BEMS-ASSISTED SEASONAL FUNCTIONAL PERFORMANCE TESTING IN THE INITIAL COMMISSIONING OF KISTA ENTRÉ AND KATSAN

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This paper reports on some concrete experiences from using intensive trending and visualization in the evaluation of the performance of the HVAC systems during the post-acceptance step in two new office buildings.

Keywords: Commissioning, post-acceptance step, visualization, trend-data.

INTRODUCTION

Most buildings are unique and their HVAC-systems are custom-designed. Proper commissioning is crucial to achieve the intended functional performance. The conditions vary significantly over the year and thus it is important to ascertain that the system performs well during all seasons.

Modern building energy management systems, BEMS, comprise ample computer power, storage, bandwidth, and hundreds of sensors. Obviously, BEMS have a large potential to support the evaluation seasonal functional performance. Diagnostic software tools for large commercial buildings are being developed to help detect and diagnose energy and other performance problems with building operations [1]. However, in Sweden the assessment of seasonal performance in commissioning typically uses trend-data from only a few days.

Our hypothesis is that monitoring and functional analysis of HVAC-systems can be done cost-effectively with a procedure based on:

- ✓ intensive BEMS-supported data acquisition (i.e. historical data logging)
- ✓ a powerful visualization tool focused on data analysis

together with existing fault detection and diagnosis methods (FDD) and detailed simulations of HVAC. In this paper we report on-some concrete experiences from using intensive trending and visualization in the evaluation of the seasonal functional performance of the HVAC systems during the post-acceptance step in two new office buildings.

METHOD

We carry out the project in close cooperation between practitioners and academic researchers and we continuously deliver results to the organizations that operate the buildings. This approach should ensure that we focus on real problems.

Buildings

The Kista Entré building is located in the northern part of the Stockhom area, Sweden. It is composed of three building blocks with a total area of 46,000 m2. The HVAC-systems are simple and robust: district heating and cooling, centralized air handling units of 51, 15, and 22 m3/s in the three building blocks, respectively. The air-handling units have liquid coupled heat recovery. Cooling is supplied with cooling beams placed in the ceilings. The three building blocks were handed over to the owner in June 2002 through June 2003.

The Katsan building is located in Stockholm, Sweden. It is a six-storey office building with a total floor area of 6,700 m2. The entire façade is covered by glass and the building uses a slab-cooling system. The primary energy sources are seawater (cooling) and district heating. The Katsan building has an untested HVAC-system and thus a lot of effort was spent on simulating the behavior to verify the performance during the design stage. The building was handed over to the owner in May 2003.

Sensors

In Kista Entré all the data points except for six heat meters in the air handling unit, LB11, is part of the ordinary BEMS-installation. These heat meters were procured as an addition to the ordinary contract.

In both Kiste Entré and Katsan a large part (>50%) of the trend-logs record data from I/O-points, which cannot easily be recorded with a data logger, e.g. control signals to valve and dampers, to frequency converters, set values, etc.

Data logging

BEMS from the manufacturer, TAC AB [2], are installed in both buildings by TAC in Stockholm. The systems comprise a Windows based PC running a presentation system named TAC Vista, controllers named TAC Xenta, and a LonWorks network.

The TAC system features central and local trend logging. Central logging is controlled by TAC Vista, which requests and stores each value separately. Local logging is controlled by a Xenta controller and batches of logged values are transferred to Vista. Central logging is easier to set up and local logging causes less data traffic on the field-bus.

The user interface of TAC Vista is "object oriented". The user sees a huge tree-structure of "objects", such as "data points", "trend logs", "diagrams", "schedules", etc., which is a users view of the Vista Database. The user interface includes dialogs to manipulate one "object" at a time. In many cases these single "object" dialogs are the main (and often only) mean to accomplish a task, e.g. create a trend-log. The names and the position in the tree of the "objects" are controlled by conventions, which are adhered to more or less strictly. These conventions are often modified for the specific project. Defining a trend-log for one data-point in TAC Vista includes many basic operations and there are few parameters, the value which are preset in an intelligent way. For example, the physical unit of the trend-log is not preset to the value of the data-point being logged and the size of the storage is not preset to the value of the previous trend-log being defined.

