Commissioning Critical Facilities- Understanding the Varied Approaches to Commissioning

Patrick A. Prendergast, P.E.
George Butler Associates – ViroCon, Inc.

John D. Riley, P.E.
George Butler Associates, Inc.

Synopsis

There is general agreement within the commissioning industry regarding the basic components included in the commissioning process. There are however, considerable differences of opinion in how the process is executed. The details regarding who performs activities and how they are performed within the process greatly determines whether or not commissioning goals are achieved. Those details must be defined within the commissioning approach.

The approach the commissioning authority utilizes to execute the commissioning process varies in several key areas. Those variances impact the depth, cost, time and ultimately, the success of the process. A critical question to ask is, "What is the depth and rigor required of commissioning to achieve the goal for my facility?" Once this question is answered, the following key areas can be further defined:

- Detailed commissioning process
- What entities will direct testing
- Will commissioning be discipline specific

When the project team, including owner, user and design professionals, is well informed about the various commissioning program approaches, they are better equipped to obtain quality commissioning services commensurate with meeting specific project goals.

About the Authors

Pat Prendergast serves as the multi-disciplined Project Manager/Commissioning Authority for many of GBA/ViroCon's commissioning projects. As the Commissioning Authority he has more than 11 years of experience providing formal commissioning services on laboratories, zero down-time facilities, and large governmental facilities.

John Riley serves as the lead electrical engineer for all of GBA's commissioning projects. John has been providing electrical systems start-up and commissioning services for more than 15 years. Projects include laboratories, data centers, central utility plants and utility power generating plants.

Introduction

In the broad view of building commissioning, there are two main components: the process used to commission the facility and the personnel executing the tasks required by that process. The quality of each of these components will determine the success of commissioning. These components define the commissioning approach. Critical facilities require a different commissioning approach from non-critical facilities. We will discuss the aspects of the different approaches and the influence the approach has on the level of assurance, commissioning costs, and commissioning agent selection.

Commissioning Process

The basic outline of the commissioning process is generally agreed upon within the industry. There are differences between the organizations which have produced guidelines/standards, but the overall steps are similar. All groups recommend the involvement of the Commissioning Authority (CxA) early in the project, beginning in the Pre-Design Phase, and continued involvement thru the end of the occupancy and operation phase.

There are other less conventional methods which have been introduced to the industry. These alternate methods include analyzing data logs and trends to prove functionality of the systems. Only systems identified as deficient through these methods are then functionally tested. Many of these alternate methods can be incorporated into the standard commissioning process, but should never replace the process. Since we are discussing critical facilities, only the standard process will be included.

Though the process is generally similar within the industry, the details regarding the depth and rigor of the individual steps are not specified. For critical facilities the depth and rigor of the commissioning process is greater. Each building owner/user must determine project goals and the commissioning process. The Owner and CxA must then work together to ensure that the commissioning process is sufficiently detailed to achieve these objectives.

Commissioning Personnel

The commissioning team's experience, integrity, and the ability to communicate with the project team are critical to the success of the project. Determining which group will be responsible to implement the various steps and, specifically, the experience of the individuals performing the process must be decided early on in the project. There are several entities that can be used to perform the commissioning tasks. Tasks can be performed by any single entity or a combination of the following entities:

- Third Party Commissioning Authority
- Construction Manager
- Installing Contractors
- Owner/Owner's Personnel

- Design Team Personnel
- Equipment Suppliers

Regardless of the parties performing commissioning, the experience and expertise of the individuals used must be sufficient to ensure the tests are written and executed to prove performance of the systems.

Depth and Rigor of Implementation

The primary factor that determines the commissioning approach is the Depth and Rigor with which the commissioning activities are performed. All activities should be considered, from those in the pre-design phase to those that are part of the occupancy and operations phase. You have to determine the level of assurance necessary for your facility and then establish the level of effort to provide that assurance through the commissioning process. This includes not only evaluating the depth of review and verification testing activities, but also includes determining which systems should be included. Depth and rigor of implementation can be discussed in three primary areas:

- Systems to be commissioned
- Component testing scope
- Systems and integrated systems testing scope

Systems to be Commissioned

This seems fairly obvious on the surface: You **must** commission the systems whose operation is "critical" to the operation of your facility. These generally include electrical distribution and environmental control (HVAC) within the critical spaces. You **can** commission the systems that are ancillary to the critical environments. The challenge is in recognizing how the "can" systems impact the "must" systems. Life safety systems including fire alarm and detection and fire suppression, have several definitive control responses affecting both the HVAC and electrical systems within facilities. Examples of these include air distribution equipment response for smoke control or containment and EPO switches. Building automation systems should be evaluated for information sharing and system architectures between "must" and "can" systems.

