IMPLEMENTATION OF PARTIAL INITIAL COMMISSIONING DURING THE ELABORATION- AND CONSTRUCTION PHASE

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Summary
This paper describes how manual methods for partial initial commissioning can be implemented during the elaboration and construction phase. The main purpose is to reduce the risk of exceeding the time schedule and the budgets of the construction of the building(s). The paper breaks down the superior building process into parts that can be connected to definite continuous procedures:
1. Continuous collection of operational instructions and maintenance documentation to secure the quality of the delivered products and to be able to perform mechanical check.
2. Splitting up of systems to perform commissioning tests (mechanical and functional) on sub system to discover errors as soon as possible.
3. Database for structuring data to get useful reports to follow up the constructors at the construction site.

Keywords: Commissioning, Technical systems, Structure of building process

INTRODUCTION

Many building projects in Norway are completed with significant deviations between design requirements and actual performance. The problems may be related to errors made during the design of the building, during the construction of the building or during the taking-over process.

The last few year media has focused on some large public building projects with large budget overruns and delayed completion dates. These two factors have led to a strong focus on the taking-over phase, where large resources are spent. This paper focuses on how it is possible to structure the initial commissioning process during the elaboration- and construction phase so that the actual performance corresponds better to the design requirements, in addition to reduce the risk for budget overrun and delayed completion date.

The standards and regulations in Norway describe the formalities concerning the commissioning process but only as an activity and a status at the end of a building project (taking-over), and not as a continuous process. The main purpose is to change from acting like commissioning is a status to acting as it is a process. This will reduce the risk of exceeding the time schedule and the budgets of the construction of the building(s).

To achieve this goal it is important to obtain control of the building site without introducing excessive procedures that are time and cost consuming. The procedures suggested in this paper imply advantages for the entrepreneurs as well.

This paper is based on the experience and knowledge from three larger building projects in Norway, where the authors are involved.

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DEFINITIONS

Product: A product may contain of several components mounted to one functional unit, in general like the definition the product codes in NS 3420.

System: Contains of two or more products built together into a static or dynamic unit. A system should fulfil a function according to the requirements. A system is defined within the same system number according to the identification system for the project.

Integrated system: Contains of two or more systems interacting to meet the desired requirements. Integrated systems may integrate two or more systems in different contracts.

Controls and tests: Testing, recording and documentation to control that the produced result meets the technical, mechanical and functional requirements.

Production area: It is necessary to divide the building into manageable spaces, called production areas, so that each production area can be controlled separately during the construction work. The production area must be reflected in the schedule of work.

Project hotel: A database or file structure available for all participants in the project. Used for exchanging documents, make drawings, minutes etc. public etc.

Control: Control include visual control, control of documents etc.

Test: Testing includes actual tests of systems or components, where the documents that have been used to build the systems are used to set proper acceptance criteria.

CMMS: Computerised Maintenance Management System is a software that helps the user with managing and controlling maintenance of assets, plants and equipment in modern facilities.

To be able to handle and control the process as structured above, a database and a project hotel are required.

THE STRUCTURE OF THE PARTIAL INITIAL COMMISSIONING PROCESS

The actual building process can be described independent of contract philosophy, project organisation etc. The general building process is illustrated in **Figure 1**.

