A SELF-LEARNING ENERGY MANAGEMENT SYSTEM FOR A SMART-GRID-READY RESIDENTIAL BUILDING

Fabiano Pallonetto
Yerlan Turenshenko
Eleni Mangina
Donal P. Finn
Objective

Develop and compare two EMS using the calibrated building model and an API to control the building. The first EMS is a simple rule based system while the second EMS uses a decision tree to forecast the best action to perform in the future.
### All Electric Test Bed House (Ireland)

<table>
<thead>
<tr>
<th>System</th>
<th>Conventional (Baseline) Dwelling</th>
<th>All-Electric Dwelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Heating</td>
<td>(17 kW oil) + (5 kW wood)</td>
<td>(12 kW GSHP) + (5 kW wood)</td>
</tr>
<tr>
<td>DHW</td>
<td>Solar Thermal + Immersion (2 kW)</td>
<td>Solar Thermal + Immersion (2 kW)</td>
</tr>
<tr>
<td>DHW Tank</td>
<td>0.2 m³</td>
<td>0.2 m³</td>
</tr>
<tr>
<td>Thermal Storage</td>
<td>None</td>
<td>0.8 m³ Water Tank</td>
</tr>
<tr>
<td>Heat Recovery</td>
<td>None</td>
<td>Heat Recovery Ventilation</td>
</tr>
<tr>
<td>Micro-generation</td>
<td>None</td>
<td>PV System (6 kWp)</td>
</tr>
<tr>
<td>Car</td>
<td>Petrol (1998 cc)</td>
<td>Nissan Leaf EV (24 kWh)</td>
</tr>
</tbody>
</table>

*Test House Energy Model*
Calibrated Energy Plus Simulation

Simulation (time step)

Pre-process

Schedules
An API to control the simulation

Energy Management System using building simulation software
- White box allow sensitivity analysis assessment based on price/weather/occupancy
- Provide dashboard and analytics for Energy Management System
Assumptions to benchmark the EMS

- Use Time of Use Tariff

- Occupancy profile are adjusted according to the building owner habits

- Weather data are from 2012 closest weather station

- Occupancy take into account no holidays
I/O for the EMS implementation

- Storage Tank Temperature (O)
- Storage Tank Set Point (I)
- Circulation pump on/off (I)
- Zone Temperature (O)

**Equipment:**
- Heating Storage Tank 0.8 m³
- Heat Pump
- Heat Meter
- T: Temperature sensor (5)
- kWh: Electricity meter (3)
- F: Flow meter (1)
EMS (1) - Rule-base Algorithm

New timestep

19:00 - 09:00 and 15:00 - 17:00

Turn Circulation Pump on during off peak hours and at night

09:00 - 15:00 and 17:00 - 19:00

Turn Circulation Pump off during peak hours and when nobody is in house
EMS (2) – Decision tree algorithm

1. Get New timestep
2. If action same as last time:
   - Traverse tree to find the most efficient path for energy saving action
3. Create state for timestep
4. Build a tree of child states
5. Execute a new action
6. If action is different:

Diagram:
- Start at Get New timestep
- If action same as last time, go to Traverse tree to find the most efficient path for energy saving action
- If action is different, go to Execute a new action
Results – Electricity profile
Results – Electricity reduction (Jan)

- **SMART CONTROLLER**: kWh 516
- **FIRST PROTOTYPE**: kWh 585
- **BASELINE**: kWh 779
Conclusion

- **Energy annual reduction of**
  - 25% (Rule Based)
  - 50% (Smart Algorithm)

- **Further works will include**
  - Increase the forecast time window above 2 hours
  - Merge the two EMS, the rule based algorithm when there no data to built the decision tree and then switch to the smart algorithm
  - Use the system in other building simulations