EQUA. | ITEA 2 INFORMATION TECHNOLOGY FOR EUROPEAN ADVANCEMENT

MODRIO

D8.5.2 - Building monitoring demonstrator

WP8 Demonstrators

MODRIO (11004)

Version 1.0

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Authors Per Sahlin, Marc Azar, Lars Ålenius and Petros Souvatzis EQUA Simulation AB.

Executive summary

In the 3.3.2 deliverable of the MODRIO project, an interface between an IDA-ICE simulation model and a well instrumented experimental building facility has been implemented and tested – a prototype Building monitoring system.

This demonstrator describes the application of the prototype to an office building in La Rochelle, France. The document describes the process of developing a simulation model of the building. It does not show screen shots from the actual demonstrator – which instead will be demonstrated live to MODRIO partners and reviewers.

1. Introduction

Buildings use about 40% of the world’s total energy for heating and cooling. However, a large share of the total international building stock can be improved by relatively simple measures. Some of the more obvious such measures deal with the improvement of the building envelope, i.e. walls and windows. Such improvements are often costly and may also be infeasible for other reasons, such as maintaining an attractive appearance. Another class of improvements that is often overlooked deals with the way building heating, ventilation and air conditioning (HVAC) systems are operated. Such measures can often be vastly more cost-effective. However, they require a way of quickly gaining an understanding of the way a building operates in order to find malfunctions or sources of unnecessary waste. Some typical examples of problems in buildings are:

- Self-acting radiator valves that are stuck and no longer provide feedback control
- Poorly balanced radiator systems, so that some parts of the building overheat, while others are too cold
- Similarly poorly balanced mechanical ventilation systems
- Heat exchangers that have been fouled and no longer perform as designed
- Automatically operated control valves that are leaky or stuck
- Air filters that need replacement and provide too high pressure resistance
- Control loops that are poorly tuned and that move continuously and therefore quickly wear down actuators
- Windows and doors that are poorly sealed and allow too much air leakage
- Systems that run (and use energy) at times when they are not needed

Modern buildings are often quite well monitored, i.e. many sensors are already installed in the building. Another trend is that wireless sensing is becoming increasingly accessible, making it cost-effective to temporarily instrument a building for diagnosis. However, this multitude of trending data is rarely explored in practice. Gaining overview of thousands of individual signals is difficult and time consuming. An efficient 3D presentation of the data in direct contrast to expected – as-designed – performance can provide the necessary overview to make the data useful.

The MODRIO Building monitoring demonstrator relies on the Building monitoring system that was developed in MODRIO Task 3.3. The aim of the demonstrator is to illustrate the application of the new tool on a small office building. The selected Vaucanson building is located in La Rochelle, France. It has been monitored in the scope of another research project.

The work of applying the T3.3 demonstrator to the Vaucanson building is described here and some selected illustrations are also included. However, the demonstrator is primarily intended for live demonstration, as will be done at the MODRIO final review, and the written account here is therefore brief.

2. Modelling Process

Building modelling is an art that involves describing reality through a series of simplifications ending with a manageable kernel, representative of the original complex system for the purpose of comprehending its dynamics. To that end one needs to collect typically three categories of data for all the subsystems intended for modelling; beginning with input data which describes the surrounding environment in which the system operates, followed by design specification data of the subsystems necessary for parameter mapping in modelling, and ending with the real logged performance data of the subsystems utilized for model validation.

