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Validation and calibration of dynamic energy models: energy audit of a public building

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Validation and calibration of dynamic energy models: energy audit of a public building

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Abstract. Detailed buildings energy audits require dynamic simulation models based on hourly input data. This paper presents the calibration and validation of an office building energy model for the heating and cooling services. Simulation are carried out by DesignBuilder software. Measured hourly heating and cooling energy supplied by the generation system are used for the calibration of the model. Employee behaviour with reference to occupancy profiles and indoor temperature settings is also considered. A good agreement between measured and simulated data is obtained for both heating and cooling seasons.

1. Introduction

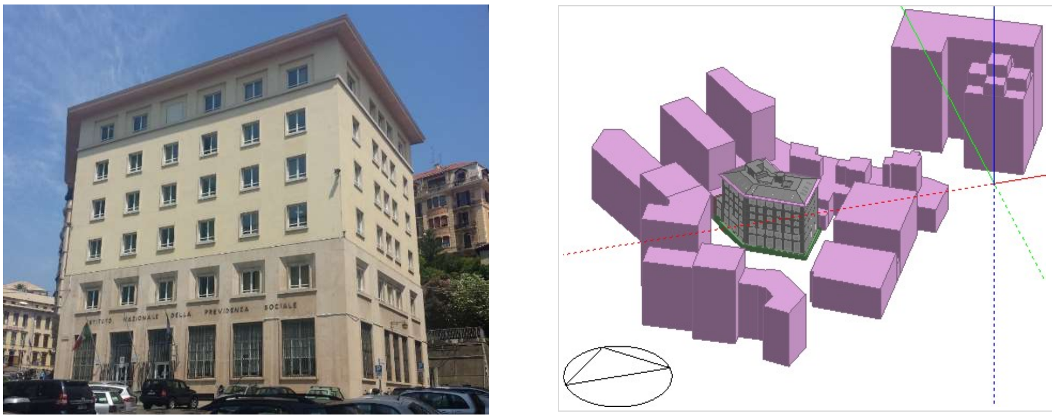
UNI CEI EN 16247-1 standard [1] and Directive 2006/32/EC [2] define energy audit as a systematic inspection and analysis of energy use and energy consumption of a site, building, system or organisation, with the objective of identifying energy flows and the potential for energy efficiency improvements and quantifying the cost saving benefits opportunities. UNI CEI EN 16247-2 standard [3], concerning the building energy audit, provides the requirements of the different levels of thoroughness and needs for the detailed one that the buildings simulation is carried out by using dynamic calculation tools. In addition, recently published national guidelines for energy audits of public buildings [4] prescribe the use of hourly based dynamic calculation if a high level of accuracy is required.

Usually, the building model validation is performed by considering data related to monthly energy consumption, since the real data are generally taken from gas and electricity bills. In [5] the model validation is carried out from the analysis of the historical energy requests, by collecting data about the last three years of the electricity and natural gas bills. In [6] the calibration process consists of the comparison of the real and simulated energy signatures. Furthermore, if temperature measurements in some rooms are available, it is possible to calibrate the model against metered data [7].

Management systems are increasingly present in buildings in order to optimize thermal and electrical consumptions. In the office building of the INPS - Istituto Nazionale della Previdenza Sociale (namely the social welfare national institute) located in Savona, a management system is installed. This system is able to detect separately the electricity consumptions on an hourly basis of the different users: lights, air conditioning, electromotive power, etc. Both heating and cooling are obtained by means of two air to water heat pumps which require electricity as the only energy vector. More, a counter of the thermal and cooling energy transferred to the water is available. In the present paper a dynamic model of the building is carried out by EnergyPlus [8] through the DesignBuilder interface [9]; its calibration and validation on the basis of the hourly measurements of useful energy produced by the heat pumps are discussed.

2. Case study and input data

The INPS office building, located in the city centre of Savona (SV) and shown in Figure 1, is considered as case study. The main façade faces south on a large square, while on the other sides the building is surrounded by palaces.



