Home Energy Management System for Coordinated PV and HVAC Controls based on AI Forecasting

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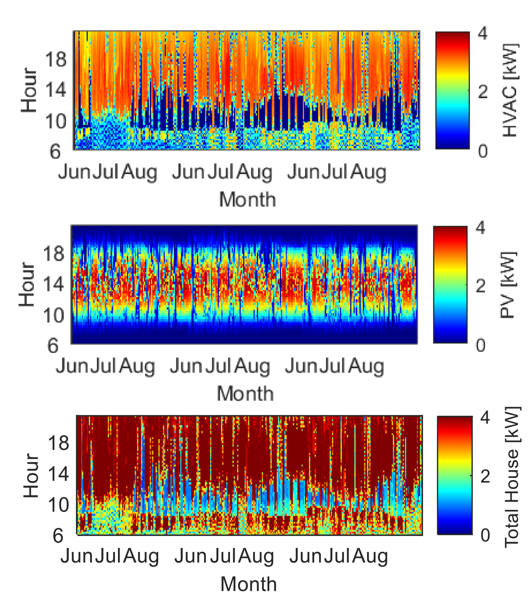
IEEE PES GM Graduate Poster Competition

Introduction

- This HEMS serves to transform HVAC system demand into a schedulable load bank or "dispatchable load" through controls based on day ahead forecasts
- Within this poster, a complete structure from data acquisition to day-ahead load scheduling is proposed
- For the purpose of study, measured data is used in place of forecasts to showcase best case results.

SHINES Field Demonstration Homes

- Experimental 15-minute data in the summer integrated to hourly timestep and isolated the daylight hours from 6am to 9pm only to reduce variability of ML inputs



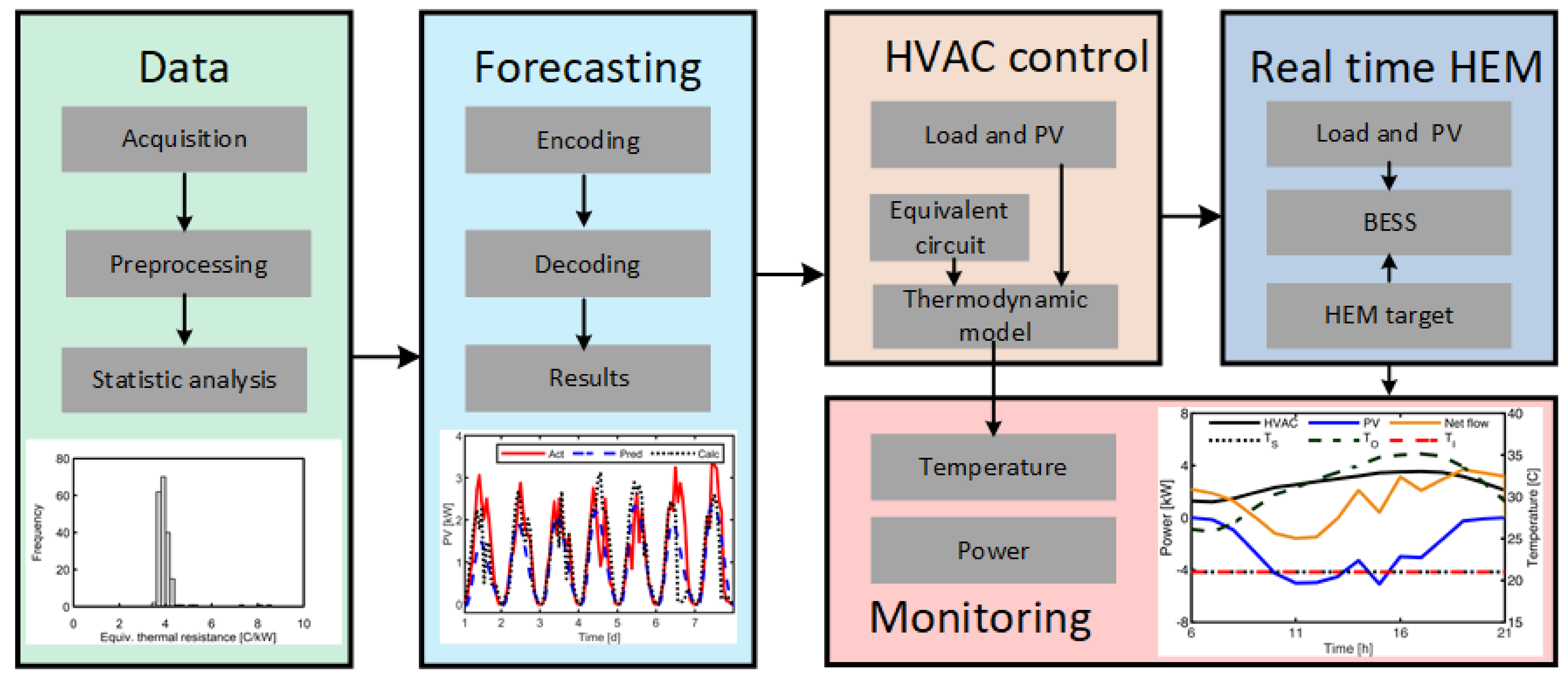
H1 6am -9am	Solar [kwh/day]	Total [kWh/day]	HVAC [kWh/day]	Water Heater [kWh/day]
Max	-27.5599	49.1441	46.10068	4.347975
Average	-18.8156	36.14439	33.0204	1.841788

