GLOBAL SENSITIVITY ANALYSIS OF NON-DOMESTIC BUILDINGS THERMAL BEHAVIOUR

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Non-domestic buildings are usually equipped with a centralised energy management system, the Building Energy Management System (BEMS). The optimisation of the control strategy and the implementation of advanced algorithms in BEMS would allow substantial energy savings in the operation of the energy systems such as Heating, Ventilation and Air Conditioning (HVAC) plants. Simulation tools are necessary to quantify the potential savings.

The existing building simulation tools do not allow the simulation of all advanced control strategies or all interactions between the indoor environment, the HVAC plant and the BEMS. An integrated model of a building was developed in MATLAB in order to perform control strategy assessments. This model comprises three submodels: a model of the building thermal behaviour, a model of the HVAC plant and the control algorithms of the BEMS. In order to be suitable for control strategy evaluation, the model should comply with the following specifications: it should be dynamic, have a short computational time and be replicable to many buildings. The modelling choices result from these specifications.

The building thermal behaviour is simulated though a thermal network model, presented here in a matrix form:

$$\begin{bmatrix} \frac{dT_i}{dt} \\ \frac{dT_w}{dt} \end{bmatrix} = \begin{bmatrix} -\left(\frac{1}{R_{air}} + \frac{1}{R_{eq}}\right) \cdot \frac{1}{C_{air}} & \frac{1}{R_{air} \cdot C_{air}} \\ \frac{1}{R_{air} \cdot C_{envelope}} & -\left(\frac{1}{R_{air}} + \frac{1}{R_{envelope}}\right) \cdot \frac{1}{C_{envelope}} \end{bmatrix} \begin{bmatrix} T_i \\ T_w \end{bmatrix} + \begin{bmatrix} \frac{1}{C_{air}} & \frac{1}{R_{eq} \cdot C_{air}} \\ 0 & \frac{1}{R_{envelope} \cdot C_{envelope}} \end{bmatrix} \begin{bmatrix} \dot{Q}_{internal} \\ T_o \end{bmatrix}$$

Here T_i and T_w are the inside and wall temperatures respectively, $\frac{1}{R_{eq}} = \frac{1}{R_{\{window,infiltration\}}} + \frac{1}{R_{ventilation}}$.

Such model has the advantage of being flexible: each thermal zone is represented by a node of the thermal network and a finer granularity is achieved by increasing the number of nodes. The structure of the thermal network is derived from heat balance equations and their physical interpretation. The values of the parameters of the thermal network model are determined by identification with measured and metered data from the modelled building. The HVAC system is modelled through a white-box model. The plant model main outputs are: the heat supplied to the indoor environment (which is an input of the building thermal submodel) and the equipment statuses (in order to have some insight about the way the HVAC system meets the heating, cooling and ventilation demands). More specifically model outputs are the evolution over time of the indoor temperature, the building thermal envelope temperature, the equipment statuses and the thermal energy provided to the indoor environment. Along with these time dependent curves, some key indicators were chosen in order to have an insight into indoor environment conditions and energy expenditure. There is a choice of the control strategies.

Uncertainty and sensitivity analysis is an important step in accessing building model applications as practically all parameters are either known with some tolerance or are uncertain. We apply variance based global sensitivity analysis (GSA) to identify key parameters whose uncertainty most affects the output. We also use this information to analyse identifiability of parameters during the calibration process.

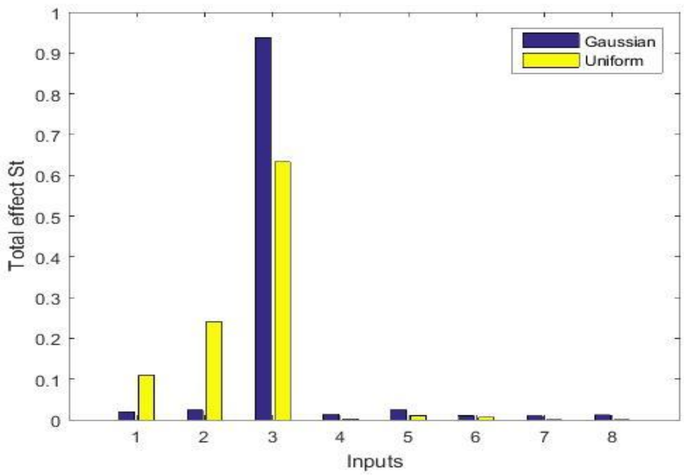
The values of conductance and resistance parameters with their uncertainty distribution parameters for a typical supermarket building in the UK are given in this table:

		Uniform	Gaussian
1	R_{air}	R_{air_Low}= 3.71e-05 R_{air_sup}= 4.54e-05	mean=4.127e-5 std= 2.17e-6
2	$R_{wall} = R_{envelope}$	R_{wall_low}= 2.11e-04 R_{wall_sup}= 2.57e-04	mean=2.34e-4 std=2.5e-5
3	$R_{eq} = R_{ventilation\ \ window}$	R_{eq_Low}= 2.48e-04 R_{eq_sup}= 3.04e-04	mean=2.76e-4 std=7.44e-5
4	$Cair = Cair$	C_{air_low}= 8.32 e+07 C_{air_sup}= 1.02e+08	mean=9.24e+7 std =1.42e+7
5	$C_{wall} = C_{envelope}$	C_{wall_low}= 9.95 e+08 C_{wall_sup}= 1.22e+09	mean=11.1e+8 std=2.35e+9

Two different distributions are considered: Uniform and Gaussian. For Uniform distribution 10% variation is assumed for all inputs. For the Gaussian distribution coefficients of variation (the standard deviation normalized by the expected value $CV = \frac{\sigma}{\mu}$) are presented in this table:

Inputs	Coefficient of variation(%)
1	5.25
2	10.68
3	26.96
4	15.40
5	2.12

The values of total sensitivity indices for eight inputs (five building parameters discussed above and three HVAC parameters) for the thermal energy provided to the indoor environment are presented in the following Fig.:



SobolGSA which is a general purpose GUI driven global sensitivity analysis and metamodeling software was used for GSA [1]. One can see that R_{eq} is the most important factor followed by R_{wall} and R_{air} for the case of Uniform distribution while for the case of Gaussian distribution R_{eq} is the only important factor. We also developed a full scale model using EnergyPlus software and linked it with SobolGSA. The results of the MATLAB based thermal network model are compared with those of a full scale model.

1. SobolGSA software (2016). http://www.imperial.ac.uk/process-systems-engineering/research/free-software/sobolgsa-software/
2. EnergyPlus software (2016) https://energyplus.net/