AUTOMATIC CX TOOL FOR ELECTRICAL BUILDING

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ABSTRACT

Commissioning (Cx) consists in specifying building system performance requirements set by the owner, auditing different judgments and actions performed by the Cx related parties in order to achieve the performance, writing necessary and sufficient documentation, and verifying that the system enables proper operation and maintenance through functional performance testing.

The process of Cx is the whole set of tasks ensuring that the performance of buildings meet the awaited performance. This process comes within the scope of Kyoto's protocol by reducing energy consumption and also emission of green house gases (GHG).

This study is carried out for an exemplary electrical building of educational facilities. The objectives of the project are to develop and test a Cx tool in order to increase the energy efficiency of the building while ensuring indoor comfort.

This study shows that an appropriate design of a building is not sufficient to ensure an effective management of energy. The Cx of installations is an essential step to meet the required energy performances.

INTRODUCTION

Buildings and systems are more and more complex and use high efficiency technology. Therefore, the energy performance of the building doesn't always meet the requirement, defined earlier in the process of construction. Malfunctioning of the installations of HVAC (Heating, Ventilation and Air Conditioning) are more linked to the Cx process [AKASHI, 2004] than to the equipments reliability. In this paper, the aim of Cx is to improve the reliability of the electrical HVAC installations.

CSTB & EDF decided to develop an automatic Cx tool for initial and continuous Cx, conception and assessment in a nursery school. Cx of the technical installations has to check that the required performances for thermal comfort and energy management have been reached [ASHRAE, 2005].

The aim of this paper is to show the methodology used to develop an automatic Cx tool for electrical buildings. The tool contains, on the one hand, several Functional Test Procedures (FTPs) for most of electrical systems used in non-residential building and, on the other hand, all the documents and reports to follow up the energy performance of buildings

This tool has been developed in collaboration between CSTB (Centre Scientifique et Technique du Bâtiment) & EDF (Electricité de France) from 2003 to 2006. It has been tested during all its development on a demonstration site to make sure that it corresponds to energy managers' expectations. The selected site was a nursery school located in Crèvecoeur-le-Grand near Paris in France.

DESCRIPTION OF THE DEMONSTRATION SITE

The demonstration site is a nursery school. It's a new building of 2429 m² and accommodates 160 pupils.

Figure 1: Photo of the nursery school

The technical applications managed by the Building Energy Management System (BEMS) are:

- Heating system (electric heating ceiling panel),
- Ventilation (mechanical ventilation system and air handling units),
- Lighting,
- Domestic hot water.

Architecture of the BEMS takes into account:

- Management of power demand and energy consumption: load shedding, sub metering, optimization of power demand according to the structure of the electricity tariff,
- Heating: scheduling, zoning, optimal start/stop, room temperature control (set point temperature, etc),
- Lighting & Ventilation: scheduling, zoning,
- Domestic hot water: scheduling.

METHODOLOGY AND TOOL SPECIFICATIONS

This Cx tool is intended for the end user, i.e. the energy manager. A particular methodology has been developed.

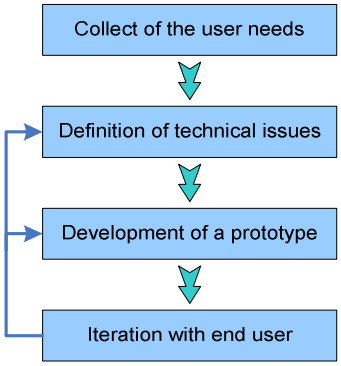


Figure 2: Methodology used to develop the tool

The first step of the methodology is to collect the user needs through enquiries.

The second step consists in the definition of the technical issues, i.e. writing the book of specifications of the objectives of the Cx tool.

The third step of this methodology is the development of a prototype of Cx tool, which has to:

- Be a stand-alone tool,
- Integrate an interface with the BEMS through data logging,
- Allow application of automatic FTPs.

The last step deals with iterations with the end user to assess the tool and to improve the user interface.