The TAC Vista system includes the tools, Database Generator, DG, and System Documentation, SD. DG is a text oriented interface to the Vista Database. It reads and writes description files, which the user prepares with an ordinary editor. It would be possible to set-up 500 trend-log-objects with a description file. SD generates point oriented text files, which primarily are intended to be displayed on-screen. However, DG and also SD are seldom used in the field. We were discouraged to use DG, since it is very "powerful". In Kista Entré we used SD to generate a huge text file (approx. 8MB), which contains most(?) of the Vista Database. We made a little Matlab program that extracts information from this text file and output csv-files, which we imported to MsWord, see Figure 1. We use this table as a reference when we analyze data, and debug trend-logs.

	TF11/12_RU	LB-LB31-TF11_RU	%	600	6048000	2003-08-18 19:38:40
TREND-LB32	FO11_RU		°C	60	604800	****-01-01 00:00:00
	FO12_RU		°C	60	604800	****-01-01 00:00:00

TREND-LB21	FF11/12_RU	LB-LB21-FF11_RU	%	600	6048000	2003-08-18 20:23:03
	GP11_BV	LB-LB21-GP11_BV	Pa	600	6048000	2003-08-18 20:24:10
	GP11_MV	LB-LB21-GP11_MV	Pa	600	6048000	2003-08-18 20:25:40
	GP12_BV	LB-LB21-GP12_BV	Pa	600	6048000	2003-08-18 20:26:31
	GP12_MV	LB-LB21-GP12_MV	Pa	600	6048000	2003-08-18 20:26:58
	GT11_BV	LB-LB21-GT11_BE	°C	600	6048000	2003-08-18 20:28:44
	GT11_MV	LB-LB21-GT11_MV	°C	300	6048000	2003-07-21 18:02:00

Figure 1. Two samples from our tables of trend-logs. The first column holds the lower part of the path to the trend-log. The second column is the name of the trend-log. The third column is path and name of the data-point being logged. Next are physical units, sample time (sec), buffer size (sec), and start time. Note that in the fourth line from the bottom the name of the trend-log and the name of the data-point differ slightly. _BV stands for a constant set values and _BE stands for "calculated" set value, which in this case is "compensated for the ambient temperature". The second and third lines from the top are trend-log object, which have been created but not configured.

In Katsan approximately 180 central trend-logs were set-up by the control contractor according to our specification. All data-points are sampled every five minutes.

In Kista Entré approx 100 + 200 central trend-logs were set-up by the control contractor according to specification of the owner and the commissioning authority, respectively. We set up an additionally 200 central trend-logs. Electricity meters are sampled every hour, other data-points every five or ten minutes. The control contractor used ten minutes and let the logging start when the return key is hit. We used five minutes and schedule the start to specific points in time, i.e. hour + n*1 minutes, where n = house number (1, 2, and 3) and n = 0 for data point of the air handling unit, LB11, and for data points common to the three houses.

Data transfer and storage

From Kista Entré we transfer data to our office over the Internet at irregular intervals. Since an appropriate application was not available the control contractor supplied us with a Java class library to communicate with their BEMS over the Internet. We made a minimal application that as input takes a list of trend-log names, which we produce automatically from the text file of the TAC tool, SD. It is started interactively and XML-files are transferred according to the SOAP-protocol. It works. However, it should be mentioned that it required too many man-hour of too many people to establish the communication through the firewall.

From Katsan we fetch data every six-week by text files on a USB-memory. We use third-party software to export the trend-data from TAC Vista to the text files, which we copy to the USB-memory.

Originally we planned to store data in an SQL-database and made some trials with Ms Access. The response times, which we achieved, were too long both for writing and reading. Thus, we keep the text files as back-ups and have working copies of the data in Matlab® [3].

PERFORMANCE ANALYSIS

We have relied on visualization and inspection of trend-data for the performance analysis and we have presented the results in reports, which are dominated by diagrams. Our simulation and FDD work has so far not produce that many traces in these documents. Here we describe these reports and how we have produced them.