Thus modelling process starts with field data collection. The field data is compiled into a checklist similar to the one described below:

Table 1. Sample table for field collected data

<table>
<tr><td rowspan="4">Building Plans</td><td>Layout drawings</td></tr>
<tr><td>Section drawings</td></tr>
<tr><td>Façade drawings</td></tr>
<tr><td>*IFC files</td></tr>
<tr><td rowspan="3">Site Specification</td><td>Geographic Location</td></tr>
<tr><td>Shading and other peripheral objects</td></tr>
<tr><td>Topographical data</td></tr>
<tr><td rowspan="8">Building Envelope</td><td>External walls</td></tr>
<tr><td>Internal walls</td></tr>
<tr><td>Insulation</td></tr>
<tr><td>Roof</td></tr>
<tr><td>Underground / basement walls</td></tr>
<tr><td>Concrete Slabs</td></tr>
<tr><td>Description of Thermal Bridges</td></tr>
<tr><td>Infiltration data</td></tr>
<tr><td rowspan="3">Glazing</td><td>Detailed window and frame drawings</td></tr>
<tr><td>Glazing Specifications</td></tr>
<tr><td>Inner and outer curtain/blind specifications, control set points, and operating schedule</td></tr>
<tr><td rowspan="8">Heating and Cooling Systems</td><td>Type of central heating source</td></tr>
<tr><td>Return and Supply temperatures</td></tr>
<tr><td>Description of subunits, storage tanks, and distribution system</td></tr>
<tr><td>Specification and set points for room heating units</td></tr>
<tr><td>Specific Fan Power and Pump rating, *flow, and efficiency</td></tr>
<tr><td>Operating schedule</td></tr>
<tr><td>Description of storage and pipe insulation</td></tr>
<tr><td>Installation capacity</td></tr>
<tr><td rowspan="5">Description and Specification of Cooling Systems</td><td>Type of central cooling source</td></tr>
<tr><td>Return and Supply temperatures</td></tr>
<tr><td>Description of subunits, and distribution system</td></tr>
<tr><td>Specification and set points of room cooling units</td></tr>
<tr><td>Specific Fan Power and chiller/cooling</td></tr>
</table>

	tower **rating,** *__flow,__ and **efficiency**
	Operating schedule
	Description of **storage** and **pipe insulation**
	Installation capacity
	Design Schema
Ventilation System	Number and **type of air handling units**
	Specific Fan Power and total air **flow**
	Specification and efficiency of **heat recovery unit**
	Specification of **Humidifier/Dehumidifier unit**
	Air supply controller and **set points**
	Fan **Operating schedule**
	Number and Specification of **exhaust fans**
	Design Schema
Zoning	**Functional description** of each **HVAC zone**
	Occupant Capacity and **Presence Schedule**
	Electronic equipment power rating
	Illuminance Level
Building Facilities	Electrical rating and operating schedule for elevators, external lighting, and other installations
	Installed capacity and control type of surface heaters and drain heaters

After collecting and compiling all field data from energy audits and building documentation, modelling is performed in a bottom-up approach, starting with location and geometric data.

Utilizing architectural drawings, one is able to extract building geometry, room dimensions, and other topographical data describing the near building environment. It is not necessary for the modeller to include each room described in the drawings, and sometimes simplifications need be made as to select an appropriate number of zones whilst remaining true to the actual physical representation of the building. This holds true to each and every step in the modelling process, whereby the modeller has to take design decisions as to best capture reality in a simplified model.

After obtaining a satisfactory empty geometric model representation of the building, the modeller proceeds to populate the zones with the data provided in complied table above. The data includes number of occupants, equipment, lighting features, etc. As well as constructing appropriate schedules for each component modelled. In modelling the schedule data, the modeller has to take yet another design decision weighing in runtime for an approximate smoothed schedule versus a detailed event based schedule.

When all zone components are well defined along with their schedules, the modelling proceeds to deal with the building systems, i.e. the plant, AHU, and zone units. Describing the building plant, AHU, and zone units along with their operational schedule, involves delving into specific performance criteria of its components along with the control structure and type.

A this stage, the modeller has to address the building envelope, inputting in structural information found in the compiled table above, which includes detailed information on walls, floors, and ceilings, as well as window and other glazing properties, ground reflectance and heat dissipation model.

