IEA EGRD
The Role of Storage in Energy System Flexibility

Flexibility Option of the Demand Side

Matthias Stifter (AIT Energy Department, Austria)
Motivation for Demand Response

Need for flexibility of the demand

- Increase of (local) distributed generation (e.g.: PV, CHP, Wind)

  → PV: „grid-parity“

  → Impact on network: curtailment (Germany: since 2013: 60% Peak curtailment)

  → Higher dynamics in the power system

  → Higher unbalance due to forecast errors
DR as a possible alternative to energy storage

Demand Response Resources

- **Electro thermal** - thermal storage
  - Warm water boilers
  - Cooling / freezers
  - Heating (HVAC)
- **Electric vehicles** – electrical storage
  - Controlled charging
- **Public services** – load shifting
  - Water pumps
  - Waste water / sewage
- **Storages** → Buffer to meet energy constraint (comfort)
- **Load shifting** for network operation is already in place for many years (ripple control)
- **Aggregation** makes it more robust → Virtual Power Plant
Potentials of DR

Technical and practical potentials in Germany

<table>
<thead>
<tr>
<th>sectors</th>
<th>Techn. shiftable power</th>
<th>Displacable Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household</td>
<td>2010: ca. 2,6 GW</td>
<td>2010: ca. 8,0 TWh per year</td>
</tr>
<tr>
<td></td>
<td>2020: ca. 3,8 GW</td>
<td>2020: ca. 12,4 TWh per year</td>
</tr>
<tr>
<td></td>
<td>2030: ca. 6,0 GW</td>
<td>2030: ca. 32,3 TWh per year</td>
</tr>
<tr>
<td>Tertiary sector</td>
<td>2010: ca. 1,4 GW</td>
<td>2010: ca. 5,0 TWh per year</td>
</tr>
<tr>
<td></td>
<td>2020: ca. 1,7 GW</td>
<td>2020: ca. 5,6 TWh per year</td>
</tr>
<tr>
<td></td>
<td>2030: ca. 1,8 GW</td>
<td>2030: ca. 9,7 TWh per year</td>
</tr>
<tr>
<td>Industry</td>
<td>2010, 2020, 2030 load shift potential of 2,8 GW to 4,5 GW</td>
<td></td>
</tr>
</tbody>
</table>

- 1,5 GW load shifting potential in Germany especially through thermal applications

Source: B.A.U.M Consult - Load shifting potentials in small and medium-sized businesses
Potentials of DR

Sectorial electricity end use in Austria (2012)

Transport in Rohrfernleitungen 144
Textil und Leder 441
Bau 635
Fahrzeugbau 763
Landwirtschaft 792
Nicht Eisen Metalle 979
Bergbau 1.072
Sonstiger Landverkehr 1.318
Eisenbahn 1.621
Sonst. Produzierender Bereich 1.656
Holzverarbeitung 1.673
Steine und Erden, Glas 1.826
Nahrungs- und Genußmittel, Tabak 2.130
Eisen- und Stahlerzeugung 3.999
Maschinenbau 4.104
Chemie und Petrochemie 4.263
Papier und Druck 4.614
Öffentliche und Private Dienstleistungen 13.371
Private Haushalte 16.860

Source: Statistik Austria, 2012
Potentials of DR

Categories of electricity use in households (2012)

Source: Statistik Austria, 2012
Potential of DR

Technical potentials in Austria

- Practical load shift demand at households in Austria

Source: Energieinstitut an der JKU Linz – Project „LoadShift“
Differences between DR and energy storage

Battery operation vs. Demand requirements

Battery:

\[ P_{\text{charge}} \rightarrow + \rightarrow P_{\text{discharge}} \rightarrow P_{\text{losses}} \]

\[ \text{SOC} = f (\text{operation mode}) \]

Demand Response:

\[ P_{\text{charge}} \rightarrow + \rightarrow (\rightarrow P_{\text{discharge}}) \rightarrow P_{\text{demand}} \]

\[ \text{SOC} = f (\text{demand}) \]
## Differences between DR and energy storage

### Battery operation vs. Demand requirements

<table>
<thead>
<tr>
<th></th>
<th>Battery</th>
<th>Demand Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operation</strong></td>
<td>charging / off / discharging</td>
<td>(forced) charging / off</td>
</tr>
<tr>
<td><strong>Self discharging</strong></td>
<td>losses</td>
<td>losses = customer demand</td>
</tr>
<tr>
<td><strong>SOC range</strong></td>
<td>depends on previous operation</td>
<td>unknown free rest capacity</td>
</tr>
<tr>
<td><strong>Rated power</strong></td>
<td>charging = discharging</td>
<td>withdraw &gt; charging</td>
</tr>
<tr>
<td><strong>Storage time</strong></td>
<td>short to long term</td>
<td>(short term) “shifting”</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>dispatchable</td>
<td>external factors (demand, T, …)</td>
</tr>
<tr>
<td><strong>Purpose</strong></td>
<td>dedicated system</td>
<td>part of demand side</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>energy management system</td>
<td>simple control (e.g., thermostat)</td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>storage of electric energy</td>
<td>shifting of energy</td>
</tr>
<tr>
<td><strong>Scale</strong></td>
<td>large / utility</td>
<td>settlement, building, households</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Large scale = industrial services</td>
</tr>
</tbody>
</table>
Examples from pilots and field tests
Sharing best and bad practices and defining use cases
Project SGMS-HiT – Smart Grids Model Region Salzburg

