Multi-user Energy Sharing: Energy Storage Service and Coalition Formation Algorithm

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Overview

• Introduction
• Methodology
  ▪ Energy Storage Service
  ▪ P2P Energy Sharing & Coalition formation
• Result
• Conclusion
Introduction

• Sharing Economy is Blooming
  ▪ Ride sharing
  ▪ Room sharing
  ▪ Energy sharing

https://brand.uber.com/guide
https://microgridknowledge.com/energy-sharing-prosumers-microgrids/
Introduction

• Simulation Dataset

**Dataset 1** comes from the UMass Smart* microgrid dataset. The dataset contains 443 unique households’ electrical data over a single 24-hour period in the United States.

**Dataset 2** comes from a field trial experiment on Bruny Island, Australia. It consists of 31 selected unique households on the island.
Energy Storage Service Sharing

- Users scheduled energy storage service based on their planned demands in one day ahead.
- Energy storage service provider notifies users the allocations of demands they can supply.
- Users still need to purchase energy from the grid if they cannot be satisfied by energy storage.
P2P Energy Sharing

P2P energy sharing scenario: cost-sharing by direct connection.

Arrange P2P energy sharing steps:
- Planning: sufficient historical consumption and supply data
- Matching: automatic tools to form coalitions
- Agreement: households agree on a cost-sharing method
- Operation: executed P2P energy sharing
P2P Energy Sharing

Variables and parameters of the P2P energy sharing management system model.

- Demand: $a_i(t)$
- Rooftop PV: $r_i(t)$
- Home Battery: $b_i$
- Grid: $C_g^+, C_g^-$
Multi-user Coalition Formation Algorithm

This algorithm is designed for large size (more than 2 users) coalitions formation in P2P energy sharing.

**Coalition Formation**

1. **Start**
2. **Input:** $\text{Pref}_i$
3. $i = 1$
4. **Update $i$**
5. **$i < N$?**
   - **True**
     - $\text{ProposeStage}(i)$
     - $\text{AssessStage}(j)$
     - $\text{PickStage}(j)$
   - **False**
     - Loop $i \in N$
8. **End**
Multi-user Coalition Formation Algorithm

Repeat these three stages until every user in a coalition is held for consideration, the coalition formation process is finished.
Energy Storage Service Result

Overall utility of two Cost-Sharing mechanisms of 9 users

**Proportional Cost Sharing**
- Without energy storage
- With energy storage

**Egalitarian Cost Sharing**
- Saved: 13.4%
- Saved: 20.8%
- Saved: 25.1%
- Saved: 27.4%
- Saved: 35.6%
- Saved: 68.5%
- Saved: 117.2%
- Saved: 235.2%

User Id: 1, 2, 3, 4, 5, 6, 7, 8, 9
Energy Storage Service Result

Energy demand $a(t)$, state-of-charge $b(t)$, consumption rate $y_i(t)$ and charging rate $x_i(t)$ of 9 users.
P2P Energy Sharing Result

3-user coalitions structure under different cost-sharing methods

<table>
<thead>
<tr>
<th>Equal-split</th>
<th>Proportional-split</th>
<th>Egalitarian-split</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 coalitions</td>
<td>9 coalitions</td>
<td>10 coalitions</td>
</tr>
</tbody>
</table>
P2P Energy Sharing Result

4-user coalitions structure under different cost-sharing methods
P2P Energy Sharing Result

Comparison of utility difference of 2 and 3-user coalitions under two battery capacities

Comparison of utility difference of 2 and 3-user coalitions under two consumption rates

Comparison of running time of 2-user and 3-user coalitions under different cost-sharing mechanisms
Conclusion

- Users can benefit from energy storage sharing through utilizing the electricity exported from energy storage which is charged during off-peak period.
- P2P energy sharing among users achieved cost saving. With coalition size increased, the benefit of users will also increase.
- Multi-user coalition formation algorithm had been developed and evaluated for 3 and 4-users.