- Home Energy Management System designed to shift HVAC load into times of renewable energy generation from residential solar PV
- Coordinated PV and HVAC controls for use with day ahead machine learning electric load forecasting
- Case study completed on a SHINES field demonstration home managed by the Electric Power Research Institute (EPRI) in Pensacola, FL.

Coordinated PV and HVAC BTM Controls

- Goal: Schedule HVAC behind-the-meter (BTM) as a "dispatchable load" to optimize renewable energy used for the benefit of the consumer
- Model the HVAC load from representative building model parameters such as:
  - Thermal envelope area [A_r]
  - Thermal resistance [R]
  - Thermal capacitance [C]
  - Heat transfer rate [P_H]
- Calculate the HVAC load and net power for the house every hour from SHINES experimental data or an electric load forecast.

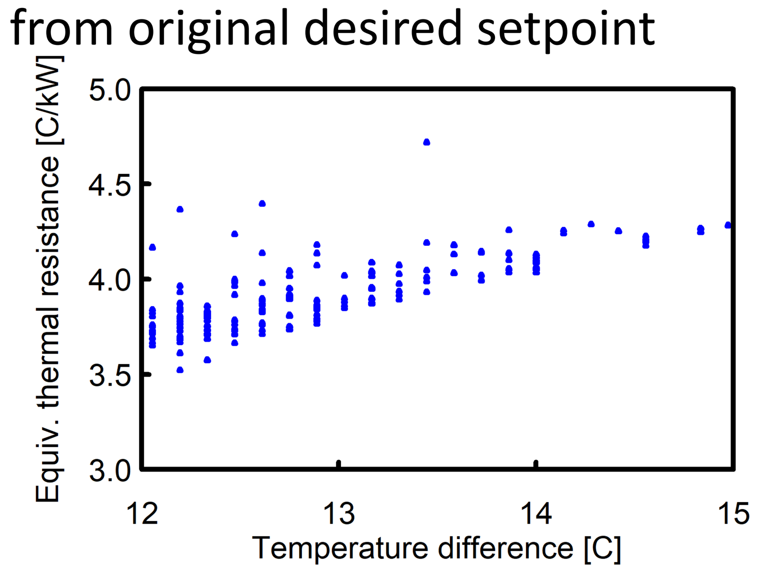
Home Energy Management System Structure



- This approach is a data driven system to schedule ahead HVAC controls based on electric load forecasts
- The system relies on historical power usage and weather data as well as a weather forecast for the future day, if this were to be applied to real houses.

SHINES Case Study Procedure

- HVAC modeled based on an assumed starting setpoint of 21° C
- Study considers daytime hours from 6am to 9pm only as this is when the PV generation occurs
- For the calculation of the equivalent resistance used in this study only temperatures greater than 33° C were considered, ie above 12° C difference from original desired setpoint