GENERAL DESCRIPTION OF THE TOOL

The automatic Cx tool for electrical building has been developed under Matlab [MATLAB, 2005]. This environment was selected for its capacity to use complex matrixes.

Its goal is to help the designers and Cx providers to test and evaluate energy performance of an electrical building. The objective of the tool is to check that HVAC systems, controlled by a BEMS, provide the expected performances as regards comfort for the occupants, energy profits and safeguarding of the technical installations [VAEZI-NEJAD, 2004].

The structure of the tool is divided into **5** steps:

- **Identification of the building:** the objective of this part is to identify the specific information about the building and its technical description (size, applications, electricity tariff, etc.) in order to perform the Cx tests.
- **Manual commissioning:** the objective of this part is to check the technical installations (presence, location, cabling of the sensor and actuators).
- **Cx of BEMS:** the objective of this part is to check the compliance of the functions implemented on the BEMS with the building owner requirements and to check that the functions operate according to the book of specification.
- **Optimizing commissioning:** the objective of this part is to optimize the performance of the implemented functions in term of thermal comfort, energy consumptions and operating costs.
- **Cx reports:** the objective of this part is to report the work of the Cx provider to the building owner. It allows to follow up the Cx progress and to save results. This document has to be updated after each use.

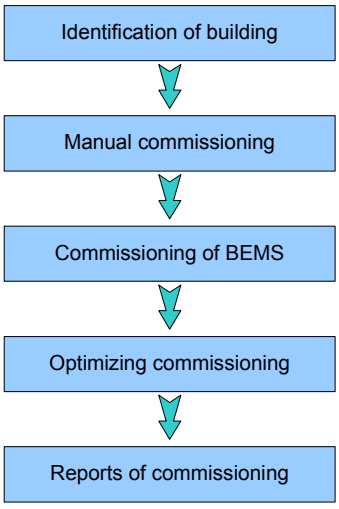


Figure 3: The Cx tool 5 steps

These five steps are all necessary to describe fully and clearly the process of Cx for an electrical building but not sufficient. Nevertheless, some others tasks which don't appear in this tool are also necessary to ensure a good Cx [HANNACHI, 2005].

Indeed, the calculation of indicators of FTPs needs some temperature sensors and energy meters. Their prescriptions have to be taken into account at the beginning of the process of construction as said in [AKIN, 2004].

IDENTIFICATION OF THE BUILDING

The objective of this part is to identify the specific information about the building and its technical description (size, applications, tariffs of electricity, etc.) in order to perform the Cx tests.

This step allows configuring the tool in function of the selected building. First, the Cx provider has to give (Figure 4):

- General information about the building (surface, volume, occupancy, etc.),
- The HVAC system installed in the building (heating, lighting, etc).

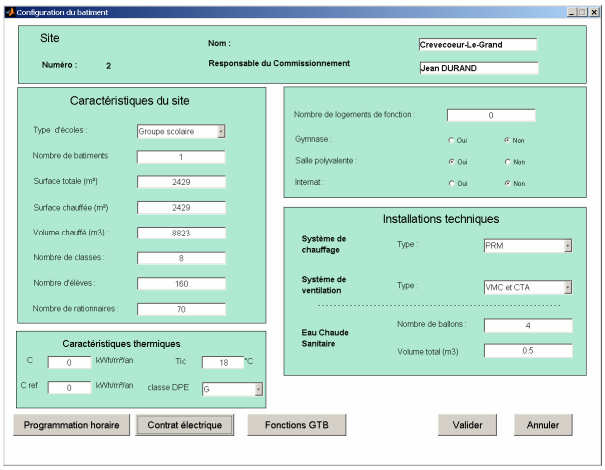


Figure 4: Identification of the building

In order to simplify the work of the Cx provider, the quantity of data to fill up the tool is limited to the data essential to perform FTPs selected, which depend on the HVAC system installed (Figure 5). The Cx provider is able to add missing information as soon as it is available.