(a) (b)

Figure 1. Case study: picture (a), model (b).

The building, that dates back to the 1930s, consists of an unheated basement, a ground floor open to the public with net height of 5.2 m and six floors of offices, including an attic, with net height of 3.5 m. The pitched roof has a central walkable area. Bathrooms and corridors at different levels are false ceilings and have a net height of 2.8 m.

Table 1 contains the main characteristics of the site and the main geometrical and thermal features of the building envelope.

Table 1. Site and building envelope properties.

Savona, IT (Elevation 6 m)	Latitude 44° 18’ 40’’ Longitude 8° 28’ 47’’		
Legal heating season November 1 to April 15	Cooling season June 1 to September 30		
Net conditioned floor area 3403 m^2	Total building floor area 5109 m^2		
Net Conditioned volume 8387 m^3	Total building volume 13779 m^3		
Vertical and horizontal components	Thickness (m)	Thermal transmittance (W/m^2/K)	Surface mass (kg/m^2)
External cavity wall	0.35 ÷ 0.75	1.34 ÷ 0.97	494 ÷ 1363
Sub-window wall	0.26 ÷ 0.49	1.86 ÷ 1.47	410 ÷ 963
Inter-floor slab	0.31	0.97	369
Pitched roof	0.26	0.94	303

Wall stratigraphies were obtained from the documentation relating to the building renovation of 1995 made available by the client. Windows, whose dimensions and characteristics have been detected by inspection, have aluminium thermal break or wood frames, double glazing and metal spacers. Their thermal transmittance is between 3.04 and 4.83 W/m^2/K.

The generation system consists of a two high efficiency air to water reversible heat pumps, each of 171.9 kW nominal heating capacity and 149.2 kW cooling capacity, located outside. A two-pipes floor horizontal distribution is present, with vertical risers in the shaft. A single room regulation system with proportional logic is installed. Emission system is provided by 120 variable power fan coils, nominal heating capacity of 2350 ÷ 5950 W and total cooling capacity of 2120 ÷ 5240 W. No mechanical ventilation system is present in the building.

A consumption monitoring system is installed since 2017: for the entire year 2018, the client made available useful thermal and cooling energy transferred to the water by heat pumps and electric load profiles per single floor due to electromotive power and lighting. The 2018 climate file is based on climatic data provided by a monitoring station located just 700 m away from the building [10].

The occupancy profiles were defined as a function of the attendance of the employees and the opening hours to the public according to the data provided by the manager. The internal office equipment thermal loads were evaluated as a function of the measured electrical consumptions of each floor. Hourly trends of natural ventilation have been determined according to the EN 18523-1 [11] standard, considering the presence of people inside the offices. Air infiltration was evaluated according to equation 38 of the UNI/TS11300-1 [12] national standard considering a medium air permeability.

3. Model calibration and results

Dynamic simulation was performed by the Design Builder software. Model validation was obtained on the basis of the hourly measured values of useful energy transferred by the heat pumps to the carrier fluid. However it is necessary to take into account that the users can adjust the indoor temperature for each room in a range of ± 3 °C around the nominal set-point values, 21 °C in winter and 25 °C in summer conditions; this entails a high uncertainty in comparing the measured and simulated data and therefore it is necessary to proceed with the model calibration. For this purpose, the maximum load condition assuming set-point values of 24 °C for the heating season and 22 °C for the cooling one and the minimum load condition with 18 °C and 28 °C respectively were considered. The simulation set-point values correspond to the air temperature inside the rooms where the fan coils are present.

Figure 2 shows the hourly trends of the measured and simulated (maximum and minimum load conditions) thermal energy supplied by the heat pumps to the carrier fluid for a period of 5 working days in winter (Figure 2a) and summer (Figure 2b) conditions. The profile of the outdoor air temperature is also reported.