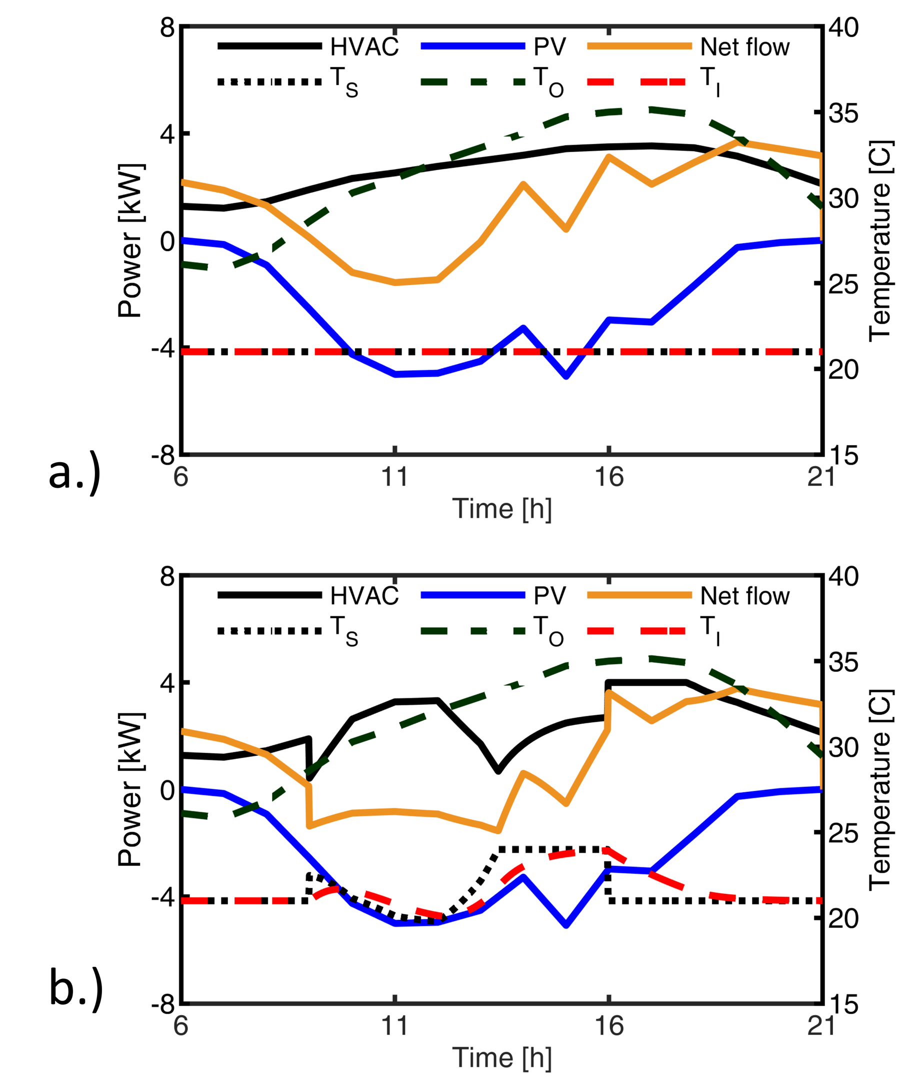


- Case study procedure incremented each timestep:

1. $P_A = COP * (-P_{PV} - P_{House} + P_{target})$
2. $T_s = \left(\frac{T_o - T_i}{R} - P_A\right) * \frac{1}{C} + T_i$
3. $P_{HVAC} = \frac{1}{COP} * \left\{\frac{(T_o - T_s)}{R} - C * (T_s - T_i)\right\}$
4. $P_{net} = P_{house} + P_{PV} + P_{HVAC}$,

where P_A is the power available for HVAC, T_o and T_i are indoor and outdoor temperature, and T_s is the setpoint .

Case Study Results: Representative Day



- Figures: Baseline conditions on July 11, 2020 (a), Controlled case (b)
- HVAC load shifted to times of high PV generation
- Indoor temperature returned to 21°C in the evening for when occupants are likely home to preserve thermal comfort
- HVAC energy use reduced by 5 kWh
- With a small energy system with a 5kWh capacity the net power would be smoothed.

Conclusions

- BTM energy controls serve to bring benefit to the prosumers of the future smart grid
- Example case study on the SHINES smart homes shows daily energy reduction from operating the HVAC system as a "dispatchable load"
- Inclusion of a small energy storage system, smaller than the Tesla Powerwall battery removes all grid fluctuations.

Future and Ongoing Work

- Expand and apply the HEMS controls to be used with day ahead electric load forecasts in real application and an energy storage system to smooth net power flow fluctuations
- Studies into battery sizing and assistance to HEMS

Acknowledgement

This work was supported by the NSF, grant ECCF 1936494. Any findings and conclusions expressed herein are those of the authors and do not necessarily reflect the views of the NSF.