Finally certain estimates have to be evaluated to fill in any lack of information the data field could not address. These include infiltration data, thermal bridges calculations, network and thermal distribution losses, etc…

Figure 1: Building modelling process

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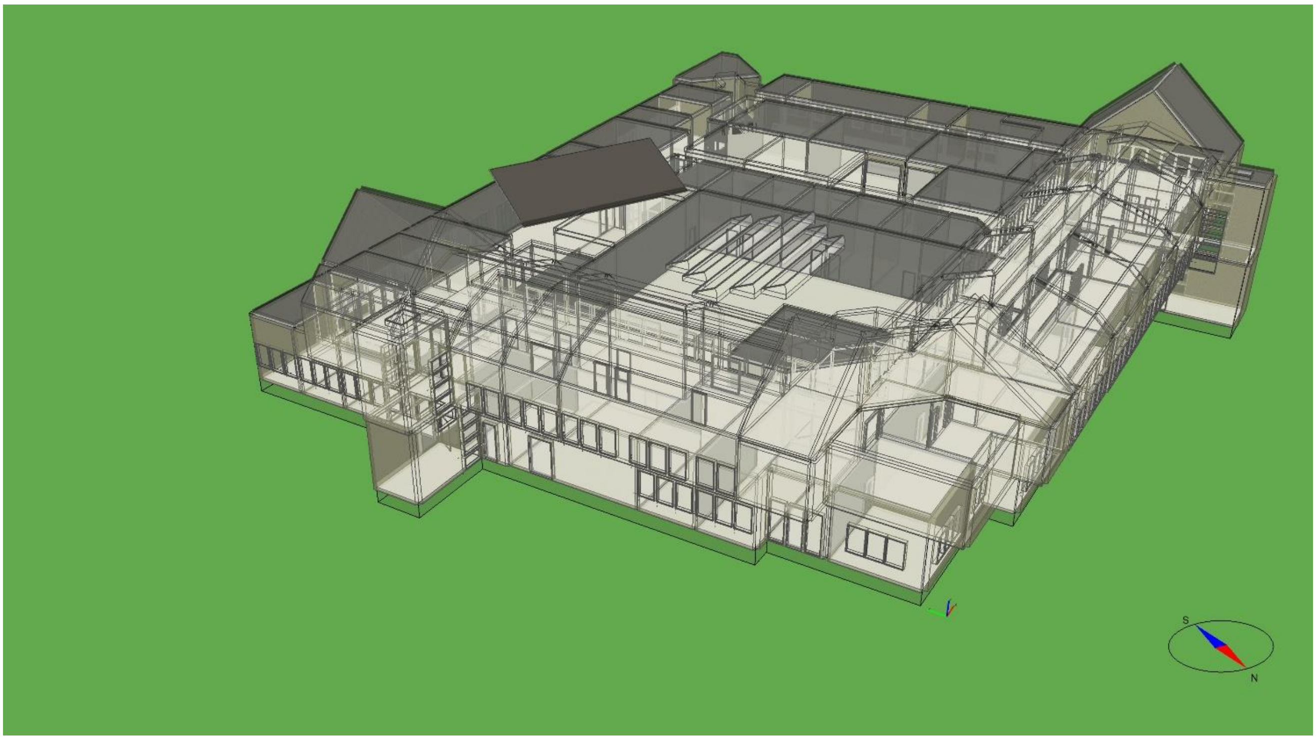

Figure 2. The Vaucanson building model in transparent mode

2.1. Description

The Vaucanson building was built in 1986 and has undergone extensive renovation in 2012, and currently has a gross floor area of 3371.5 m^2 over two levels. The building services 60 people on average, along with meeting areas with capacity of 116 people and training rooms capable of accommodating up to 70 people.

