FOUR YEARS OF ON-GOING COMMISSIONIONG IN CTEC-VARENNES BUILDING WITH A BEMS ASSISTED CX TOOL

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Summary
The development of Building Energy Management Systems (BEMS) offers new opportunities to automate some aspects of commissioning. Reduction of process cost and manual effort on site, transformation of a one time application to a continuous process generating benefits over the entire life of a building, development of a detail systematic approach to improve quality assurance process and integration of energy audit capabilities to improve the overall performance of buildings are some of them.

This paper presents the four years result of an on-going commissioning project performed in the CANMET Energy Technology Centre - Varennes (CETC-V) building that has generated 35 % reduction in the energy used. An on-going BEMS assisted commissioning tool, DABO, developed under IEA Annex 40 by the Canadian team has largely contributed in the verification and optimisation of the performance of the building.

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KEYWORDS
Commissioning, On-going commissioning, HVAC, Fault Detection and Diagnosis, Building energy management system.

1. INTRODUCTION

This paper builds onthe paper "A BEMS-Assisted Commissioning tool to improve the energy performance of HVAC systems" where, (Choiniere et Corsi 2003) described the use of BEMS assisted commissioning tools and have identified the potential to facilitate the application of initial, retro and on-going commissioning process.

In this context and to identify the best tool functions to automate, an on-going commissioning project has been conducted in parallel with the development of DABO, a BEMS assisted commissioning tool developed under IEA Annex 40 by the Canadian team that verifies and optimizes the performance of building HVAC systems using the capabilities of BEMS.

This paper presents the results of the four-year on-going commissioning project conducted at the CETC-V building.

2. BACKGROUND

The work presented in this paper describes a demonstration project that was part of Canada's contribution to the International Energy Agency's (IEA 2001a) Annex 40, Commissioning of Building HVAC Systems for Improved Energy Performance. Annex 40 is a research project within the framework of the Energy Conservation in Building and Community Systems (ECBCS) program of the IEA. The objective of Annex 40 was to develop, validate and document tools for commissioning of buildings and building services that will facilitate verifying and optimizing the performance of energy systems within a building.

A result of these research efforts has been the commissioning module of the Diagnostic Agent for Building Operators (DABO) (Choinière 2003), developed by the CANMET Energy Technology Centre-Varennes.

On-going commissioning (IEA 2001a) is defined as a systematic approach used to inspect, verify and document the installations and operation of building systems to ensure that they operate at their optimum energy performance levels. This state is only achieved when buildings consume the minimum energy at the lowest cost while simultaneously considering the building's function and comfort level, available energy source(s), building energy systems and energy rates. To be efficient, many tasks must be performed continuously, an undertaking that can be facilitated by monitoring the condition of HVAC systems and building energy consumption using a BEMS.

Since 1998, the CTEC-V building has been used to test and demonstrate various tools developed in the contex of the CANMET Intelligent Building Operating Technologies R&D plan (Jean, G. 2004) of which DABO is the central component. In this context and principally for the last 4 years an on-going commissioning process has been conducted. DABO, a software package that uses a hybrid technology composed of conventional and artificial intelligence techniques to ensure optimum operation of building systems has been used actively in the project delivery system for the continuous monitoring of all HVAC equipment and meters (e.g., terminal unit, air handling unit, plant equipment and energy meters), the analysis of the incoming information, the detection and diagnosis of major HVAC component faults , non optimum set points and sequence of operation and the monitoring of implemented measures .

3. DABO, A BEMS-ASSISTED COMMISSIONING TOOL

The commissioning tool, designed to assist and perform some functions described in the on-going commissioning process section is a module of the DABO, the Diagnostic Agent for Building Operators (Choinière 2001) which serves as the interface between the end-user (e.g., building operator, commissioning agent, energy manager) and the control system (BEMS).

As shown in figure 1, the tool continuously monitors the building control data and stores it in a structured database to be used on-line or upon request. Data resulting from standardised test procedures invoked manually or automatically are also stored in the database. The database functions as a server for reasoning algorithms that perform intelligent analyses of the monitored data, perform additional automated tests of components and systems, identify faults and diagnosing them, and evaluate potential improvements in energy efficiency. The tool produces reports adapted to the different partners involved in the on-going commissioning process (Building operators, service technicians, energy managers, commissioning agents, HVAC&R engineers).

