

# COMMISSIONING OF BUILDING HVAC SYSTEMS FOR IMPROVED ENERGY PERFORMANCE.

## A SUMMARY OF ANNEX 40 RESULTS

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### Summary

Annex 40 is an international research project which aims at developing, validating and documenting tools for commissioning of buildings and building services. A few months before the end of this 4 years project one presents here an overview of its main achievements.

These achievements can be split in 4 categories: 1) tools to manage the commissioning process, 2) manual commissioning tools, 3) approaches to use building energy management system to assist in building commissioning, 4) approaches to use component as well as whole building models to improve commissioning.

Keywords: commissioning, HVAC, energy

### INTRODUCTION

The demands of building users regarding the environment are growing. We all request a comfortable and healthy indoor environment but we do not accept any more excessive use of natural resources and pollution of outdoor environment.

The heating ventilation and air conditioning industry seeks solution to fulfil these higher requirements. Many new products and systems are developed such as high efficiency generation systems using renewable, low energy cooling systems, natural ventilation systems, integrated control systems... We are clearly leaving the time of low efficiency stand alone products to enter the period of high efficiency integrated systems.

Moving from products to systems enables to develop more efficient and flexible solutions but leads to a higher level of complexity. Complexity for the building owner who shall define more in details the demands. Complexity for the designer who has to define a full system on the basis of a growing number of attractive components. Complexity for the installer who has to install systems which are all different and often innovative. Complexity for the users which have

access to more and more choices for the operation of the building.

The management of this complexity requests new approaches, new skills, new tools. Commissioning is one of these new approaches to manage the complexity of today's HVAC systems.

#### Annex 40

The Energy Conservation in Buildings and Community System programme of the International Energy Agency supports has supported for years project to facilitate and accelerate the introduction of energy conservation, and environmentally sustainable technologies into healthy buildings and community systems.

In 2001 a project called Annex40 was launched on Commissioning of Building HVAC Systems for Improved Energy Performance. The goal was to develop, validate and document tools for commissioning of buildings and building services.

10 countries ( Japan, France, Canada, Belgium, Switzerland, Sweden, USA, Germany, Norway, Finland) took part as full members, observers participated from 4 other countries (The Netherlands, Korea, China, Hungary).

The Annex is organized in 5 tasks according to the structure illustrated in Figure 1:

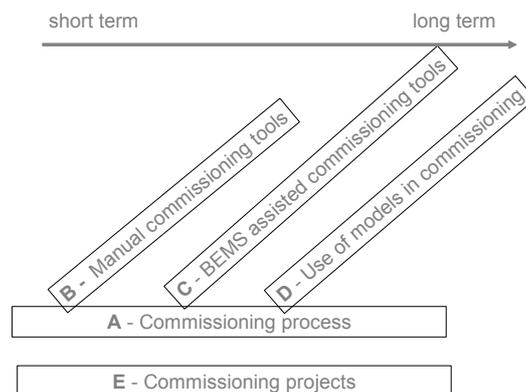


Figure 1 : Organisation of Annex 40

The annex is now close to its end and one presents here an overview of the main achievements of the different tasks.

### TOOLS TO MANAGE THE COMMISSIONING PROCESS

The key challenge to commission a building is to well manage the process. A central document for that purpose is the commissioning plan which defines the actions to be performed. The commissioning plan will be the key tool for the different players to understand what is meant by commissioning on a specific project, what amount of effort and money it will required and how it will be managed.

Three types of tools were developed or used within the annex to support the definition and application of the commissioning plan: standard model commissioning plans, checklist and matrix for quality control.

tool	description	Level of detail
<a href="#">Standard model commissioning plan (SMCP)</a>	A typical description of commissioning actions all along a project  To be used as a guideline to define the commissioning plan for a given project	Medium
<a href="#">Checklist</a>	Minimum level of definition of a commissioning plan.  Is specific to a given type of HVAC system	Low
<a href="#">Matrix for Quality Control (MQC)</a>	An extended tool for the management of the quality of the whole construction project.  Includes commissioning plan as well as other elements in a very structured way	High

Examples of standard model commissioning plans, check list and matrix for

quality control will be available on the final annex CD. They will be supported by description of their application to different projects.

In addition to these tools a detailed multilingual glossary is developed and will be available in the annex report and CD.

### **MANUAL COMMISSIONING TOOLS**

Functional performance test are the core of commissioning. They are devoted to the detection of possible malfunctions and to their diagnosis. The malfunction may be due to : Selection or sizing mistake, Manufacturing fault or initial deterioration, Installation fault, Wrong tuning, Control failure, Abnormal conditions of use.

A standard format was defined to describe the Functional Testing Procedures and different procedures were developed and apply. The annex report describes a general approach to develop FPT procedures, a set of documented procedures and also includes a description of main sources of existing FPT.

### **THE USE OF BUILDING ENERGY MANAGEMENT SYSTEM TO ASSIST IN BUILDING COMMISSIONING**

Building energy management systems (BEMS) are seen by some players as a future key tool to enable an efficient commissioning. Nevertheless this dream can be achieved only if the BEMS system itself is properly commissioned.

The annex has realised an enquiry on the state of the art of BEMS commissioning in Japan, Canada, USA and France. The results presented in the report highlight the difficulties to be overcome.

The annex has then clarified the different approaches for using BEMS to commission HVAC and energy systems.

