A plug&play home energy management algorithm using optimization and machine learning techniques

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Smart homes’ EMS and challenges

1. Computationally intensive optimization algorithms! Assuming perfect predictions!
   ✓ Look-up table with efficient policy, having historical data
   ✓ With imperfect prediction

2. New end-users without historical data!
   ✓ Plug&play algorithm based on other end-users’ look-up table
Data needed for creating the look-up table

- Historical data:
  - End-users demand
  - PV generation
  - ToU tariff

- Optimal policy for state of charge (SOC) of the battery being computed off-line
  - Using dynamic programming (with perfect prediction)
Policy function approximation (PFA) training

- Look-up table or PFA trained by historical data:

- ✔ End-users demand \( (P_d) \)
- ✔ PV generation \( (P_{PV}) \)
- ✔ ToU tariff \( (c) \)
- ✔ Optimal SOC \( (s^*(t)) \)

\[
\hat{s}(t + 1) = f(P_d(t + 1), P_d(t), \ldots, P_d(t - n + 2), P_{PV}(t + 1), P_{PV}(t), \ldots, P_{PV}(t - n + 2), c(t + 1), c(t), \ldots, c(t - n + 2), s^*(t), \ldots, s^*(t - n + 1))
\]

- Recurrent neural network (RNN) applied to tune \( f \), in such a way to make \( \hat{s}(t + 1) \) close to the \( s^*(t + 1) \)
Real time execution of tuned PF + control policy

- To compute and send the ctrl signals to the battery:

\[ \hat{s}(t + 1) = f(\tilde{P}_d(t + 1), P_d(t), ..., P_d(t - n + 2), \]
\[ \tilde{P}_{PV}(t + 1), P_{PV}(t), ..., P_{PV}(t - n + 2), \]
\[ c(t + 1), c(t), ..., c(t - n + 2), \]
\[ s^*(t), ..., s^*(t - n + 1)) \]

- Predicted data

✓ \( \tilde{P}_d(t + 1) \): demand of 7 days before (seasonality)
✓ \( \tilde{P}_{PV}(t + 1) \): PV generation of current time step

- Control filter checking if computed SOC is feasible

\[ \tilde{s}(t + 1) = F(\hat{s}(t + 1)) \]
Plug&play algorithm for new end-users

1. Find end-users with considerable historical data
2. Cluster them based on different consumption pattern (k-mean)
3. Train PFA for each of those end-users
4. Find the *indicator PFA* in each cluster
5. Assign new end-user into one of the clusters (based on a survey)
6. Apply indicator PFA for that end-user
7. Compute ctrl signal related to $\hat{s}(t + 1)$
Simulation study

- Solar PV 6 kW
- Battery 10 kWh
- Indicator PFA trained on user 5 for the first 300 days of 2013
- Indicator PFA applied to user 1 on the day 355
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