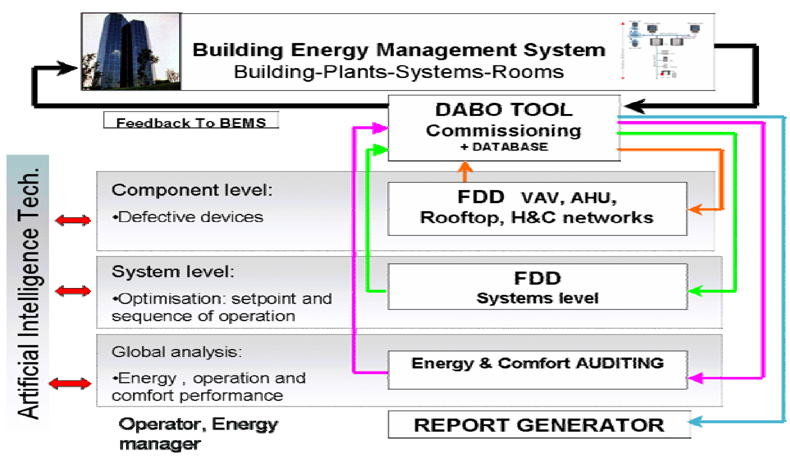

Figure 1: Structure of the on-going commissioning tool for HVAC systems embedded in DABO.

The standardized test procedures are performed at three levels. At the first level, an hourly component analysis of individual HVAC devices and equipment is performed automatically using a combination of control loop indices and expert rules to verify their proper operation. The second level of testing consists of an integrated system analysis to verify the operation and energy performance of the overall HVAC system over a longer period of time (e.g., hours, days, weeks or months). At this level a set of component performance indices and expert rules is also used in the analysis. The third level performs basic energy performance and operation control quality reports that provide the information required to evaluate potential energy measures on specific devices. To reduce data traffic on the communication networks, the tool's steady state detectors and zone fault detectors are directly embedded in controllers. Specific applications of the fault detection and diagnostic (FDD) methods implemented in DABO are described further in Section C of IEA 2001b

4. ON-GOING COMMISSIONING PROJECT

The demonstration building is the CANMET Technology Energy Center (CETC-V) located in Varennes, Québec, Canada. Built in 1992, the single floor 3600 m^2 building includes office spaces for 90 people as well as eight laboratories, two industrial pilot plants, conference rooms and a cafeteria.

The building is designed to be energy efficient incorporates low energy technologies such as a passive solar preheating device, ice bank storage, photovoltaic cells, as well as a central gas heating plant and a central electric chilled water plant. Each area of the building is served by a specific air system designed for its occupation. The HVAC systems are central controlled by a BEMS system. (Table 1)

HVAC systems	**Capacity**	**Location**
Heating		
Fire tube boilers (2)	470 kW each	Building
1 primary and 5 secondary hydronic circuits, 7 pumps, constant volume		
Cooling		
1 air cooled chiller	406 kW	Building
2 ice bank tanks	1145 kW-hour	Building
1 hydronic circuit, 2 pumps, constant volume		
Air Handling system		
M1 (CAV, HEA)	2, 735 l/s	Pilot plant1
M2 (VAV, 100% fresh air, HEA,CO)	5,815 l/s	Laboratories
M3 (VAV, HEA, CO)	5,500 l/s	Office phase 1
M4 (CAV, HEA)	1,265 l/s	Storage phase 1
M5 (CAV)	160 l/s	Mechanical room
M6 (CAV)	1,030 l/s	Boiler room
M30(VAV, HEA, CO)	1,660 l/s	Office phase 2
M31(CAV, HEA)	5,200 l/s	Pilot plant 2
M32(CAV)	2,000 l/s	Mechanical room 2

Table 1 CTEC-Varennes HVAC systems

The on-going process started in 1999 and continued til 2004 aimed resolving operating problems, improve comfort, optimize energy use and recommend retrofits where necessary. Delivery of the on-going commissioning project system included a series of tasks performed in four steps; planning, investigation, implementation and hand off (Table 2). Tasks survied out with DABO are shown in italic. As it is an on-going-commissioning process, the investigation and implementation has been gradually and continuously performed over the 4 years period and DABO's still use on a regular basis to insure the persistence of savings and detect new deficiencies.
The initial project is almost completed; only final reports remain to be presented.