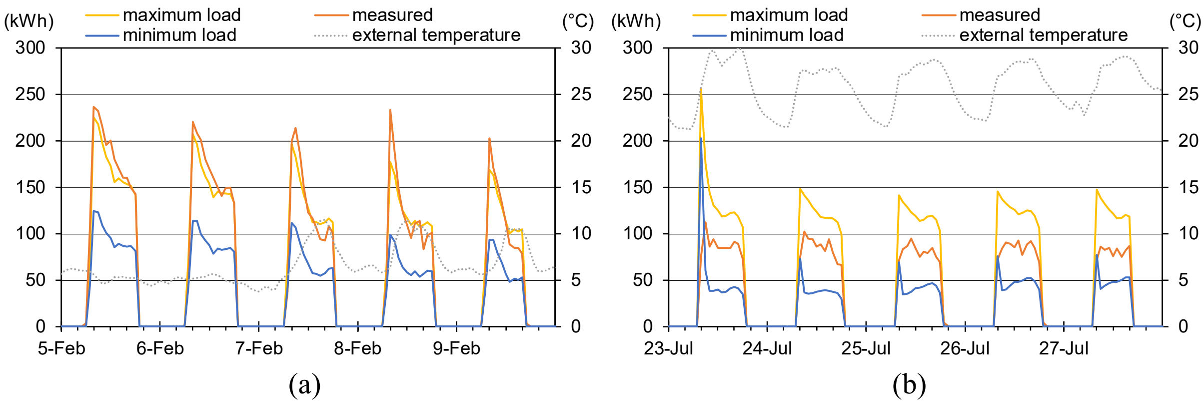


Figure 2. Supplied energy and external air temperature: winter (a) and summer (b) conditions.

It is noted that in winter condition there is a good agreement when the room thermostat is set to the maximum allowed temperature of 24 °C, while in summer condition the default set value of 25 °C agrees with measured data.

Measured and calculated useful thermal energies on a monthly basis are then compared in Figure 3, by setting an internal air temperature of 24 °C for the winter season and of 25 °C for the summer one. A good agreement can be observed: in the heating season the model underestimates 6.5% of the overall heated energy supplied by the heat pumps, while in the cooling season it overestimates 8% of the subtracted cooling energy.

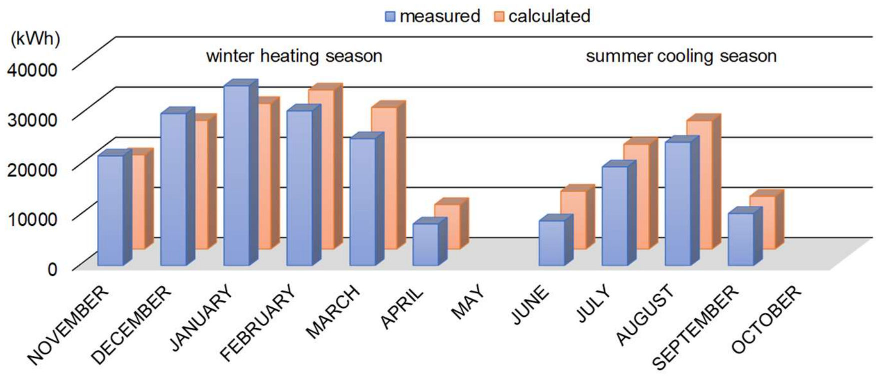


Figure 3. Measured and calculated thermal energy.

4. Conclusion

In the present paper the calibration and validation of a dynamic model for the analysis of the energy performance of an office building is presented.

The available measured data are adequate to obtain a correct calibration of the model. Simulations carried out for different set point temperatures in both heating and cooling seasons also allowed to evaluate the current use of room thermostats, which can be assumed on average to be set to the maximum value in winter season and to the intermediate default value in summer one.

Results of simulations show a good agreement with the measured data, with errors of 6.5% and 8% for the heating and cooling seasons respectively.

Acknowledgments

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