Matlab and our set of functions, Pia [4], are our main tools for visualization, inspection, and generation of the diagrams for the reports. Pia requires a set of time series, which are equidistant and synchronized. Since the time series from the BEMS are not synchronized, we interpolate the data when loading it into Matlab. We typically make batches of synchronized data of 50-100 MB in size and save them in the binary format of Matlab. The fast response and the well-defined diagrams of Pia make this approach possible.

The cumulative report of Kista Entré includes forty-two anomalies. Here we present a few snapshots. The purpose is to illustrate the kind of reports we make, rather than to discuss the particular behavior of the HVAC systems.

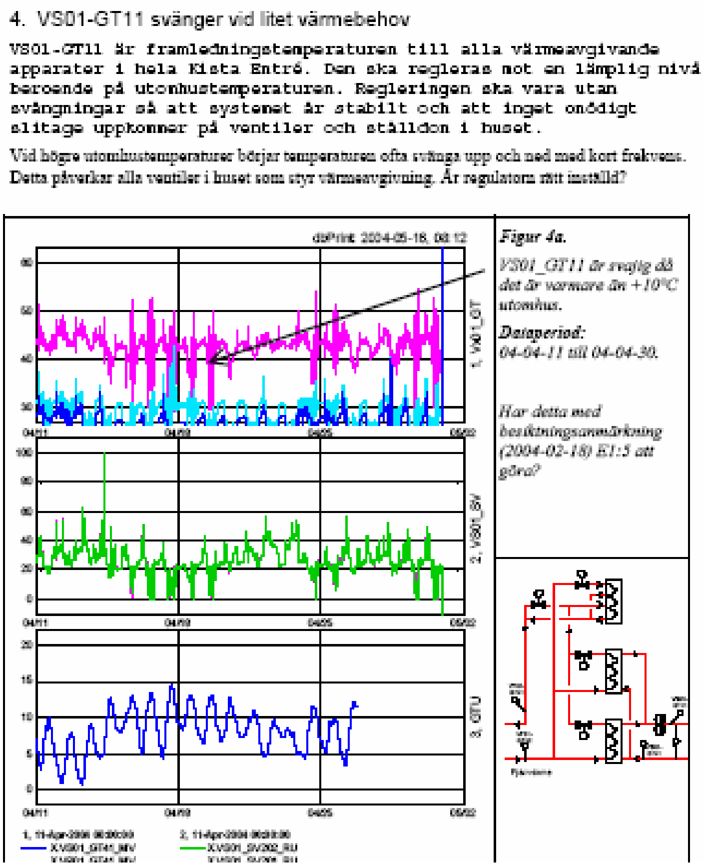

Figure 1. The presentation of Anomaly #4 is typical. On one page there are a few lines of text describing the intended and the actual behavior, some synchronized diagrams, and a small schematic drawing. The arrow points at traces of an oscillating valve. This was not the only oscillating valve.

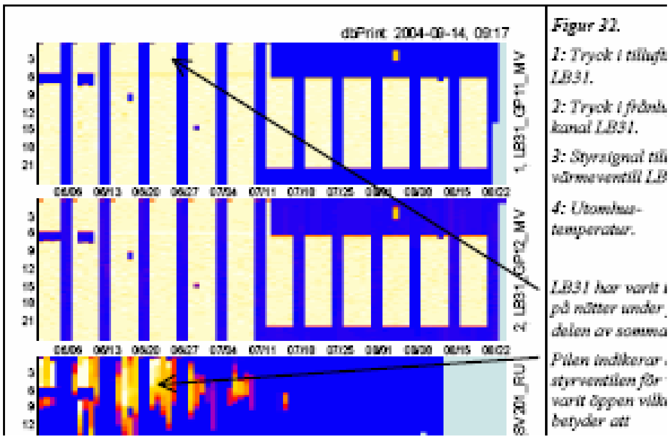

Figure 2. Anomaly #32: Air handling unit, LB31, was running nighttime in the beginning of June. The bottom diagram shows that the heating valve was open. These "carpet plots" are a bit special. The scale of the y-axis is the time of the day, which runs from 0 to 24 from top to bottom. The scale of the x-axis is the dates of the period that the diagram spans: June –August. The quantity displayed is color-coded. Thus, each whitish rectangle represents the operating time during one week. The blue ribbons in-between are the week-ends.