PLANNING
• Choose the team • Define project objectives, scope and deliverables • Review building documentation and energy bills • Develop Commissioning plan • Initiate cooperation with the building operation team

INVESTIGATION (continuous over 4 years)

- Assessment
  - Site, design and occupant needs assessment
- *Installation of DABO*
- *Develop and carry out diagnostic tests and system monitoring*
- *Analyse monitoring results*
- Develop list of deficiencies and improvement
  - Include capital improvement opportunities
  - Include training recommendations
- Select the most cost effective opportunities

IMPLEMENTATION (continuous over 4 years)

- Implement improvements identified in investigation phase
- *Retest and re-monitor to confirm the results*
- Adjust, if necessary, the improvements carried out during the investigation phase
- Review the energy consumption reduction estimates
- Building Operator training and occupant information

HAND OFF

- Prepare and present final report
  - As-Built Recommissioning work
  - New sequence of operation manual
  - TAB report (air, water)
  - Energy baseline
  - Check-up of energy bills (3 months)
  - Proposal for EE measures with longer payback
- *Implement a continuous commissioning process and an energy management plan*
  - *Ensure that the use of DABO is well understood by the operators so as to maintain the recommissioning benefits*

Table 2 The on-going commissioning delivery project system followed at CETC-V

5. RESULTS

Major measures and corrections describe below were identified and gradually implemented over the project. Where available, the installation costs are shown.

Modification of air Handling Unit (AHU) and room terminal unit operation to meet the actual user needs.

In Pilot Plant 2, the 100% fresh air AHU day operation schedule was modified to operate in recirculation, a local switch was installed to bypass the normal operation when test bench operation require.

Laboratories designed for hazardous operation are actually operated without contaminant emission or as office spaces. Room terminal device operation has been optimised to the current occupation (reduction of number of minimum air change per hour, removal of room pressure control)

AHU operation schedule resets
AHU start/stops schedules were optimized to the real occupancy schedules to minimize the runtime.

AHU temperature resets
AHU supply air temperature set points have been fine tuned to reduce the room terminal reheat. Where possible, supply air set points based on return air temperature have been replaced by direct room temperature feedbacks.

AHU pressure resets
Variable air volume supply pressures have been optimised based on the actual zone airflow needs.

Improved economizer operation and reset minimum fresh air setting
Enthalpy algorithms have been improved, Minimum fresh air has been adjusted to the actual needs.

Optimize chiller/ice bank control
Criteria and set points for chiller-ice bank start-stops were fine-tuned as a function of the building load, the outside air temperature and the building electric peak load demand. These actions have improved the system staging sequences, the part load chiller efficiency, the supply water temperature stability and have reduced the short cycling of compressors. Priority to use the smallest pump has also been implemented to reduce the electric power and the pump heat transfer into the chilled water.

Optimise boiler Control
Boilers staging, start/stop sequence and hot water supply temperature reset schedules were refined as a function of the time of the day and the outside air temperature. These have reduced the short cycling of the burner during night and the morning warm-up period. It has also reduced pipe heat loss and improved part load room temperature control.

Heating pump operation scheduled resets
Pump start/stops schedules were optimized to the actual occupancy and building heating load to minimize runtime

Calibration of sensors and tuning of PID loop (detected by DABO)
Keys sensors were recalibrated and unstable control loops were tuned.

Replacement of leaking heating valves($3,000 CDN)

Addition of heating capacities in 3 rooms ($10,000 CDN)
This has allowed us to initiate a night set back temperature control strategy and reduce the heating supply water temperature

Addition and replacement of DDC control ($20,000 CDN)
Boilers and chillers have been linked to the BEMS. Locally, sensors have been added on some AHU's to improve performance of DABO as well as provide better control.