Buildings as interactive participants in the Smart Grids
SGMS – HiT

Utilizing HVAC-Systems (heating, hot water)

- Separate **usage of energy** from **energy supply**
  - **Buffering** with thermal storages

- Use **energy** which is most **efficient** for the grid
  - PV - Heatpump
  - Biogas (CHP)
  - Grid
  - District heating
  - **grid friendly building**

- **Comfort** must be **preserved**.
SGMS – HiT
Three heat sources feeding into one storage tank

- District heating
- Combined heat and power plant (68 kW therm, 30 kW elec)
- Heat pump (45 kW therm)

90m³ Hot water storage tank

62 ºC
Project: gridSMART® - Residential Real-time Pricing

Overview – Transactive Grid Control

1. Automated, price-responsive device controls express customer’s flexibility (based on current needs)

2. Customer system aggregates responses to form overall price flexibility curve

3. Utility aggregates curves from all customers

4. Aggregator determines price at which grid objective achieved, broadcasts to consumers
Project: gridSMART® RTPda Demo

- First **real-time market** at distribution feeder level with a tariff approved by the PUC of Ohio
- **Value streams**
  - Energy purchase benefit
  - Capacity benefits: e.g., peak shaving
  - Ancillary services benefits
- **Uses market bidding mechanism** to perform distributed optimization – **transactive energy**
  - ~200 homes bidding on 4 feeders
  - Separate market run on each feeder
  - “Double auction” with 5 minute clearing
- **HVAC automated bidding**
  - Smart thermostat and home energy manager
  - Homeowner sets comfort/economy preference
  - Can view real-time and historical prices to make personal choices
Electric Vehicles

Electric storage as a flexible resource to integrate renewables
EV Simulation Environment

- Power Grid Simulation
- CP & EV Simulation
- Mobility Simulation
- Scenario & Use-Case

Results

- Power demand
- Trip data
- Traffic data

- Traffic data
- Trip data
Use-Case Description: Basic Data

Data of District Lungau

<p>| | |</p>
<table>
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<tr>
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</tr>
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<tbody>
<tr>
<td>Population 2008</td>
<td>20835</td>
</tr>
<tr>
<td>Passenger vehicles Lungau 2008</td>
<td>10960</td>
</tr>
<tr>
<td>50% BEV/PHEV</td>
<td>5749</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Battery [kwh]</th>
<th>Charging Specifications</th>
<th>Range [km]</th>
<th>Consumption [kWh/km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEV</td>
<td>27,5</td>
<td>16 230 3</td>
<td>130</td>
<td>21,15</td>
</tr>
<tr>
<td>PHEV</td>
<td>10,5</td>
<td>16 230 1</td>
<td>60</td>
<td>17,50</td>
</tr>
</tbody>
</table>
Impact of different maximum charging power (11kW)

Opportunity Charging – Summary (Summer & Winter)

<table>
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<th>Scenario</th>
<th>Number of EVs</th>
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<td>5%</td>
<td>574</td>
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<tr>
<td>25%</td>
<td>2873</td>
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Charging power: 11 kW
Impact of different maximum charging power (43kW)

Opportunity Charging – Summary (Summer & Winter)

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Charging power:
11 kW
43 kW
Power demand in a car park (Park & Ride)

- Distribution of parking duration and the zone of attraction

Distribution of parking duration of 147 electric vehicles (t=60min)  
Zone of attraction for the car park
Uncontrolled Charging (2020)

- Charging power for best case (summer) / worst case (winter) (147 Cars)
Controlled Charging Worst Case - Winter (2020)

- Charging power for worst case (147 Cars)
Controlled and uncontrolled charging of BEVs (MV)

- Local supply - demand match in medium voltage networks

<table>
<thead>
<tr>
<th>Number of BEVs</th>
<th>Battery capacity</th>
<th>BEV max. charging power</th>
<th>Power limit</th>
<th>PV $P_{peak}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>306</td>
<td>23 kWh</td>
<td>11 kW</td>
<td>400 kW</td>
<td>100 kW</td>
</tr>
</tbody>
</table>

Medium Voltage Power Grid Lungau

3 MV nodes
Integration of Renewable Energy

- Local supply - demand match in medium voltage networks

Uncontrolled and controlled charging of 306 EVs with 11 kW during two summer days. Note: wind is accumulated on top of PV generation