Component Testing Scope

Each component within a system has a specific purpose and operation to fulfill that purpose. The extent to which that component is tested to ensure it operates correctly needs to be established based upon its impact on system performance. If a temperature within a space needs to be maintained at +/- one deg F, then the space temperature sensor should be tested against those criteria, in its installed configuration, within the actual operating temperature range. If we have a public address system – do we generally determine that the speaker volume and clarity is acceptable by standing in the room, and listening to whether we can adequately hear what is being broadcast. Or, do we set up a test stand with sound level and quality equipment to test the

speaker against a specific performance criteria. The answer depends on how critical you believe that component to be for the operation of your facility.

Systems and Integrated Systems Testing Scope

Systems are designed to operate per a specified sequence of operation. The sequence is a combined group of operational criteria to be maintained and system responses to data inputs to achieve those criteria. The testing of a critical system must test **all** the designed sequences, in **all** component configurations, in a real world environment. If your chiller plant has three chillers and is designed to operate with all three in a lead/lag redundant configuration, then we need to load test the chiller staging all the way up to three chillers and all the way back down to one chiller. And, this needs to be done with all three lead chiller configurations. Why? Because the system is designed for that scenario and that scenario will occur in real life. The coordination of pump start/stop, isolation valve open/close and chiller start/stop/status needs to be tested to ensure it works in all configurations.

Integrated systems testing should duplicate real life operation of the facility as closely as possible. For a data center facility, smaller suitcase load banks (30kva) should be spread evenly over the raised floor area to mimic the computer load. Then commence with integrated systems testing to ensure the CRAC units are providing uniform heat removal, proper chiller staging, IR scanning should be performed for hot spots, etc. It is also important to research to local utility's substation breaker reclosure scheme in order to develop real life "pull the plug" power outage testing scenarios. Often overlooked is a short time outage when a substation breaker recloses after clearing a fault.

Phases/Activities

As defined by the BCA and ASHRAE, the commissioning process consists of the following phases, each with multiple tasks. The major tasks within each phase are listed below, with examples of the types of issues requiring significant definition and detail.

Pre-Design Phase

The Pre-Design Phase lays the foundation for the commissioning of the project. It is in this phase that the Owner's Project Requirements (OPR) is detailed and the commissioning scope and plan are determined. It is also in this phase that the "depth and rigor" of the testing must be determined. Key steps in this phase include:

- Developing the Owner's Project Requirements
- Identifying the scope and budget of the Commissioning Process
- Developing the initial Commissioning Plan

The purpose of commissioning is to ensure the delivered facility meets the OPR. For data centers, the OPR will include the required the Tier level, user requirements, environmental and

safety requirements, redundancy levels, system expectations, operating efficiencies along with other Owner expectations for the facility.

The CxA must work with the Owner to identify the depth of testing which will be the basis for the commissioning scope. As described throughout this document, the scope of services for critical facilities will have to be much more detailed than the standard scope of services.

The CxA will transform the commissioning scope into the commissioning plan. The plan will identify all steps in the process, detailing the performance, documentation and acceptance criteria. Again, the Cx plan for critical facilities will have to be much more detailed than that of a normal project. Clearly and thoroughly defining the requirements and the process from the project outset is necessary to achieve this end result.

Design Phase

The Design Phase is where the design team takes the previously defined OPR and creates the construction documents. It is in this phase that the CxA must ensure the systems and facility proposed will meet the OPR. It is also key to ensure the commissioning requirements are detailed in the construction documents and in the Cx Plan. Major steps in this phase include:

- Basis of Design (BOD) Review
- Ensure Cx Requirements are detailed in specifications
- Defining Training Requirements
- Commissioning review of design documents, including issue resolution

The CxA must review the design documents from the BOD through the issuance of construction documents. The reviews need to focus on the documents ability to meet all aspects of the OPR with sufficient detail to ensure the contractors can fully understand the system requirements. It is essential that the documents do not leave the contractor to interpret any part of the system sequence, which often results in “this is how we always do it” or “this is how we did it on my last project” reasoning for implementing deficient operating sequences.