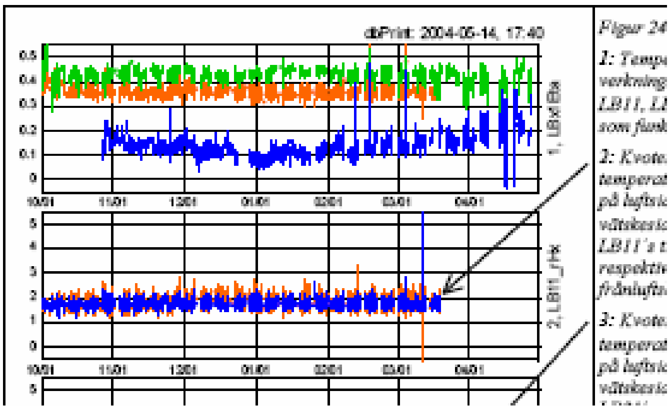

Figure 3. Anomaly #24. The effectiveness of the liquid coupled heat recovery systems is low in the three large air-handling units, LB11, LB21, and LB31. The upper diagram shows effectiveness and the lower shows ratios between temperature differences on the air and liquid sides of LB11. The time axis spans the heating season.

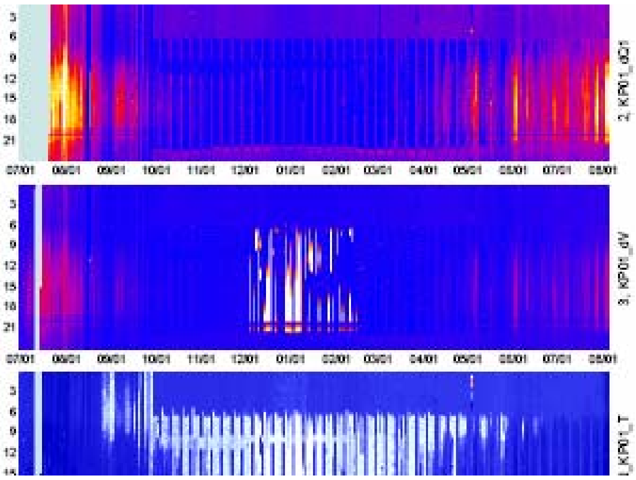

Figure 4. These three diagrams illustrate the behavior of the district-cooling substation of Kista Entré during a period of twelve months, July - June. The upper diagram shows the cooling load, which is high in the summer and low in the winter. In nighttime there is a load throughout the year because free cooling is not in operation when the main air-handling units do not operate. The middle diagram shows the liquid flow rate on the primary side. Daytime in the middle of the winter it is much larger than anytime during the summer. The bottom diagram, half of which is cut off, shows the temperature "fall" of the liquid on the primary side. White depicts zero and dark blue minus fourteen. Thus, in the middle of the winter lots of water flows through the heat exchanger without taking up any heat.

With Katsan a batch of data was quickly scrutinized every six week to identify missing variables and check building performance. More thorough analysis was performed every six months. We detected many deviations from expected behavior by visually inspecting the monitored data:

- ✓ The cascade control of the supply air temperature was not correctly implemented until about half a year after occupancy of the tenants.
- ✓ A malfunctioning outdoor temperature sensor lead to low indoor temperatures when the pump supplying heat was turned off for about two weeks.
- ✓ A fouled seawater filter caused high indoor temperatures during a week because heat was not properly disposed from the slab-system.
- ✓ The ventilation system was operating more than intended. During nights and weekends only the first floor (containing a restaurant and a bar) should had been ventilated. In practice all floors were ventilated continuously.

- ✓ The light on floor 3-5 was operating during nights for several months due to some problems in the electrical system (see figure 5).
- ✓ The belt of the supply fan was defect for about a week. This caused low indoor temperature and smell of cooking in the entire building.
- ✓ The set points of the supply air temperature, the floor heating on the first floor, the sea water flow rate, the air pressure in the supply duct and the flow rate to the cooling beams have been changed one or several times. Also the set-points actually implemented in the control code often differed slightly from what was specified by the HVAC-designer.
- ✓ The control of the slab-cooling system was not properly programmed until four months after occupancy of the tenants.