### Two days simulation in summer

<table>
<thead>
<tr>
<th>Charging Mode</th>
<th>empty EVs</th>
<th>P-peak [kW]</th>
<th>Charged Energy [kWh]</th>
<th>DER Energy [kWh]</th>
<th>DER Coverage [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>uncontrolled 11kW</td>
<td>15</td>
<td>751</td>
<td>9964</td>
<td>8079</td>
<td>54%</td>
</tr>
<tr>
<td>controlled 11kW/SOC50</td>
<td>55</td>
<td>366</td>
<td>6832</td>
<td>8079</td>
<td>89%</td>
</tr>
<tr>
<td>controlled 11kW/SOC25</td>
<td>66</td>
<td>324</td>
<td>6229</td>
<td>8079</td>
<td>99%</td>
</tr>
</tbody>
</table>

### Two days simulation in winter

<table>
<thead>
<tr>
<th>Charging Mode</th>
<th>empty EVs</th>
<th>P-peak [kW]</th>
<th>Charged Energy [kWh]</th>
<th>DER Energy [kWh]</th>
<th>DER Coverage [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>uncontrolled 11kW</td>
<td>135</td>
<td>883</td>
<td>12613</td>
<td>3971</td>
<td>26%</td>
</tr>
<tr>
<td>controlled 11kW/SOC50</td>
<td>197</td>
<td>552</td>
<td>7267</td>
<td>3971</td>
<td>50%</td>
</tr>
<tr>
<td>controlled 11kW/SOC25</td>
<td>218</td>
<td>353</td>
<td>5051</td>
<td>3971</td>
<td>71%</td>
</tr>
</tbody>
</table>
Validation of charging management

- Real and simulated EVs for charging management validation

![Diagram showing the validation process involving electric vehicle simulation environment (EVSim), charge controller, and real-world charging station. The diagram illustrates the data exchange interface (OPC) and the connection to renewable generation and distributed energy management system (DEMS).]

Tolerance range, \( P_{\text{set}} \) and \( P_{\text{act}} \) during simulation and deviation
In a dedicated demo area supplied by a 250 kVA secondary substation:

- PV system at every second roof top
- Electric vehicle in every second garage
- Field test of an integrated smart grid solution for low voltage grids
- “anticipating the future”
- funded by Austrian Climate and Energy Fund & Province of Salzburg
Controlled e-car charging

source: Roman Schwalbe, AIT
Markus Radauer, 2014
IEA DSM Task 17
Objectives, Subtasks, Outcomes
Subtask of Phase 3 - Introduction

Systems view on enabling flexibility in the smart grid

- **Different views** on the Smart Grid:
  - Technology
  - Customer
  - Policy
  - Market

- Focus on the **enabling of flexibility** and the impact of it on the stakeholders:
  - What are the requirements?
  - How do we manage it?
  - How will it effect operation?
  - What are the benefits?
Summary
Challenges and Outlook
Summary

Changes and impact on stakeholders operations

- Mayor differences between battery and DR
- Several studies have identified DR as a cost effective way to integrate Renewables
- Processes with thermal or electric storage have high potentials
- Large customers, but also medium and small customers could be targeted
- Charging / positive power has more potential
- DR for balancing forecast uncertainties of renewables
- Dynamic of load is a challenge for the system operation. Research in understanding and developing tools (e.g. prediction) needed
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Appendix
Additional Information
Subtask of Phase 3 – Subtask 10

Role, and potentials of flexible prosumers (households, SMEs, buildings)

- **Controllability** requirements (generation and consumption)
- **Opportunities, challenges** and **barriers** for flexibility services (providers and technologies)
- Energy and power **balancing potentials**
- **Smart technologies** (SM and Customer Energy MS)
  - VPPs
  - EV charging
  - DG-RES integration and storage
  - Integrating heat pumps and thermal storages
Subtask of Phase 3 – Subtask 11

Changes and impact on stakeholders operations

- Methodology development for assessing/quantifying impact
- Grid, market and customers (prosumer/consumer) interaction
- Sharing common benefits/losses
- Optimization potential (eg. DR building audits and customer requirements)
- Regulatory and legislative requirements
- Comparison costs vs. delayed investments
Subtask of Phase 3 – Subtask 12

Sharing experiences and finding best/worst practices

- **Collection of data**
  - Workshops

- **Lessons learned** from existing pilots
  - EcoGrid-EU Bornholm, PowerMatchingCity I and II, Linear, Greenlys, Building2Grid, SmartCityGrid: CoOpt, eEnergy, …

- **Country specifics**
  - differences in the implementation
  - applicability

- **Extrapolation** of the results from previously collected projects on applicability
Subtask of Phase 3 – Subtask 13

Conclusions and recommendations

- Based on the **experts’ opinion**

- Will provide a **ranking** based on
  - Impacts
  - Costs
  - Future penetration of the technologies
CEMS and Power Management System interfaces

IEC 62746 Technical Report Objective

Use cases and requirements for the interface between the power management system of the electrical grid and customer energy management systems for residential and commercial buildings and industry.

- User stories → use cases → data model → information content & structure
- Examples:
  - The user wants to get the laundry done / EV charged by 8:00pm
  - Grid recognize stability issues
  - CEM feeds own battery pack energy into own network or into the grid
  - Heat pump and Photovoltaic Operation with Real-Time Tariff

Figure 6: Cascaded CEM architecture