The CxA and design team should meet to ensure that any issues identified are understood by the designers and resolved in a manner which satisfies the Owner. One item which needs careful attention is the design operating sequences. The system sequences must be developed to ensure every operating condition is clearly defined. Normal operation, staging up/down, failure, emergency sequences all need to be completely described.

The specifications should detail the requirements of the contractors and define the commissioning process, including testing plans and acceptance criteria. Critical facilities will require considerably more verification testing than other types of projects. The training requirements must be included in the appropriate equipment sections to ensure that sufficient training is provided to allow the Owner’s O&M staff to operate the facility as intended.

Construction Phase

Although this is the phase most people associate with commissioning, if the steps in the previous phases have not been correctly implemented this phase will be difficult to successfully complete. Key steps in this phase include:

- Submittal / O&M review
- Detailed test procedure development / execution
- Installation verification / Startup testing
- Verification testing
- Training Verification

The CxA will review the submittals to ensure the equipment will meet the OPR and can be properly commissioned. Key items to focus on in submittal review are part load conditions due to concurrent operation of redundant equipment and ensuring the control systems detail all operating sequences.

The approved submittals and O&M manuals will be used to develop the installation, startup and functional testing procedures. The sequences in critical facilities are not standard. Generic, or canned, test procedures will not test all required sequences nor detail the expected results. The test procedures must detail all sequences and required results for the specific systems installed.

Verification of the HVAC systems balancing will need to be performed on 100% of the critical systems prior to functional testing. Functional testing of mechanical systems which cannot deliver/receive design flow will not provide accurate test results.

With all of the interlocks and redundancy on systems serving critical facilities, the CxA performing/witnessing the testing must have the experience to identify possible failures or system shortcomings which are not obvious to the untrained eye. Simply observing tests and checking boxes on a form does not provide a quality service.

Due to the complexity of critical facility operation, the O&M staff must be properly trained to understand the operation of all equipment, systems and sequences. For the sustainability of the site, the O&M staff must understand and be comfortable with all of the systems.

Occupancy and Operations Phase

The Cx Team should assist in coordinating contractor callbacks and perform any deferred systems testing. Additionally, the Cx Team should work with the Owner's Operations and Maintenance (O&M) staff to identify systems not operating efficiently, including causes and solutions to return the systems to efficient operation. Key steps in this phase include:

- Deferred Testing
- Warranty Site Visit

- Enhanced O&M Staff Training
- Lessons Learned Workshop

While performing the deferred testing and warranty site visit, the CxA should go over the operation of the facility with the O&M staff, identifying any issues the group may have with system/component operation. The CxA should provide additional training to the staff as necessary to provide the staff with the knowledge and comfort level in the system operation.

Who Does What

The second critical factor in the commissioning approach is identifying the qualifications of the personnel required to facilitate the depth and rigor of the process. With all of the tasks associated with the process, how do you determine "Who does What"? The CxA and Owner should determine who will perform this testing and to what level, based upon the level of assurance necessary. Possible conflict of interest issues need to be evaluated when determining roles and responsibilities. The criticality of the systems to be commissioned will be a primary factor in deciding who is best suited to perform the commissioning tasks.

Assurance Testing Performance

Contractors are very good at providing labor and materials and constructing a facility in the most logical and economical manner to fit a schedule. Design engineers are very good at producing a set of construction documents to provide reality to the owner's facility needs. Commissioning agents are very good at evaluating and testing systems to provide assurance the systems fulfill the requirements of the facility. For critical facilities, each entity should perform the work best suited to their strengths.

A knowledgeable third party commissioning agent provides an independent point of view in the installation and operation of the systems. Knowledge in the design combined with experience operating the equipment and systems provides a unique set of skills that the commissioning agent must possess. The perceived disadvantage of the independent CxA is that there is significant extra cost associated with this option. As we will explain later, this is not the case.