The information described in the tool allows:

- To define the tests available according to the configuration of the building,
- To parameterize the tests to carry out (ex: instructions, contractual demands, etc),
- To define the indicators to evaluate the tests of optimization (ex: consumptions per square meter, consumptions per person, etc.),
- To check the accuracy of information coming from the BEMS by comparison with those indicated by the Cx provider.

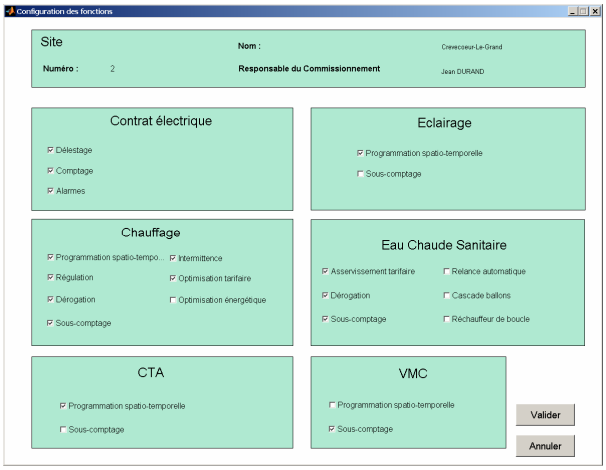


Figure 5: Existing systems in the building

In a second step, the Cx provider has to define precisely the structure of the electricity tariff. Maximal value and scenario are also needed.

Cx provider has also to define the required power per application.

MANUAL COMMISSIONING

The objective of this part is to check the technical installations (presence, location, cabling of the sensor and actuators).

The objective of the manual Cx are:

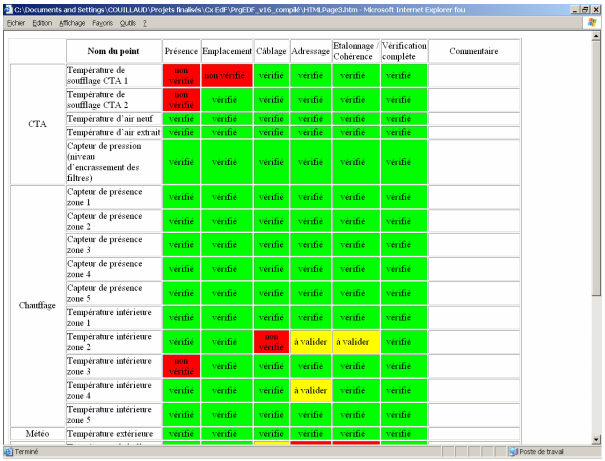
- To supply the Cx provider with procedures and checklists of Cx tasks,
- To allow the Cx provider to visualize and save in Cx report the progress of Cx.

The manual Cx permits to check three points:

- The HVAC system (sensors, actuators, networks and local units). The Cx provider is able to check, according to the element, its presence, its location, its wiring, its supplying, etc,
- The BEMS: the Cx provider can check that all FTPs are implemented,
- The documentation: the Cx provider can check that the present documentation contains all specific information to correctly perform the Cx.

For the moment, results of manual Cx are presented in the form of html dynamic tables. The user can directly modify the table by clicking within it.

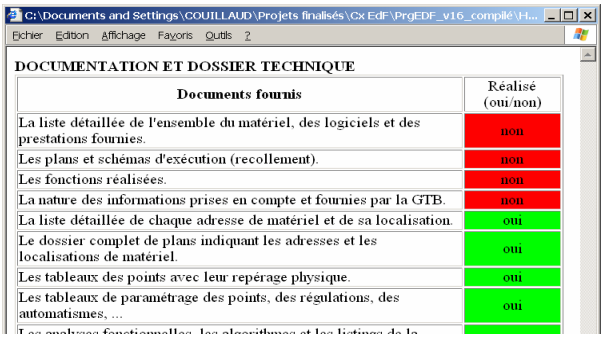
Several checklists are available to help the user to carry out the manual Cx. A first one guides the user to check the HVAC system (Figure 6). It is composed of a list of questions and the user has to click on the list to define if the task is correctly done, badly done or still to be done.



