Systems engineering-based model development: predictive simulation of a net-zero home

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Motivation

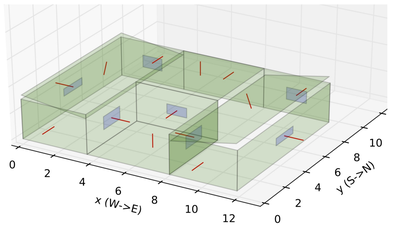
In conjunction with the Solar Decathlon 2017, the Virtual House was developed to:

- Help diagnose and size equipment for *reACT*'s design
- Use in supplying reports to the DOE for compliance with deliverables
- Serve to simulate real-time depictions of a customized model based from *reACT*

Solar Decathlon 2017

The University of Maryland is currently a participant in the Solar Decathlon, an intercollegiate competition held by the Department of Energy. The Maryland team for *reACT* is currently working to construct a net-zero solar-powered house, transport, and reassemble in Denver, CO by October 2017 [1]. As part of this competition, universities integrate and showcase emerging technologies that make it possible for anyone to improve their level of sustainability [2]. *reACT* hopes to enable lifestyle changes through unique engineering and architectural design.

Virtual House

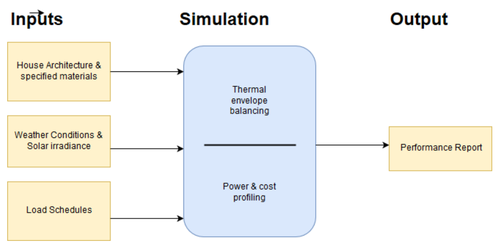


The Virtual House (above) has been designed to use architecture, material properties, weather effects, solar irradiance, and load schedules for input and is simultaneously run among several locations.

This open-source model, written entirely in the Python programming language, includes first-principles descriptions of:

- Solar irradiance
- House PV array power output
- Nominal house energy-related loads
- Thermal modeling of the house primarily the HVAC system

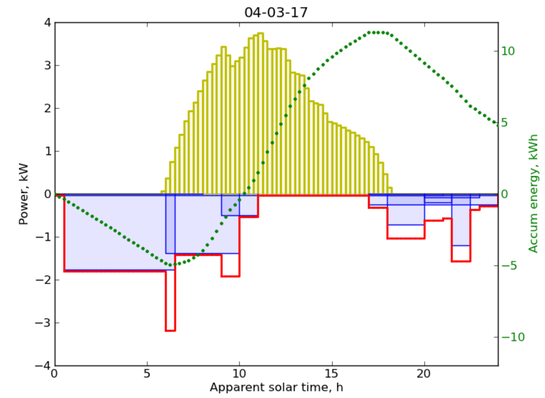
Method

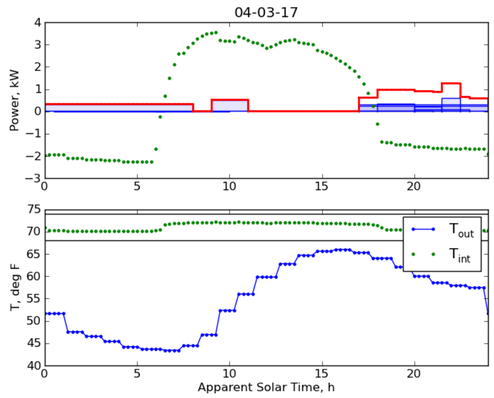


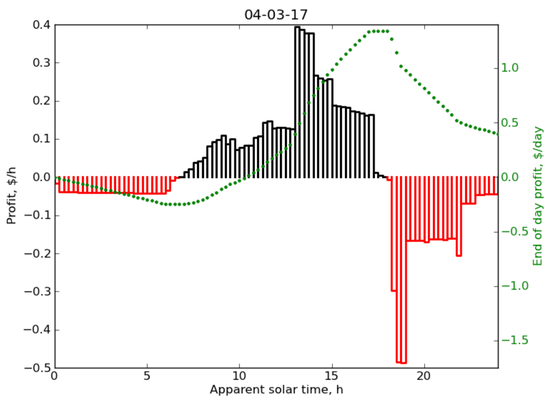
The general schematic of simulation (above) is divided into three parts: inputs, simulation, and output.

- Inputs are mostly specified as parameters from *reACT* (architecture design, material properties, and load schedules), weather forecasts, and solar irradiance model.
- Simulation consists of dynamic simultaneous thermal and power models based from fundamental principles through Euler's method.
- Outputs indicate daily profiles of heat, power, and profit values.

Results & Discussion







Predicted profiles for College Park, MD, April 3rd, 2017.

Power profile (top left): Solar panel power in yellow (kW), total scheduled loads in red (kW), energy accumulation (kWh) in green.

Thermal profile (top right): Waste heat in red (kW) and heat transfer with environment in green (kW) (top half), indoor (green) and forecast (blue) temperatures °F.

Profit profile (bottom left): profits ($/hr) (red and black) and accumulation ($) (green).

The main focal point from the presented data is the accumulated energy and profits showing promise for *reACT*'s anticipated performance throughout the day. As of now, *reACT* has not been constructed, and so validation through direct comparison with actual performance data cannot be done. At this stage the framework for the Virtual House simulation has been completed. It is hoped that through data comparison, a magnitude of significance can be attributed towards each parameter. Model refinement can then be directed towards the variables that impact the house the greatest. Results of this Virtual House simulation are now being stored daily at 12:30 am EST.

References

[1] reACT Team (2017). "reACT - resilient Adaptive Climate Technology" University of Maryland, College Park, https://2017.solarteam.org/, accessed in March 2017.

[2] Solar Decathlon (2017) "Solar Decathlon 2017" Department of Energy, https://www.solardecathlon.gov/, accessed in March 2017.

Future Work

With the framework for the Virtual House built, the model can be adapted to use parameters from other buildings instead. Prior to construction of *reACT*, there are plans to make use of *LEAFhouse*, the previous Solar Decathlon entry in 2007 as a test bed for sensors to report real data. Through this, modeled and real data can be assessed for further refinement on the Virtual House.

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