2.2. Systems

Vaucanson is equipped with two open ground source heat pumps rated at 40.2kW and 53.1 kW respectively. The heat pumps are modelled in IDA-ICE empirically, by fitting the performance data into a parametric equation model of a heat pump; this is done through optimization algorithms which produce an optimal parametric configuration of the empirical model. The building has a complex plant that has been modelled together with its control system in detail in IDA ICE (Figure 4).

Concerning Domestic Hot water, Vaucanson model is also equipped with three electric heaters rated at 1.6, 2, and 2.2 kW each with a total capacity of 220 litres. While selected rooms are equipped with water radiators (some manual control, others with thermostats), while the large meeting area has ceiling heating panels and a 218 m^2 surface floor heating area. The ceiling heating panels are passive with rated power of 1065 Watts, while the floor heating panel has a thermal resistance of 3.7 m^{2}W/K and is 80 mm under the internal floor. The supply hot water temperature of the room units is 55 degC with a return temperature of 45 degC, save for the large meeting area which has a hot water supply temperature of 35 degC and a return water temperature of 30 degC.

Vaucanson has two air handling units (AHUs), the biggest of which supplies the whole building with ventilation while the smaller AHU feeds only the large meeting area. Both AHU are equipped with enthalpy wheels, while the larger model has heating coil as well as an additional electric heating coil. Currently the enthalpy wheel model in IDA-ICE is replaced by an air-to-air heat exchanger mimicking the heat exchange performance of the enthalpy wheel, without taking into account the air moisture content. This simplification will be rectified in future model versions. The design use of both AHU is for heating purposes only. The operational schedule of the main AHU includes pre-heating and night set back; the schedule runs at 30% value from 5:00 till 7:00, the modulates to 100% from 7:00 till 18:00, only to have a set back at 30% value from 18:00 till 23:00. The Vaucanson model also includes two air split units for cooling the server and electric room. The total cooling power (sensible + latent) of the split units is 6.8 kW and 26.8 kW respectively.

The Vaucanson model also includes a photo voltaic cell configuration having a total power generation capacity of 14.426 kWc spanning over 190 m^2 of roof surface area.