	Nom du point	Présence	Emplacement	Câblage	Adressage	Etalonnage / Cohérence	Vérification complète	Commentaire
CTA	Température de soufflage CTA 1	non vérifié	non vérifié	vérifié	vérifié	vérifié	vérifié	
	Température de soufflage CTA 2	non vérifié	vérifié	vérifié	vérifié	vérifié	vérifié	
	Température d'air neuf	vérifié	vérifié	vérifié	vérifié	vérifié	vérifié	
	Température d'air extrait	vérifié	vérifié	vérifié	vérifié	vérifié	vérifié	
	Capteur de pression (suivant d'encrassement des filtres)	vérifié	vérifié	vérifié	vérifié	vérifié	vérifié	
Chauffage	Capteur de présence zone 1	vérifié	vérifié	vérifié	vérifié	vérifié	vérifié	
	Capteur de présence zone 2	vérifié	vérifié	vérifié	vérifié	vérifié	vérifié	
	Capteur de présence zone 3	vérifié	vérifié	vérifié	vérifié	vérifié	vérifié	
	Capteur de présence zone 4	vérifié	vérifié	vérifié	vérifié	vérifié	vérifié	
	Capteur de présence zone 5	vérifié	vérifié	vérifié	vérifié	vérifié	vérifié	
	Température intérieure zone 1	vérifié	vérifié	vérifié	vérifié	vérifié	vérifié	
	Température intérieure zone 2	vérifié	vérifié	non vérifié	à valider	à valider	vérifié	
	Température intérieure zone 3	non vérifié	vérifié	vérifié	vérifié	vérifié	vérifié	
	Température intérieure zone 4	vérifié	vérifié	vérifié	à valider	vérifié	vérifié	
	Température intérieure zone 5	vérifié	vérifié	vérifié	vérifié	vérifié	vérifié	
Météo	Température extérieure	vérifié	vérifié	vérifié	vérifié	vérifié	vérifié	

Figure 6: Results of the checking of the components

A second list permits the user to define if all necessary documents and information are available or not (Figure 7).



DOCUMENTATION ET DOSSIER TECHNIQUE

Documents fournis	Réalisé (oui/non)
La liste détaillée de l'ensemble du matériel, des logiciels et des prestations fournies.	non
Les plans et schémas d'exécution (recollement).	non
Les fonctions réalisées.	non
La nature des informations prises en compte et fournies par la GTB.	non
La liste détaillée de chaque adresse de matériel et de sa localisation.	oui
Le dossier complet de plans indiquant les adresses et les localisations de matériel.	oui
Les tableaux des points avec leur repérage physique.	oui
Les tableaux de paramétrage des points, des régulations, des automatismes, ...	oui

Figure 7: Results of the checking of technical documents

The Cx provider can thus estimate the percentage of manual Cx tasks realization and decide on the end of the task according to the predefined requirements for the building.

CX OF THE BEMS

The objective of this part is to check the compliance of the functions implemented on the BEMS with the building owner requirements and to check that the functions operate according to the book of specification.

Actually, automatic FTPs have been implemented in the BEMS. Functional tests are carried out with the saved data by the BEMS from building for several years of operating. Event-driven functions (deviation, control on event, etc.) require the intervention of an operator to generate the event.

Available FTPs depend on:

- Information provided by the Cx provider during the building's identification step,
- Data saved by BEMS (frequency/period of sampling and length of data recording).

Several FTPs have been implemented into the automatic Cx tool:

- Management of the electricity tariff (load shedding, electricity meter per tariff period),
- Electricity meter for each HVAC application,
- Heating intermittence,
- Thermal comfort in occupancy period.

The next paragraphs are dedicated to some examples to highlight some of the options of the automatic Cx tool. The examples presented are the electricity tariff period, the hourly programming of the lighting and the hourly programming of the heating.