Experience

The requirements of the commissioning team must be specific to ensure that the tests are written and witnessed by personnel with sufficient experience to verify that the systems will meet the OPR. The appropriate level of experience should be provided for each task of the process. This does not mean that a professional engineer with 20 years of experience needs to take a Pitot tube duct traverse to ensure a restroom exhaust fan is delivering design flow. But that level of expertise is required to verify all the required operating scenarios are included in the control sequences for a data center chiller plant.

The commissioning team should be diverse, with system specialists/engineers and technicians. The appropriate personnel should be applied in a cost-efficient manner to specific tasks, while still ensuring that the systems will operate as required. For critical facilities, most of these personnel should be affiliated with the third party CxA.

Discipline Specific

Due to the increased complexity of today's critical facility systems, it is not possible for one person to be an expert in all commissioned systems. The complexity of the HVAC, building automation, electrical, fire and life safety and security systems requires discipline specific specialists in each area. For example, the CxA may have an incredibly strong background in building automation systems with the ability to determine if a control loop is properly tuned, but may not be well-suited to identify the requirements of and be knowledgeable in testing generator paralleling gear with load shedding. It is necessary to pull together multiple experts in the various disciplines to perform the discipline specific commissioning activities.

Total Initial Cost of Commissioning Effort

When considering the total initial cost of the commissioning effort keep in mind all the work performed by all the team members is included in the total cost. The two key words are *total* and *initial*. Total cost includes time spent by the commissioning agent, contractors and equipment suppliers, construction management and the design team. Commissioning has cost implications far beyond the initial hours spent by the team members during the commissioning process; however, we will only focus on the initial costs for this discussion.

The total commissioning costs can be divided into two primary groups; the commissioning agent and the contractor. The contractor group includes the general contractor and/or construction manager, subcontractors and equipment suppliers. The owner and design team also have costs directly related to the initial commissioning effort, however they are typically inconsequential compared to the commissioning agent and contractor. The commissioning approach greatly determines the total initial commissioning cost and establishes how those costs are divided between the commissioning agent and the contractor.

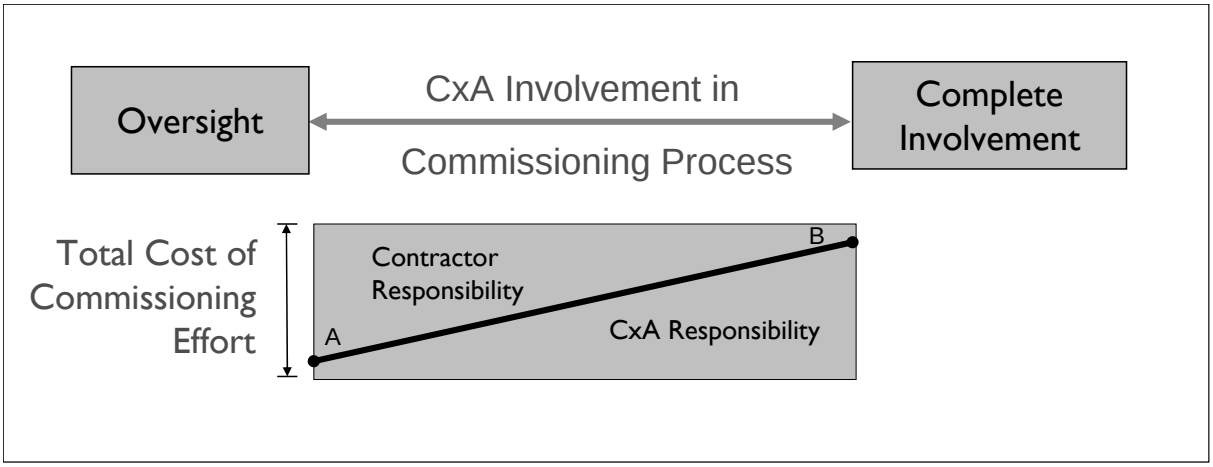

Figure A: Commissioning Agent involvement vs. division of total costs

Figure A shows the graphic relationship between the commissioning agent involvement in a project and how the total cost is divided between the commissioning agent and contractor. The percentage of the total cost attributed to the contractor varies inversely with CxA involvement. The percentage of the total cost attributed to the CxA varies directly with CxA involvement. The determined approach will dictate where on line A-B your project resides.