Installation of Variable speed drives ($12,000 CDN)
Variable speed drives have replaced inlet vanes on 3 fans where the utilisation profiles indicated a short payback

Connection of the solar passive preheating device to AHU M2 ($15,000CDN)
As a result of converting Pilot Plant 2 to normal recirculation mode from 100% fresh air, its passive solar fresh air preheater was connected to also serve AHU M2 (Labo), which remain as a 100% make-up system.

6. Energy reduction

The figure 2 shows the impact of the on-going commissioning project implemented on CETC-V energy consumption since 1998.

During this period, measures implemented have resulted in a 35% reduction in electricity and 45% in natural gas consumption. For 2003-04, the cost savings represented $62,045 CDN, or 40% of the building energy bills

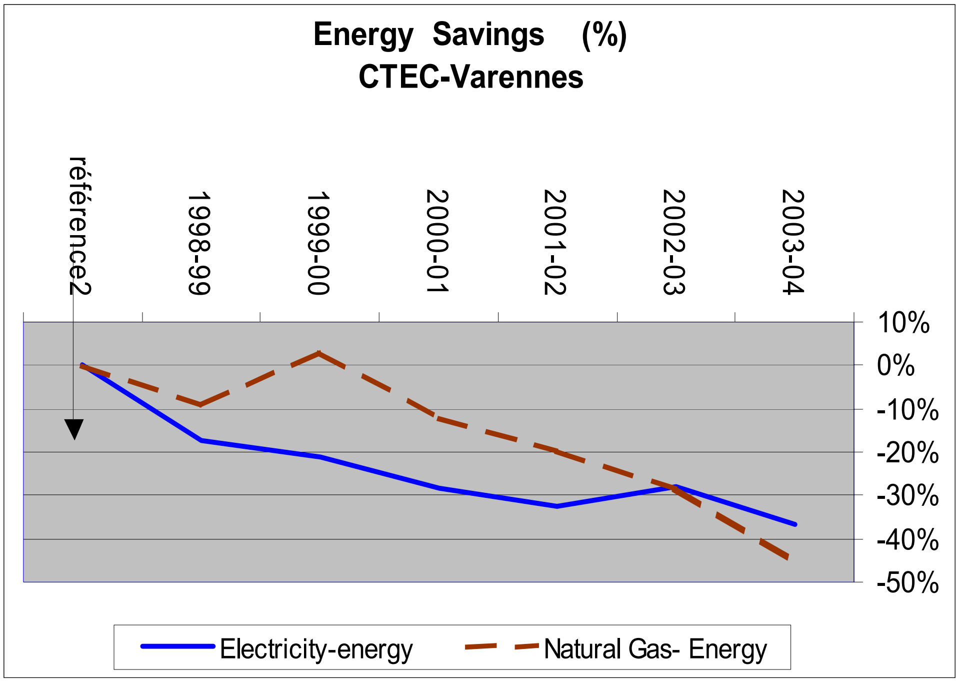

Figure 2. On-going commissioning impact on CETC-V building energy cosumption

The project payback period was however impossible to establish since the project primary aim was to develop and determine the application of BEMS assisted tool into the on-going commissioning process.

New demonstration projects are actually in the planning stages, to evaluate all the associated cost and the full impact on the on-going commissioning project payback.

7. CONCLUSIONS

An on-going commissioning process ensures that buildings achieve and operate at their optimized energy cost and performance levels, while ensuring comfort conditions for occupants. The project conducted at the CTEC-Varennes has generated 35% reduction in the electric use and 45% in the natural gas consumption.

DABO, a BEMS-assisted commissioning tool has monitored the enormous amounts of data produced by BEMS and provided an extensive analysis of the incoming data.

The use of a BEMS assisted commissioning tool has helped to circumvent commissioning barriers by automating some parts of the process, which has reduced the costs for commissioning. Developing a detailed systematic automated approach has improved the quality assurance process and the overall performance of the building. Furthermore, automating this essentially manual process has allowed its application on an on-going basis, generating benefits over the entire life of the CETC-Varennes building.

The future potential market opportunities have been proven by the success of the tool's usefulness and the energy consumption reductions.

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8. ACKNOWLEDGEMENTS

This work has been funded by the Panel on Energy Research and Development (PERD), a Canadian government program.

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