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Definition and Validation of a Simplified Multizone Dynamic Building Model Connected to Heating System and HVAC Unit

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INTRODUCTION

In 2005, primary energy consumption in the European Union-25 stood at 1,725 *MtOE*. Without efforts to contain the rise, consumption could reach 1,900 *MtOE* by 2020. Furthermore, the EU is becoming increasingly dependent on imported energy. *Energy efficiency* has emerged as a global priority and is viewed as one of the most effective instruments for combating climate change. Accordingly, in March 2007, the European Union has set an ambitious goal of cutting its energy consumption by *20%* by 2020.

The *buildings sector* accounts for *40%* of the EU's energy demand (while industry accounts for *30%,* and transport for *30%*). The buildings sector offers the largest potential for energy efficiency. Research shows that more than one-fifth of the present energy consumption and up to 30-45 MT of CO2 per year could be saved by 2010 by applying more ambitious standards to new and when refurbishing buildings. This represents a considerable contribution to meeting the Kyoto targets.

To improve building energy efficiency, engineers and architects need *models*. Models can provide them results regarding the influence of building parameters on energy consumptions, for a given level of comfort. Heating and cooling equipment performances can also be evaluated as well as influence of control strategies.

A model is a formalized structure characterized by a set of *parameters* which can be *tuned* by experimentation. Once those parameters are identified, the model can be used to perform *simulations* in order to observe its behavior for various solicitations differing from the experimental ones, while included in the range of application associated to the model.

Model *tuning*, *validation* and *quality evaluation* can be distinguished [10]:

- Models can be *tuned* on the basis of manufacturer catalogue and/or experimental data, before attempting to validate them

- Models can be *validated* in different ways: analytically (seldom), or by comparison with other more detailed models, called "mother models", or by comparison with experimental data. This validation consists in verifying that, after having been tuned, the model can well reproduce the behavior of the component considered in the whole domain of use.

- *Quality evaluation* of the model must integrate, not only the validation results, but other considerations, such as tuning "easiness" (according to how much information is required and how much "skill" is required to use this information) and model "robustness" (i.e. its ability to stay realistic in all circumstances, even when going outside its tuning domain…)

Building physics can use models for new building design, or for the audit of existing buildings. The modeling process is regarding the *building* itself (indoor and outdoor walls, ventilation apertures) as well as the *equipments* intended to maintain a given level of comfort for occupants (heating, ventilating, air conditioning). The aim of the simulation can be:

- To verify the ability of the equipments to provide a given *level of comfort* to the building occupants

- To yield a complete *energy balance* of the building and of its system in order to further propose different energy saving strategies and to evaluate their financial and environmental impacts.

Building and System entities are generally modeled separately, and called in a sequential way during a simulation process. The building model allows the determination of the *heating and cooling building demand* as function of the weather data and occupancy schedules, while the system model convert that demand into an *energy consumption*, through a set of parameters.

This approach provides building heating and cooling demands whose values are independent from the system parameters. They don't take into account the limit regarding the maximum available power of the plant, as well as the system specific control laws. Difficulties can also occur to evaluate emission losses resulting from the building and system interaction.

The establishment of a complete model of the building connected to its heating or cooling system is a fascinating task requiring a lot of parameters related to outdoor environment, outdoor and indoor building walls, wall location, thermal bridges, air apertures, air movement, convection heat exchanges, occupant behavior and equipment components.

This thesis work is aiming to build such a building model, with two majors concerns:

- The building model is *dynamic,* called *lumped model,* i.e. built on a set of resistances and capacities, and solved by differential equations. Lumped models are well adapted to the use of a solver such as EES witch is very powerful to solve differential equations.

- The dynamic lumped model is associated to a *building ventilation model*, built on a set of resistances and generators. The use of a solver such as EES is then very convenient because it allows equations not to be written in an explicit form.

All the models are developed through EES solver (Klein, ref [42]).

Lumped models have already been developed by Laret [18], Ngendakumana [22], Kummert [17], Wang [13]. Our purpose is to validate such models by comparing their results to those provided by a detailed dynamic model, built on wall response factors [24], [25]. The validation process can lead either to add more parameters to the model in order to improve its reliability, or to suppress some parameters in order to simplify the model while keeping good quality results, in agreement with the model simulation objectives.

Our purpose is also to build a ventilation model which would include natural air movement as well as mechanical devices (fans and ducts). The model could then yield infiltration and exfiltration air flows referring to fan pressurization test method [27], [28], [29]. The ventilation model complexity should be adapted to the building under study (residential, commercial) and should be able to provide a good estimation of the air quality level, of the thermal comfort when free-cooling is performed, and of the building energy balance.

We are aiming at connecting our building lumped model to equipments including heating and cooling terminal units as well as water pipes, air ducts, heating and cooling plants. The equipments models should be simplified. They can be built on parameters deduced from correlations drawn on more detailed equipment models named *mother models* [11]. Then they can be called *daughter models*. The connection between the building model and its system, through control laws, can provide an estimation of the system ability to maintain indoor comfort. Primary energy consumptions, carbon dioxide emissions and energy costs can also be evaluated.

The complete model can be used to provide results regarding the influence of control strategies on comfort and energy consumption, and to estimate different equipments performances.