METHOD FOR VALIDATION OF BUILDING SIMULATION RESULTS USING SENSOR DATA

Donal Browne, D.Browne@ucc.ie
Karsten Menzel, K.Menzel@ucc.ie
IRUSE Group, University College Cork (UCC), Ireland

ABSTRACT

In general, current Building Energy Simulation Tools are used for pre-construction design and comparison of designs rather than a full exact varying representation of reality. To provide the best level of detail full CFD analysis for the entire building would be required. However this is currently by far outside the scope of current computing power for a building energy system. Because these simulation tools are designed for comparison of potential designs and because of the difficulty in predicting occupant behaviour, very often the predicted results do not correlate with the real actual performance when buildings are in operation.

From project experience encountered in the EU FP7 IntUBE project, a deficit has been encountered whereby the correlation between simulation results and real measured data is not entirely accurate. This paper discusses a method of validation, which will provide a means of comparing measured data (e.g. sensors and weather data), and simulated data (e.g. near future simulations).

This method for validation of building simulation results initially involves a comparison of data from building simulation and respective measured sensor readings. From this comparison, value is added from correction of simulation results, and/or input to simulation parameters. Further worth can also be provided by gaining knowledge for creation of simulation profiles which are difficult to predict before construction & operation. Additional value can also be derived from identifying conditions of poor results and relevant factors which can be corrected. Simulation data and actual data is available from a housing unit in Barcelona Spain and research building in Cork Ireland.

The expected result to be derived from this method is to give an indication of quality of simulated data results and provide feedback. If the difference between simulated and real data is too large, steps to improve results will be suggested. In future it is envisioned that automated adjustments may performed to simulation inputs to correct results. Aside from near future simulation validation, the tool may be able to provide long term commissioning feedback to detect and alert users to long term degradation of systems and possible maintenance or repair remedies.

Keywords: Simulation, Data Modelling, Validation

1. INTRODUCTION

As new and retrofitted buildings are developed with more complex monitoring, control and automation systems, more data is being produced. A goal of the scientific and engineering community is to provide a holistic and integrated building information solution which can utilise this information and provide value by reducing building energy consumption. Better use and more integrated use of building energy information can contribute to meeting requirements of both the European EPBD and the European 20-20-20 targets which require the EU to reduce Greenhouse Gas levels by 20%, reduce domestic home energy consumption by 20% and increase Renewable Energy by 20%, all by 2020.

A key part of this holistic energy information solution is the integration of building energy simulation tools. Energy analysis plays an important role in developing an optimal HVAC and Architectural design for new buildings and in determining optimal retrofit and commissioning measures for existing buildings. (Liu & Liu, 2011). However a barrier to this integration is that the majority of commercial building simulation tools are developed for design solutions rather than absolute accurate representations of minute by minute building performance. Therefore, pre construction simulations

often do not exactly correlate with operating building performance even though building simulation tools operate with accurate physics algorithms (Clarke J. , 2001). The reason for this mismatch is that detailed input information is required to produce the correct output (Kusada, 1981). To calibrate a dynamic building simulation, measured data from buildings can be used. Calibrating computer models to actual metered data is not a new practice (Liu & Liu, 2011). As early as 1970, recommendations were made to calibrate models based on measured data (Ayres & Stamper, 1995) Most calibration procedures require months of measured data. (Liu & Liu, 2011). Previous studies have developed a calibration procedure based on developing archetypes whereby patterns of similar buildings which operate alike would be developed and used for future similar buildings. This can be used to calibrate buildings to better predict future similar buildings (Flores Larson, Filippin, Beascochea, & Lesino, 2008).
Comparison of simulated cooling and heating energy simulation against time of day is a very important step in model calibration (Flores Larson, Filippin, Beascochea, & Lesino, 2008)and short term cooling load forecasting, with lead times from 1h to 7 days, can play a key role in the economic and energy efficient operation of cooling appliances (Clarke & al, 2004). The study under development presented in this paper is based on calibrating accurate building information models and associated simulation models with real measured sensor data procured from existing buildings.

2. INTUBE ENERGY INFORMATION INTEGRATION PALTFORM

The main aim of the IntUBE project is to develop intelligent Information and Communications Technologies (ICT) to improve the energy efficiency of these buildings. IntUBE will primarily focus on integrating existing software functionalities using open standards and their open source implementations. Based on the open data from multiple life-cycle stages (especially 'design' & 'operate') new advanced services will be developed to inform inhabitants in intelligent ways of how to change their energy consuming behaviour in ways that reduce energy consumption and improve comfort (Böhms, Plokker, Charvier, Madrazo, & Sicilia, 2010). At the core of the IntUBE approach lies an Energy Information Integration Platform (EIIP) which stores energy information generated along the different stages of the building's lifecycle: conceptual design, design development, operation and retrofitting. The information is organised into three repositories, each dedicated to storing/retrieving different kinds of energy information: a BIM repository for building descriptions, a SIM repository for the simulation results and a PIM repository for the monitoring data.
Problems for simulation, a common language is required, "nuances of capability" exist. (Crawley, Hand, Kummert, & Griffith, 2008) different simulation tools provide a challenge. Therefore a key output of the project is the value that can provided from integrating building simulation, the processes involved and the form used to provide a methodology for storing relevant information from simulations in the EIIP with reference to informing building operation. Although the IntUBE project made use of only two different energy simulation software tools (primarily VABI software) the EIIP is adaptable and can be altered for use with any other simulation tool. This paper describes progress made to date and plans for the future with reference to plans for integration of building simulation and measured sensor data.