Results of automatic FTPs are presented in graphs or tables.

Electricity tariff structure

As first example, the graph on Figure 8 shows the electric load measured by the BEMS and the electricity contractual level according to the period. This type of graph shows immediately the possible electric overload or an oversized electric_contract. The Cx provider can thus easily adjust the electric contract to the actual building loads.

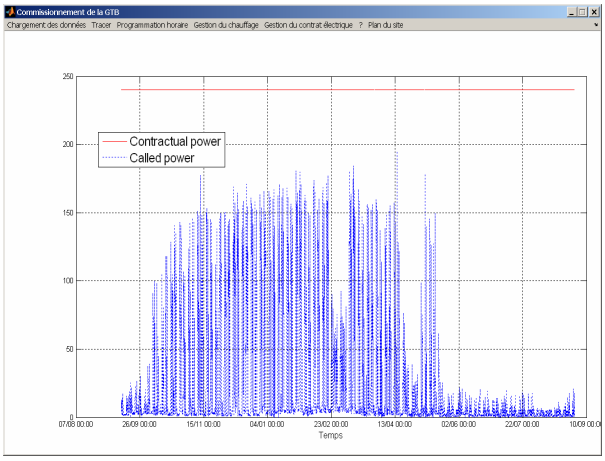


Figure 8: Electric called power

Lighting hourly programming

The second example shown in this section is the hourly programming of lighting (Figure 9). This graph shows the coherence between the hourly programming of lighting implemented in BEMS (grey patched) and the real utilization of lighting (blue solid line). The Cx provider can easily identify a malfunction in the use of light.

The solution for solving this malfunction is, for the Cx provider, to check the hourly programming implemented into the BEMS and to check the occupancy profile of the building.

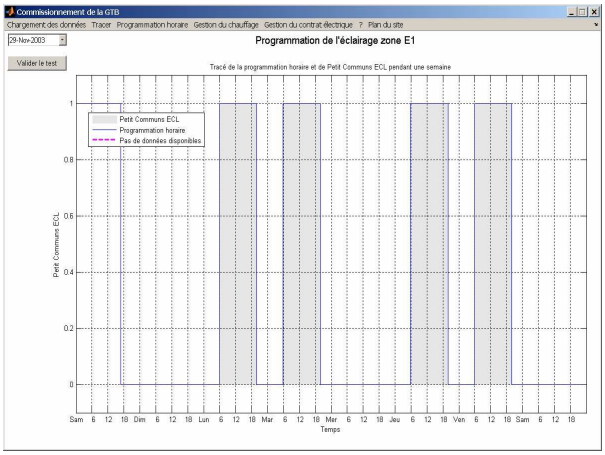


Figure 9: Hourly programming of lighting system

Heating hourly programming

The third example details the hourly programming of heating (Figure 10). The grey-patched part corresponds to the minimum indoor temperature to reach implemented into the BEMS. The blue solid line adds to the previous schedule the optimal start stop period of the heating system.

This graph shows to the Cx provider the coherence between these two values. In case of malfunction, he has to correct the schedule programmed in the BEMS.

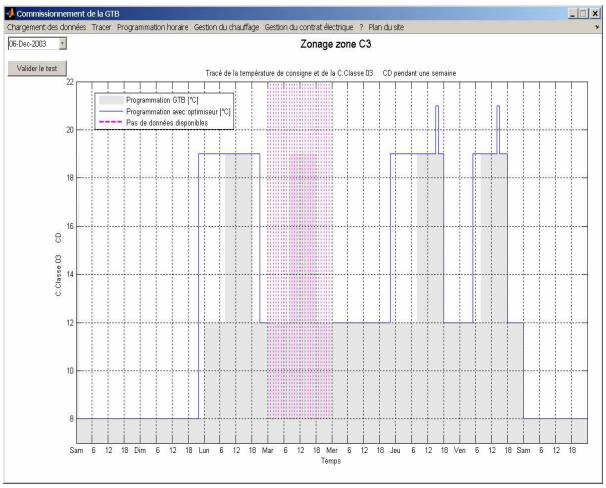


Figure 10: Hourly programming of heating system

The pink-patched part on the graph shows that there is no data available for the considered period.