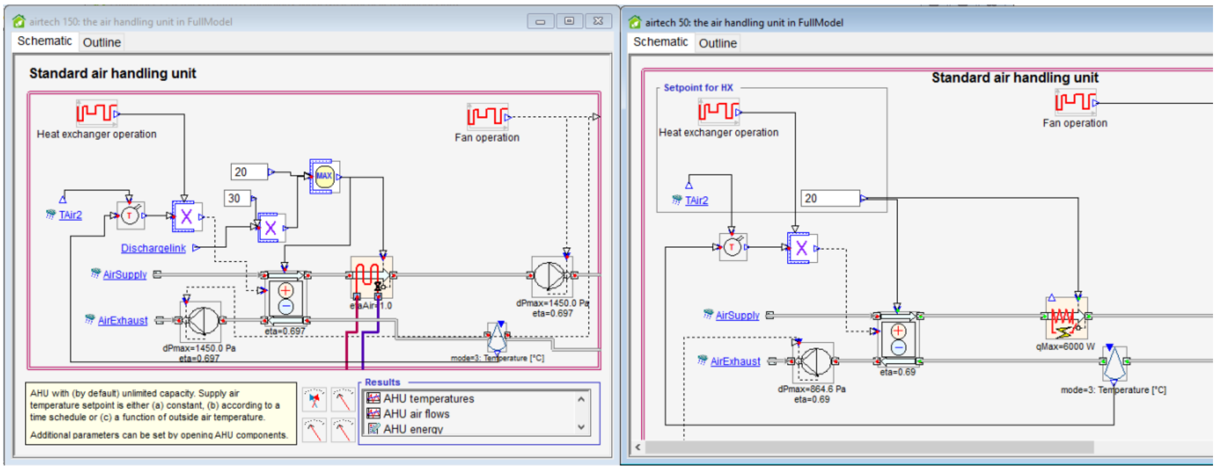

Figure 3. Vaucanson AHU schematics

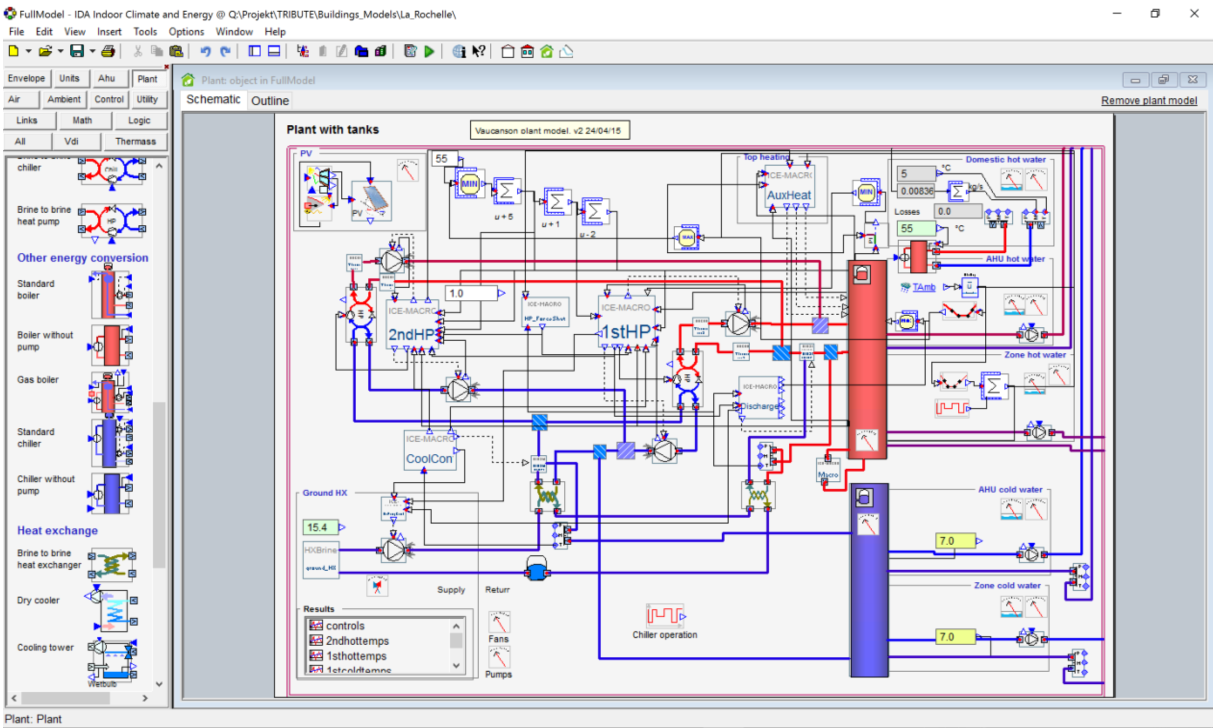

Figure 4. Vaucanson plant schematic

2.3. Envelope

During the renovation, the building envelope was radically changed, and currently has a low U value of

0.18 W/m²K for the external façade, and 0.6 W/m²K for internal walls, 0.15 W/m²K for external roof, and 0.44 W/m²K for internal floors. The glazing optical properties is still missing in the model, with only the thermal properties provided by the audit and set at 1.4 W/m²K. Furthermore Vaucanson takes advantage of natural day light through a series of small skylights speckled across the roof, and a large skylight roof in the main meeting hall. The windows to the south east and west are provided by external shades, while other windows have internal blinds. Thermal bridges were approximated from the thermal imaging done on the building.