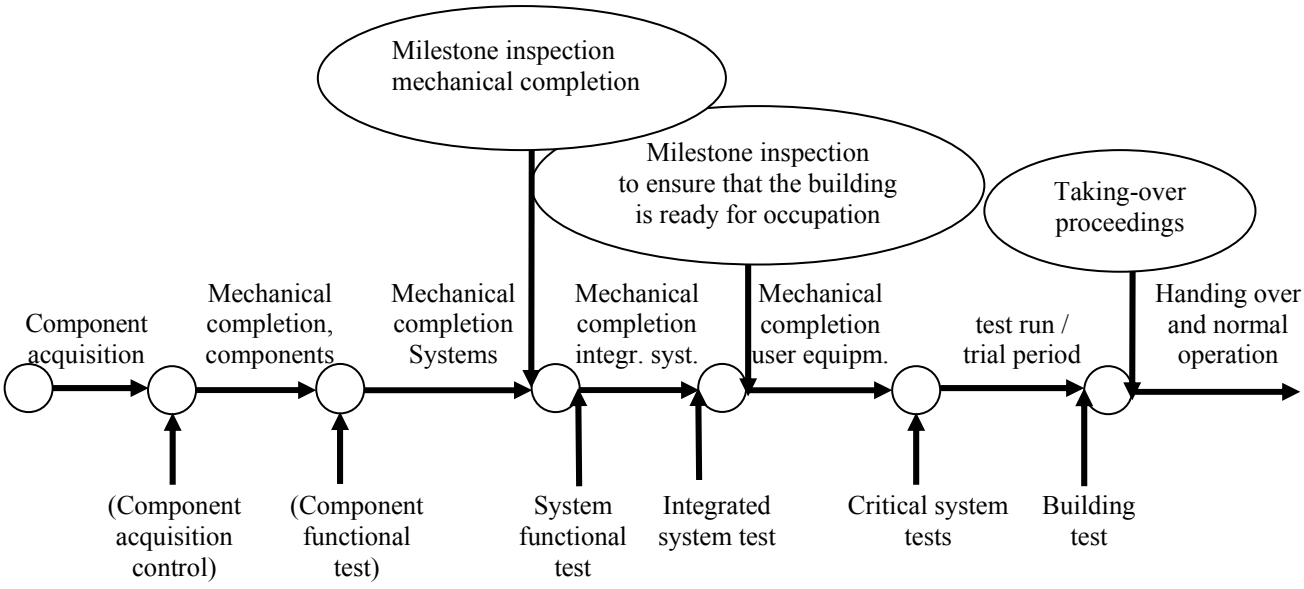

Figure 1 The general building process

Figure 1 shows the building process from component acquisition, through mounting of components, systems, integrated systems and user equipments, to the taking-over. The processes are described on top of the process line. Each process ends with tests or control and documentation. The tests or controls are shown below the process line.

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MILESTONES

The oval rings above the process line shows the normal contractual milestones, often combined with the plan for invoicing:

Mechanical completion: The milestone where all mechanical equipment are mounted. All operational and maintenance data sheet should be delivered to the project at the same time.

Building is ready for occupation: Milestone inspection. All activities after this milestone can be carried out with the user in the building. In Figure 1, this milestone is placed as soon as possible, in other building processes this milestone can be placed after the taking over proceedings.

Taking-over: Contractual proceedings according to national building codes.

COMPONENT ACQUISITION CONTROL

This is a part of the contractor's internal control to document:

- that the products used meet the requirements (technically, mechanically and functionally)
- that the quantity is correct
- that it is delivered at time

When the components arrive at the construction site, the operational documentation and maintenance documentation for the component shall be delivered to the building owner by placing all files into a structured file system at the project hotel.

The building owner controls the documentation and the construction site by spot checks.

Documentation: Data sheet, operational documentation, maintenance documentation, data acquisition tool for CMMS (Computerised Maintenance Management Software).

COMPONENT FUNCTIONAL TEST

This is a part of the contractor's internal control. When all components are mounted in one production area, a notice is sent to the building owner. The building owner may carry out spot checks or complete checks for the actual production area.

The building owner controls mechanical completions of the components with the documentation collected in the component acquisition. The control is carried out with spot checks and control of the contractors internal control documentation.

Documentation: Contractors internal control documentation, test protocols from the spot checks.

SYSTEM FUNCTIONAL TEST

The intention is to:

- control that all products in the system is mounted
- control that the system meets all its requirements
- ensure that one system does not delay commissioning of other systems.

When the system is mounted and ready for control and testing, the contractor shall send a notice to the building owner together with all relevant documentation.

The system functional tests are milestones in the contracts, and all relevant parties are bound by contract to participate in the system functional tests. The tests should be carried out according to general predefined procedures.

If substantial errors or deviations are found has to be put right and new tests performed before the next phase and integrated system tests can be performed.

INTEGRATED SYSTEM TEST

The intention with the integrated system test is to control that the interaction between different systems meets the requirements. Two or more systems can be tested, while the totality of the whole building is ensured in the commissioning test.

The integrated system tests are based on functionality because the systems themselves are tested in the system functional tests.

When the two or more systems are ready for integrated system test, the contractor shall send a notice to the building owner together with all relevant documentation like:

- A declaration that documents that the quality assurance is performed according to quality plan.
- A declaration that documents that all systems are tested, controlled and completed.
- Documentation that all necessary official approvals, that the contractor is responsible for, are in order.
- Documentation that functional control and TAB (testing and balancing) is carried out.

Systems are tested and documented separately before integrated tests are carried out (system functional tests). The tests are carried out with the clerk of works, project team and contractors following the procedures outlined by the commissioning authority and project team.

Significant errors and defects, including lacking documentation, has to be corrected before new integrated system tests can be performed.

CRITICAL SYSTEM TESTS

Critical system tests are carried out in buildings where risk analysis shows that there is a need for extra tests and additional tests. Examples can be systems critical user equipment is supplied by the technical infrastructure in the building or systems that supply critical areas that has to be tested under controlled environment with the users or user equipment. Examples are medical or process equipment that is supplied by ice water or special ventilation and computer centrals.

BUILDING TEST

The building test is the last test carried out in the building project. The purpose of the building test is to carry out live full-scale tests in the building, and to ensure the building owner that all functions are correct from the user point of view.