For future works, active FTPs should be implemented. In this case, this Cx tool would be directly implemented into the BEMS. Thus, active tests could be executed during the operating phase.

On the one hand, active FTPs should be carried out according to the Cx provider schedule. On the other hand, automatic FTPs should be executed periodically by the BEMS and generate an alarm if there is some malfunctions.

OPTIMIZATION OF THE BUILDING PERFORMANCE

The objective of this part is to optimize the performance of the implemented functions in term of:

- Energy consumptions per application,
- Several indicators on thermal comfort,
- Operating costs.

Several automatic tests have been implemented to highlight the potential of energy management improvement:

- Management of electrical loads,
- Heating system management,
- Annual visualization of thermal comfort.

The next paragraphs are dedicated to some examples to highlight some of the options of the automatic Cx tool. The examples presented are the management of electrical loads, thermal comfort in building zones, calendar vision of the internal temperature and energy classification.

Management of electrical load

The management of electrical loads consists in adding the total power needed by each system and comparing it to the electricity tariff (Figure 11). The goal is to check if these two values are coherent.

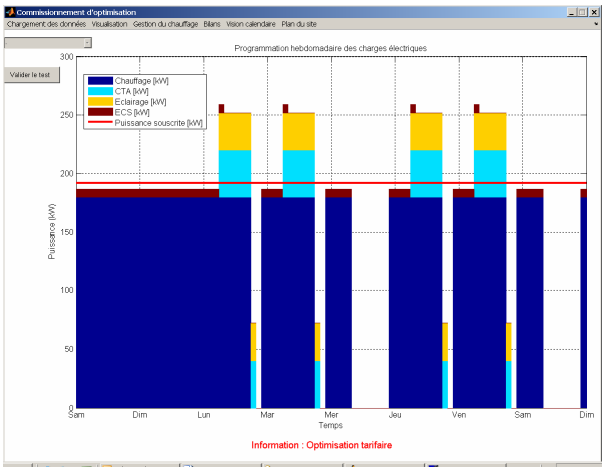


Figure 11: Management of electrical loads

Thermal comfort in building zones

The thermal comfort in building zones is defined in three classes (Figure 12): cold zone of discomfort (blue lower part), hot zone of discomfort (pink upper part) and comfort zone (white middle part).

By clicking on a point, a new window appears and shows details on this point:

- Name of the zone,
- Date,
- Outside temperature
- Graph of internal temperature including this point.

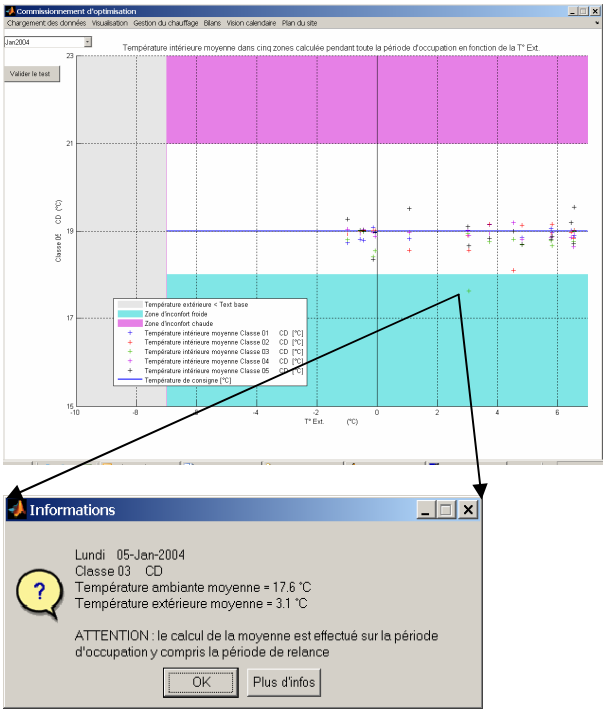


Figure 12: Thermal comfort in building zones

Calendar vision of the internal temperature

The calendar vision of the internal temperature allows the Cx provider to see the evolution of the selected internal temperature on the same figure for a large part of the year.