3. SIMULATION INFORMATION PROCESS

The simulation process can be considered to have a number of steps.

- Pre processing of Simulation Data
- Run Simulation process
- Export of results to SIM server

It is important to set up the simulation(s) to run depending on the required value or output. The easiest method of determining simulation value is to compare similar simulations. In the example of the Cerdanyola building informing users, two simulations are performed with only one variable differing, in this case blinds open or blinds closed. Whichever is predicted to be most energy efficient is presented to the occupant as the preferable position.

Value of Simulation

The value that can be derived from simulation is relative accurate prediction of near future performance of buildings to minimise energy use. Adjustments can be made to systems or building operation as simple manual adjustments such as opening or closing blinds or windows or as advanced as continuous adjustment of a HVAC system as occupancy/weather conditions and energy tariffs are altered. The output of the system could be a simple display to inform occupants or a complex integration into an intelligent building management system [IBMS].
Potential variables include but are not limited to

- Windows open or closed and degree of same
- Blinds open closed and degree of same
- Control of water radiator heating systems WRT timing and amount
- Control of ventilation systems WRT timing and volumes and treatment

These variables can be adjusted as inputs to the simulation to provide the best output to minimise energy use. This is the purpose of the simulation tool.

SIM Ontology

The SIM ontology has been developed as a SIM operational form. This form records all results from the simulation software and stores it in the EIIP for future use (See Table 1).
Openness of form is provided by allowing for results from more than one simulation tool, whereby any information not created can be left blank in the form. The form can be expanded upon if any other simulation software has results not already covered or listed.

Simulation Undertaken

Results using VABI Simulation. Simulations were undertaken on the Cerdanyola building based on the BIM model from BIM tool set. Single day simulations undertaken with an appropriate lead in time with blinds open or closed provided very slight variations in energy consumption which can be used as a recommendation for occupant before leaving their property.
From this research IES requires more automation; VABI software on the other hand is better developed.

Time Stamps Frequency

Simulation tools used in this project have the ability to perform simulations and create results in a selectable and adjustable minimum time frequency value, typically 5, 10 or 15 minutes. Running simulations at the shortest frequency will take longer to complete and produce more (possibly unnecessary) data. Producing results in greater time frequencies (e.g. 60 minutes or 120 minutes) will be more efficient from a computing point of view, but may not produce accurate representation of near future building conditions.
To provide balance between, it is suggested that 15 minute intervals are used for simulation results. A further advantage of using a 15 minute interval is that it is best suited to match PIM values, i.e. providing an easy comparison between real sensors readings and predicted simulation results.
If greater results periods are required (daily/monthly/quarterly/annual) if any other function, these can be extracted and summed from 15 minute results stored in the EIIP.

Initial Results

This section provides a short description of the set up and results provided from initial simulations for a social housing block in Cerdanyola. Two similar but contrasting simulations were performed using Vabi simulation software. These simulations were performed on the "L" shaped apartment in Cerdanyola. The only difference between these simulations is that the simulations were run with and without solar protection. As a general trend, it was observed that in winter months and cold days that with the shading device, the heating demand is greater and comfortable temperatures will be met.

Operational Simulation Form	
General Building Load Data (15 no Variables)	
Room heating palnt sens. Load	kW
Room hum. Plant load	kW
System air heating load	kW
Aux vent heating load	kW
Boilers load	kW
Ap Sys boilers non-DHW load	kW
Ap Sys boilers DHW load	kW
Room cooling plant sens. Load	kW
Room dehum. plant load	kW
System air sens. clg. Load	kW
System air lat. clg. Load	kW
Aux vent sens. clg. Load	kW
Aux vent lat. clg. Load	kW
Chiller load	kW
Ap Sys chillers load	kW
Weather Variables (14 no variables)	
Dry-bulb temperature	ºC
Wet-bulb temperature	ºC
External dew-point temp.	ºC
Wind Speed	m/s
Wind Direction(E of N)	º E of N
Direct radiation	w /m2
Diffuse radiation	w /m2
Global radiation	w /m2
Solar altitude	º
Solar azimuth	º
Cloud cover	oktas
Atmospheric pressure	Pa
External relative humidity	%
External moisture content	kg/kg
Model Energy Variables (18 no variables)	

