commissioning cost effectiveness is not proven out. In the program administration area we are developing improved tracking and reporting systems. Finally, we are putting more emphasis on promoting the value of commissioning to upper management and field staff within the utility as well as to customers.

Endnotes

1. Energy savings for energy efficiency measures are often climate and building sensitive. Readers should not apply our findings without first assessing measure savings in their own regions and building base.

2. Alternatives to eliminating funding for such energy efficiency measures include working with manufacturers to identify and correct the causes of frequent failure, and specifying these measures in greater detail.

3. Usually O&M manuals are contractually specified for larger projects. Therefore, the commissioning agents end up preparing O&M manuals primarily for smaller projects. But the smaller projects also tend to be the ones where no one is designated to be responsible for O&M.

4. This applies to heat pumps, chillers, and air conditioning units. These units generally have field-measured efficiencies that are as close to manufacturers' ratings as field measurement accuracy can determine, However, checking of refrigerant charge is often advisable, especially with split system units.

5. This assumes that a competent air test and balance job was done and documented.

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