Examples of building tests are:

- Provoke fire alarm in areas to control:
  - Smoke evacuation (pressurization of stairways, fire hatchway etc.)
  - Door functions
  - Visual and acoustic alarm (fire bells etc.)
  - Fire tableau for overriding technical systems
- Provoke fire alarm combined with power failure to test:
  - The above functions
  - Backup power supply
  - Emergency light
  - Uninterruptible power supply

All documentation and all tests should be controlled and approved at this point, in addition to a test run/trial period, so the building tests should be a formality and should not reveal any unexpected errors.

TAKING OVER

According to most contracts, it is necessary to carry out a formal inspection to ensure that the building is ready for occupation. All tests and documentation has to be in order and accepted by the building owner before taking over can be carried out.

DATA ACQUISITION FOR THE OPERATION PHASE

All buildings are built to serve the user in the operational phase. It is not sufficient to hand over a well functional building, without proper documentation.

Most of the documentation from the design phase and tender documents are not suited for use in the operational phase. This means that the documents must be worked out and collected during the construction phase. In Norway it has been customary to demand a 90% finished draft of the building documentation a few weeks before the taking over, and complete building documentation some weeks after the taking over. This system is based on documents in paper and has never worked well.

In accordance to the development in computers and software (CAD drawings, schedules, documents, email etc.), the data acquisition for the operational phase is usually collected in spreadsheets. Documents like data sheets, is structured and linked to certain cells in the spreadsheet. The spreadsheets are used to import data to the building owner's CMMS. The spreadsheets can be developed by the producer of CMMS or by independent producers. The data acquisition system developed by independent producers can to a certain extent (for small buildings) be used as CMMS. Examples of information that the contractors have to complete are shown in Table 1.

Table 1 Examples of information in the data acquisition system

	Key word	**Explanation**
System System information	System identification	A unique identification number for all systems according to the projects identification system
	System name	The name of the system
	Coverage	Description of the area the system covers
	Placing	The identification of the room number where the systems is placed
	Distribution panel	Identification number to the distribution panel that supply the system
Product Design information	Identification number	A unique identification number for all products according to the projects identification system
	Product name	The name of the product, for instance *Circulation pump*, *Ventilation fan* etc.
	Manufacture	The name of the manufacture
	Contract number/Contract name	
	Capacity/Performance	The capacity of the product (kW, m^3/h, l/s, Amp etc.)
	I/O	Number of AI, AO, DI, DO and PI for the components
Product Product information	Designation of type	
	Supplier	
	Product information	Key information of the product
	Date of installation	
	Service interval	
	Localization	Where is the product placed (room, area)
	Supplied from distribution panel	Which distribution panel supplies the component
	Data sheet	The path and name of datasheet
	HSE data sheet	Data sheet with health, security and environment information
Spare parts	Delivery time	Delivery time of the spare part
	Category	Piping, electricity, ventilation etc.
	Unit price	Unit price of the spare part
Product/System Maintenance	Maintenance description	Short description of the maintenance routine
	Maintenance interval	How often maintenance should be performed
	Stop	Is it necessary to stop the system? For how long?
	Work routine	Description of the maintenance work routine
	Time consumption	Time consumption of the maintenance work routine
	Person	Background of the maintenance personnel
	Spare parts	What spare parts are necessary
	Tools	What tools are necessary

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It is of high importance that all systems and products are identified correctly in the data acquisition system. During all phases described above, information should be added as the building process progresses. The design information (see Table 1) should be registered in the design phase. As the contractors orders products and transport them to the construction phase, the rest of the information should be registered successively.

The data registered should be used by the clerk of works to control:

- the standard of the product against the specifications
- that the product is according to the products in the bid
- that the product is mounted correctly in the correct place

DATABASE TO FOLLOW UP THE CONSTRUCTORS AT THE CONSTRUCTION SITE

All data in the data acquisition spread sheet can be imported into a database to extract the relevant data at the different phases of the construction phase. At the beginning of the construction phase, the clerk of works can use it to extract data to control certain products, or certain contractors or certain parts of the building or certain technical systems.

When the building is ready to be tested (from the system functional test), the database can be a tool for the building owner to get an overview of the building and technical systems. To get a full overview, more information has to be imported in the database, like:

- space functional program (database with the planned function of each room)
- database with all user equipment
- etc

From a database with this information, multidisciplinary reports can be extracted:

- What user equipment has influence on the technical systems
    - What technical system is influenced
    - In which rooms is the equipment placed
- Which rooms has individual temperature/lighting control
- Which technical systems supplies the different areas/rooms
    - Heating, ventilation, power, cooling
- The relation between the technical systems
    - distribution panels supply technical systems
    - cabling between systems/equipment
    - distribution panels supply equipment

All this information has always been available in construction processes, but is seldom easy available or shown in multidisciplinary reports.

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