Table 1 Example of SIM form

During summer months and on warmer days with the shading device will reduce heat gains and provide temperatures that are more comfortable.
Therefore value can be provided by these results by advising use (or not) of shading devices, determined on a day by day basis, with the aim of minimising heating energy providing that maximum temperature does not exceed a comfortable level.
As the data extracted from the EIIP is in Microsoft Excel workbooks, it was decided to undertake early analysis using this format. Although general patterns could be compared, unfortunately initial results of simulation and real sensor data did not closely match, as would be expected. The main contributory factor for this was differences in weather data. Further deficits on a micro level occurred due to

differences in expected occupancy patterns and volumes. As mentioned previously, this real sensor information will provide input to the simulation to improve accuracy. Development of this early feedback loop will compromise part of future research.

4. ENERGY SIMULATION VALIDATION/CHECKER TOOL

The future step is for the tool is to integrate as part of the EIIP system and will act as a validation tool which will provide a means of comparing measured PIM data (e.g. sensors and weather data) and simulated SIM data (e.g. near future simulations). The value derived from the tool is to give an indication of quality of data, simulated in particular. If the difference between simulated and real data is too large steps to improve results will be suggested. In future system may be developed to allow automated adjustments to be performed upon simulation inputs to correct results. Aside from near future simulation validation, the tool may be able to provide long term commissioning feedback to detect and alert users to long term degradation of systems and possible maintenance or repair remedies.. Possible anomalies could be sourced from alterations to building fabric or use which may not been updated on the BIM model. Another BIM correction may be the potential to identify differences between the "as built" model and real building.

An alternative method of providing value is to allow output from the tool to perform adjustment of results from the SIM to match real measured results. For example if simulation temperatures are continuously too hot, a crude adjustment of results could be undertaken. Further value could be derived from identifying conditions of poor results and relevant factors which could be corrected.

Matching of similar SIM and PIM data will be a straightforward comparison between simulation results and real data in many cases, e.g. straightforward comparison of maximum room temperature or daily meter readings. Greater complexity will occur from adjustment or providing corrective measures if a close comparison does not occur.

5. CURRENT AND FUTURE PLANS

The process described in this paper comprised a small section of the IntUBE project which has now concluded. Future development of the process will be undertaken as part of the SFI funded ITOBO project (http://zuse.ucc.ie/itobo/). Early comparisons have been performed using excel, it is envisioned that macros will be developed to better utilise this information.

Live instantaneous simulation can provide benefit from tuning BMS for near future tweaking of BMS/control systems (continuous commissioning), building certification and IntUBE energy profiles, design performance review.

Possible scenarios which could be implemented include:

- Design Review and comparison: During design phase, inputs for "Design SIM" are estimated future building usage, occupancy density, etc. For "Operational SIM", inputs can be real functional data, from BMS and observation. "Operational SIM" can provide a design check on the Design SIM allowing feedback to designers for future Design SIM improvements.
- Building Benchmarking: Benchmark building energy use as compared to other, similar buildings to identify need for improvement. Will also allow for potential improvements/alterations to BMS setpoints to be simulated to allow for energy savings.
- Energy Use Tracking: Track energy use to monitor changes. Continuous simulation can identify deviations from previous trends or simulated "should be" trends to identify damaged equipment (e.g. broken fan/condenser) or altered user conditions (e.g. change of use, from office space to server room). This can aid facilities managers in detailing the work required for repairs of equipment or building operator to change BMS setpoints.
- Trend Data Analysis: Trend key system parameters to detect problems early and assess system performance. As above.

- Recommissioning or Continuous commissioning: Perform ongoing recommissioning activities to ensure that the building meets its current needs. Identify and correct deviations from “Ideal” initial operating conditions.
- Creation of Building Certification: can provide a more efficient method or an automatic Operational phase building simulation

Further worth can also be provided by gaining knowledge for creation of simulation profiles which are difficult to predict before construction & operation. Additional value can also be derived from identifying conditions of poor results and relevant factors which can be corrected. Simulation data and actual data is available from a housing unit in Barcelona Spain and research Building in Cork Ireland. The expected result to be derived from this method is to give an indication of quality of simulated data results and provide feedback. If the difference between simulated and real data is too large steps to improve results will be suggested. In future it is envisioned that automated adjustments may performed to simulation inputs to correct results. Aside from near future simulation validation, the tool may be able to provide long term commissioning feedback to detect and alert users to long term degradation of systems and possible maintenance or repair remedies

6. CONCLUSION

This paper describes a small portion of the EU FP7 IntUBE project whereby comparable data is produced from energy simulation software and real measured sensor data. The process for providing useful raw data has been completed; future research will focus on providing more value from this data. Although the IntUBE project ended in April 2011, the simulation validation process described here is to be developed further as part of the ITOBO research project. It is envisioned that this will take shape towards Q4 2011.

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