By clicking on a day, a new window appears and shows the evolution of the internal, outside and set point temperature.

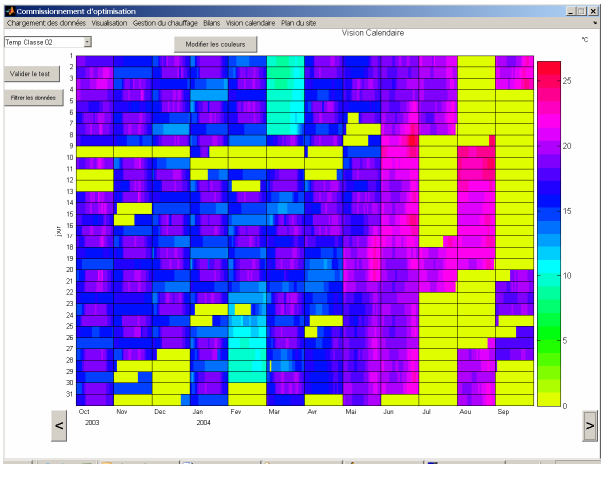


Figure 13: Calendar vision of the internal temperature

Energy classification

The energy classification used in this Cx tool is not the same as implemented in the Energy Performance Building Directive [EPBD, 2007]. It's a simplification of the EPBD not including the same methodology of calculation.

This energy classification (Figure 14) allows the Cx provider to follow the evolution of the energy performance of its building through time.

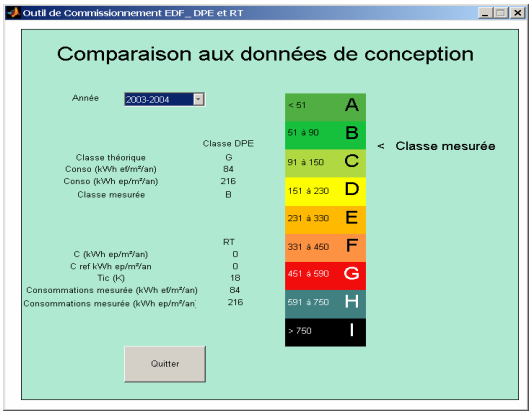


Figure 14: Energy classification of the building

CX REPORTS

The objective of this part is to report the work of the Cx provider to the building owner. It allows to follow up the Cx progress and to save results. This document has to be updated after each use.

Reports of Cx are meant to present in the form of table, the summary of the results of tests carried out by the Cx provider. It highlights the good performances of HVAC systems as well as the malfunctions.

Annual Cx reports allow to appreciate the evolution of the energy consumptions of the building and to evaluate the malfunctions of systems.

Cx provider can publish the Cx reports separately according to the stage of the Cx process:

- Identification of the process,
- Manual Cx,
- Cx of the BEMS,
- Optimization of the Cx.

In this Cx tool, the Cx reports are available in:

- Light version: containing only the appreciation of the test,
- Full version: containing all figures and comments.

Light Cx report

Light version of Cx report only informs the Cx provider if the test is done or not. If the test is performed, the report indicates if the test is fulfilled, partially fulfilled or not fulfilled (Figure 15).