Two approaches to commissioning using the control system that have been considered in Annex 40 are passive testing and active testing. Passive tests involve using the control system to monitor and record sensor and actuator signals from energy systems operating under normal conditions. These tests are non-invasive in that they do not introduce any artificial disturbances into the systems. The most important aspects of passive testing are to properly select points to monitor and to apply appropriate data analysis methods. Active testing

involves making artificial changes to the systems under control in order to interrogate behavior. Active tests can reveal more information about a controlled system in a shorter time period than passive tests, but can be more expensive to implement.

Four main techniques were studied to implement automatic commissioning tools: model based, rule based, performance index based, logic tracer.

1. A model-based method involves comparing predictions of a model with the measured performance of a component or system.
2. A rule-based method transform physical and logical prior (expert) knowledge of a system into a set of rules, e.g., IF/THEN. The rules should duplicate the same reasoning that an expert would use. Performance indices are calculated values or control values that quantify the performance of a control loop, component, or system.
3. The performance index-based method involves comparing indices of similar controllers or components under specific conditions (outside air temperature, humidity, etc) or under a specific period (instantaneous, one hour, one week). Limits can be set to define a range of values corresponding to acceptable behavior and values that lie outside the range can indicate that a problem exists.
4. The control logic tracer approach allows control algorithms to be visualized and understood by designers and operation managers. This understanding enables to diagnose failures by tracking down the causes when operation or control in a HVAC system fails.

The annex has also address possible approaches for the implementation of the automation of commissioning. It includes a description of the different possible architectures and a discussion about communication issues, data bases, and user interfaces.

In addition to the description of these different techniques and on the approach to follow to implement them in a real BEMS, the final report describes 8 automated tools tested during the annex.

### **USE OF MODELS IN COMMISSIONING**

Models are more and more widely use for the design of HVAC components

and for the design of whole buildings and energy systems. The annex has developed approaches for the application of models for commissioning purposes.

At the component levels two main use of models were studied. 1) Using models to perform Functional Performance Test. The goal is here to include the model in the Functional Performance Testing Procedure applied on site. 2) Using models to design tests. The goal is here to optimize the Functional Testing Procedure. In this case the models are used by the test designer but not by the persons who apply the tests.

The step to follow in these two cases are described in the annex report. For performance test using models these steps are the followings:

- Configure the models with manufacturer data and system design information
- Perform an active test under a specific set of conditions to check initial performance
- Analyse test result and fix possible problems
- If needed perform again an active test
- Re calibrate the model using results of active test
- Monitor performance during on going operation.

The annex also enabled to describe different architectures which can be applied to implement Functional Performance Test using models in real buildings. The architectures differ by the ways used to transfer information between models and measurements.

Finally, in order to facilitate the use of models in commissioning the annex has collected a model library which and a toolbox of software routines developed to help implementing model based functional testing tools at the component level.

#### **USE OF MODELS AT THE WHOLE BUILDING LEVEL**

A clear understanding of the different possible use of models at the whole building level for commissioning was achieved by the annex. 6 categories were defined

Models may be used early in the design process – to assist in “commissioning” the design. Typically, models configured for rapid use, such as TRNSYS Light, Enerwin, etc. are used for this purpose. They may or may not be used for energy simulation. This modelling is not used during the commissioning after construction.

Use in the standard commissioning of new buildings. A design simulation of the building may be used to predict heating cooling performance and the predictions may be compared with measured use –significant deviations then serve as clues to identify problems in the building. The design simulation should have the occupancy schedules changed if necessary to reflect the actual occupancy of the building. Simulation may also be used at this stage to refine and optimize control strategies. Relatively complex simulations are used for this purpose.

Design simulation for on-going commissioning. The same simulation developed in the design process may then be run at specified intervals, e.g. weekly, monthly, etc. and the model predictions compared with the measured energy consumption. Deviations may serve to trigger an alarm when building performance degrades. Diagnostics for the probable causes of such deviations need to be developed. These simulations will probably be run off-line, but may be run on-line if the control system can accommodate the simulation.

Use of calibrated simulation for retro-commissioning. A rapidly calibrated simulation may be used as a diagnostic aid and to predict the savings that will be achieved from implementing proposed commissioning measures.

Calibrated simulation for on-going commissioning. The calibrated simulation developed in the retro-Cx process may then be run at specified intervals, e.g. weekly, monthly, etc. and the model predictions compared with the measured energy consumption. Deviations may serve to trigger an alarm when building performance degrades. Diagnostics for the probable causes of such deviations need to be developed. These simulations may be run off-line or on-line if the control system can accommodate the simulation.

Use of simulation to evaluate new control code. Either the design simulation or a calibrated simulation may be used to test the energy impact of proposed changes in control code before implementation. This will generally be done off-line.

A series of papers illustrating each one simulation applications will be

available on the annex CD.

### COMMISSIONING PROJECTS

Most of the tools developed within the annex were applied in real commissioning projects. The annex report includes a synthesis of these projects. It gives a vision of the variety of applications of commissioning.

### ANNEX DELIVERABLES

Three groups of deliverables will be publicly available in spring 2005 after a revision process managed by the executive committee of the AIE ECBCS. The annex report, a synthesis of the annex work will enable the interested readers to get in about 100 pages an overview of the annex work.

The annex web site [www.commissioning-hvac.org](http://www.commissioning-hvac.org) and CD will present in addition the detailed results of the annex: tools description, software presentation, commissioning site presentation...

The ICEBO2004 conference enables a detailed description of many of the work tools developed within the annex.

#### Acknowledgement

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