Approach and Commissioning Costs

The approach taken in the execution of the commissioning process determines both the overall project commissioning costs and the commissioning agent costs. Both the personnel involved in the process and the depth and rigor of testing impact the cost. Total commissioning cost is determined in two primary areas: basic cost factors and the approach.

Basic Cost Factors

There are four basic cost factors that influence the cost of commissioning. There are other contributing factors related to local labor rates, schedule, current economic conditions, etc., however for this discussion we are going to focus on these four:

- Systems included in the commissioning scope
- Complexity of the systems
- The quantity of equipment and components in the systems
- If a sampling strategy is employed

Systems included in commissioning scope

Generally people associate commissioning primarily with the mechanical and building automation systems. With critical facilities, the electrical, fire suppression, fire alarm and detection, and security systems are all very critical to the operation of the facility. Electrical systems can include emergency/standby generators, UPS, normal and emergency power

distribution, programmable lighting and public address systems. The more systems added to the scope of work, the greater the total cost of commissioning.

Complexity of Systems

The facility systems' complexity is directly proportional to the effort involved in commissioning those systems. It takes considerably more time to commission a double-ended main-tie-main, PLC controlled programmable switchgear with parallel generator controls, and soft-transfer and load add/shed programming, than it takes to commission a simple standby generator and ATS installation. The level of redundancy greatly affects the system complexity and testing effort. The additional effort occurs at every stage of the commissioning process and affects all the team members.

Quantity of Equipment

Obvious, but often unrealized; it takes twice as much time to functionally test two air handling systems as it does to functionally test one. While we can receive some economy of scale benefit in the design and construction phases, field testing and verification time is dependent upon the quantity of components and systems included in the effort. All components, systems, and inter-systems that are critical to the proper operation of the facility must be verified as operating correctly.

Sampling Strategy

The terms *Critical Facilities* and *Sampling Strategy* should seldom be uttered in the same breath. If the components and systems are critical to the success of the facility, they should be included in the commissioning process. A sampling strategy can be employed for Non-critical components like VAV terminal devices in office support space. A sampling strategy directly impacts the quantity of equipment discussion in the above paragraph. If you can't answer the question: "Which component, system or system operation can fail and not adversely affect the facility?", then a sampling strategy should not be used.

How Approach Affects Cost

The approach taken to commission your facility directly impacts both the time required to perform the tasks and cost/hour of the personnel performing the tasks. Again, the two are not mutually independent. If you decide that you want a high level of assurance, necessitating detailed and rigorous testing, then the expertise of the individuals facilitating that testing will need to be commensurate. There really is no magic to determining cost of commissioning.

(# Hours) X (Cost/hour) = Commissioning Cost

The depth and rigor with which the commissioning activities are performed determine the number of hours required to carry out the process. Depth and rigor also dictate the experience

and expertise level of the individuals involved in the process. Experience and expertise determine the cost/hour. The cost/hour increases as the experience and expertise increase.

Selecting a Commissioning Agent

The two primary methods for selecting a commissioning agent are *Qualification*-based selection and *Price*-based selection. For critical facilities, Qualification-based selection is strongly recommended. An RFP for both methods should include information on the experience and qualifications of the personnel slated to perform the commissioning tasks for your facility. The experience should be evaluated based upon performing the commissioning tasks at the level necessary for critical facilities, and experience with the particular systems proposed to operate your facility.

A price-based RFP will need to include additional information regarding the four basic cost factors discussed earlier; systems included complexity of systems, quantity of equipment and sampling strategy. In addition, significant detail will need to be provided regarding the desired approach. Generally, this information is not known at the time of the RFP. The design has not been developed enough to determine the basic cost factors, and the experience of a commissioning agent, as the expert, should be used to assist the owner in determining the required approach commensurate with the desired assurance level. It is very difficult to get 'apples to apples' comparisons for pricing. Bidding professional services rarely provide the results desired for a critical facility.

We recommend selecting the commissioning agent based upon qualifications, then determining the approach necessary for the facility, with the obvious influence of budget. Once the approach and scope are agreed upon, negotiate a price based upon that information.