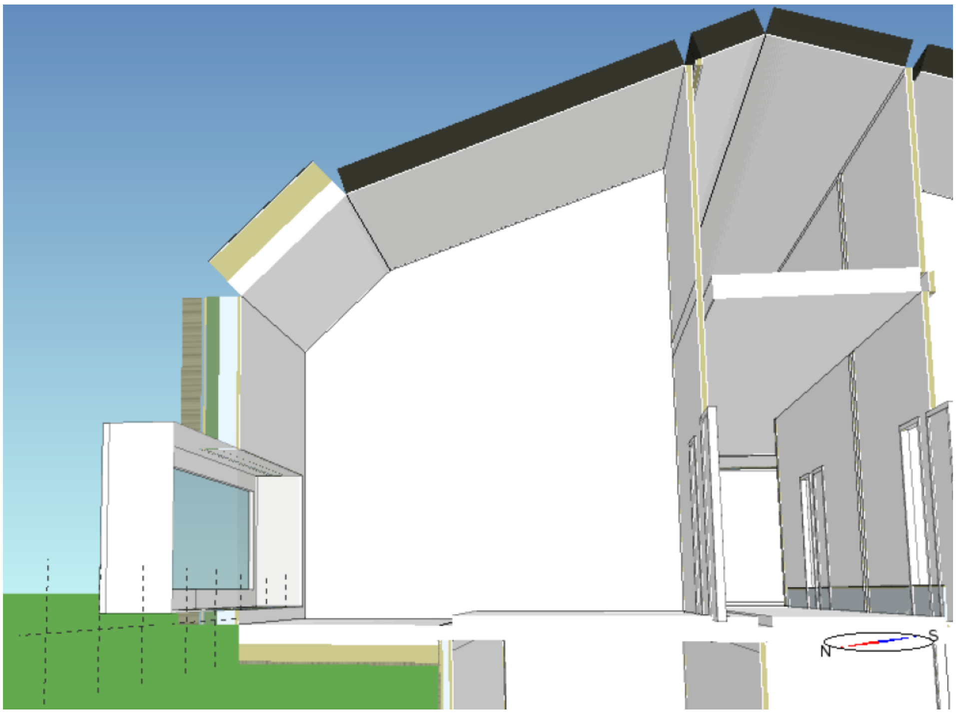

Figure 5. Vaucanson building envelope

2.4. Schedules

The occupant schedule follows an 8:30 till 17:00 routine with 75 min lunch break at 12:15 for weekdays. Equipment, split units, and lighting adhere to the same schedule, in contrast with heat pumps which exhibit a night set back and pre heating according to the schedule described in the System section.

3. Monitored signals

The Vaucanson building has a total of 560 sensors that provide continuous measurements of electricity use as well as signals from the HVAC systems. 40 of the sensors are wireless and monitor the state of the rooms, each one of these measure temperature, humidity, light and (total) pressure.

The majority of these sensors have been connected to the demonstrator simulation model.

4. Demonstrator

The actual demonstrator is intended for live demonstration and is not presented in this document.

5. Conclusions

The building monitoring system that was developed in T3.3 has been applied to an office building in La Rochelle. A number of problems in the building have been revealed by comparing and visualizing simulated and measured signals:

1. Since the building does not have any mechanical cooling system, it is necessary for occupants to open windows in large parts of the year, also when the heating system is active. This is likely to waste significant amounts of energy.
2. Excessive manual window ventilation has been observed during large parts of the year, i.e. not only when the building is overheating.
3. The control strategy whereby surplus heat from the server facility is dumped into the building, irrespective of heating need is likely to lead to unnecessary occupant window ventilation and is, thereby, likely to waste rather than save energy.

The building is not faulty in the sense that it is not operating according to its design intentions. However, the practical consequences of the design is that occupants often find that the building overheats and they correct this by excessive individual window ventilation.

The HVAC system should be redesigned as to provide a more comfortable year-round indoor environment and thereby eliminate the need for excessive manual ventilation. The dumping of excess heat from the server operation into the building should be avoided. An air-cooling coil in the supply air stream to the office spaces could be served by water from the ground source loop (15 Degrees C) and thereby provide year-round free cooling.