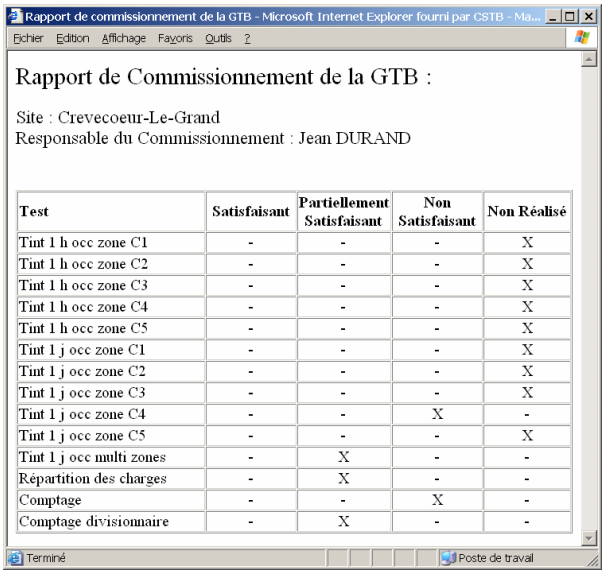


Figure 15: Light version of Cx report

Full Cx report

Full version of Cx report goes deeper into details by presenting, for each test, several comments on it (date, name of Cx provider, etc.) and figure to illustrate the results and comments (Figure 16).

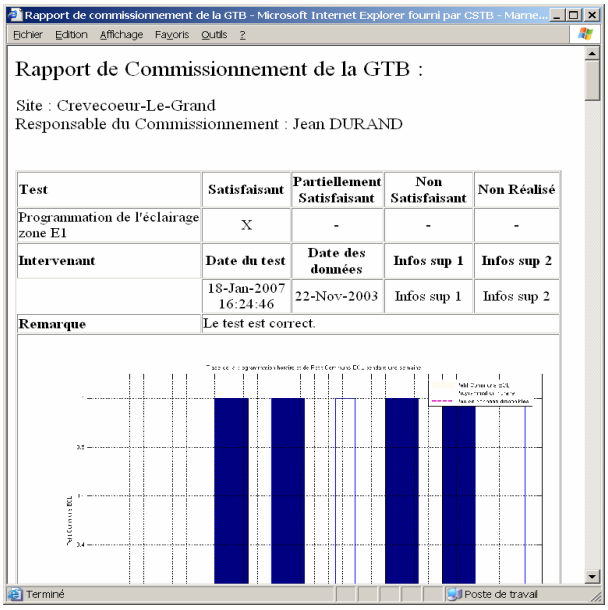


Figure 16: Fully version of Cx report

Update of Cx report

After performing a test, the Cx provider has to validate it, i.e. he has to judge the result of the test while choosing among three levels of satisfaction: satisfied, partially satisfied or not satisfied (Figure 15). He can also write a comment to explain his choice.

This information is then automatically saved into the Cx report corresponding to the performed test.

MAIN RESULTS DUE TO CX TOOL

The development and the use of this Cx tool on the demonstration site allowed to highlight a variety of facts:

- The lack of some technical information: some documents are missing,
- The lack of labeling in the electrical boxes,
- The discrepancy between BEMS information and ventilation operating,
- Under heating in north zone: the AHU (Air Handling Unit) control is not optimal,
- Cx providers appreciate technical reports: they help them to better manage their systems and transfer knowledge between actors (building owner, energy manager, occupants, etc.).

CONCLUSION

This paper deals with the development of an automatic Cx tool for electric building. It includes five steps from identification of the building to the edition of Cx reports:

- Identification of the building
- Manual Cx
- Cx of the BEMS
- Optimization of the building performance
- Cx reports

This tool helps the Cx provider to check the good functioning of the building energy management system and the system itself to ensure that the energy performance and the comfort in the building meet the requirement defined in the book of specifications.

The reduction of energy consumptions and GHG emissions need tools as this one to ensure the energy performance of the building and to follow it during the life cycle of the building.

FUTURE WORKS

Future works consist in adapting this prototype tool to a generic tool allowing energy managers to use the same tool for all of their building. They would be more efficient to analyze the performance of their building and more profitable.

A second step of investigation would be to implement new functions and FTPs to be able to check performance of non-electric building.

Finally, it would be interesting to integrate some protocol of communication to allow managing buildings stocks easily.

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