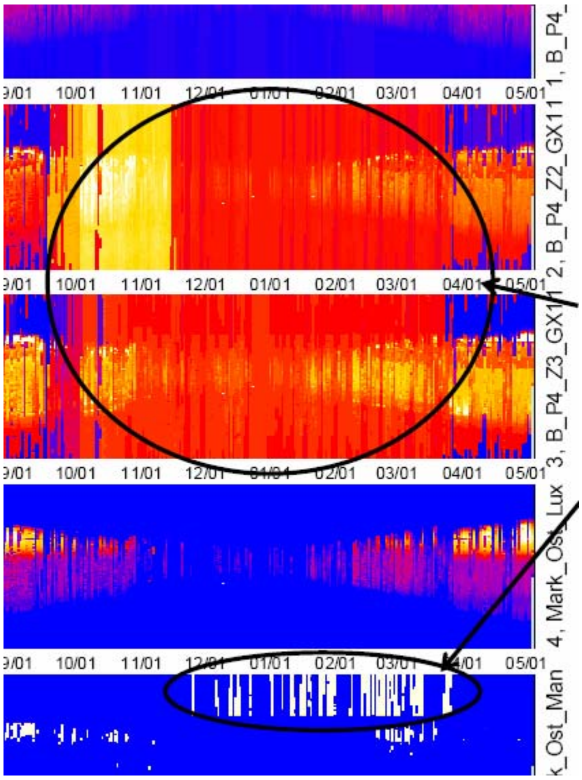

Figure 5. The large circle on the upper diagrams emphasizes that electrical light was operating during nights for several months. The lower diagram shows that the sun shading was operating in nighttime during the same period of time.

EXPERIENCES AND DISCUSSION

The BEMS could easily assist the seasonal functional performance testing much more effectively than it did in the two projects that we have reported on in this paper. These buildings are equipped with BEMS from TAC. However, to our experience the support of trend logging that TAC Vista provides is typical for the industry.

It is time consuming and error prone to set up trend logs. We find it remarkable that our little tool to make lists proved to be so useful in Kista Entré (see Figure 1). Without that we would have been required to manually maintain a correct list of name and path of all trend-logs. Furthermore, without the tables we produced the debugging of the trend-logs would have been much more difficult. In Katsan one set of trend-logs was specified from the beginning. Errors have popped up continuously and recently we discovered that one important trend-log is not recording data from the intended data-point. The administration of trend logging is simply too expensive and too error prone.

In next project we plan to use e-mail to transfer trend-data. Sending e-mail shall be a scheduled task that is handled automatically by the BEMS. We will have a special e-mail account that is dedicated to this purpose. This way the data will be transferred automatically and we will not need to cope with firewalls.

Most visualization tools require synchronized data, i.e. the data need to be organized in a "table" with columns and rows. Most BEMS do not deliver synchronized data; the logging needs to be spread out in time to avoid peaks in the data transfer on the field bus. If the logging capacity of the BEMS is limited one need to be aware that data displayed in the graphs have been "synchronized".

Our tool Pia makes it reasonable to inspect trend-data interactively and to make reports with lots of diagrams. However, there are at least two open questions. The result, to what degree does that depend on the skill and diligence of the analyzer? How many anomalies have we overlooked? We have an interesting study ahead of us. That is to revisit these trend-data when we know more about the systems and have the FDD-and simulation tools running [5]. What we have found so far is well documented [6, 7].

This work has been done during the post-acceptance step of Kista Entré and Katsan. That makes decent documentation valuable and showing anomalies that have been in effect for a long time makes convincing evidence. Furthermore, prompt reporting of anomalies might not be so important. Nevertheless, we must admit that we are running behind presenting anomalies months after they occurred.

Reports on anomalies do not save energy. Action based on the reports must be taken. From our point of view not much has been done in Kista Entré. There is a rationalization and that is shared responsibility. The original owner Skanska

Fastigheter sold the building to Vasakronan a short time after the hand over. Contacts with the contractor are handled via Skanska Fastigheter, which make things complicated and slow. Recently, Katsan was sold and we have similar experiences in this building.

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