Specification and Assessment of Electric Energy Storage Systems based on Generic Storage Load Profile

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Agenda

- Motivation
- SDA-Methodology
- Specification Process
- Application Example: Industrian Plant
- Discussion and Conclusion
Motivation

- Rapid increase of renewable energies in the grid
- Renewable energies are highly volatile
- Energy consumption is hard to predict

Electrical Energy Storage Systems (EES) serve as intermediates between consumption and renewable production
Motivation

- Depending on task different storage types and properties are necessary:
  - Type of storage technology
  - Capacity
  - Maximum charge and discharge power
  - Cycle-life and energetic losses

- Decisions are crucial for the profitability of the energy storage system

**Properties of the energy storage system must be thoroughly determined**

**No general methods available for this task**
Object:
Find the optimal energy storage system for the application

Challenge:
- No methodologies
- Documented procedures for specific applications

Approach:
- Development of a technologically neutral process
- Analysis of the Process
- Definition of four standardized steps:
  1. Specification
  2. Design
  3. Assessment
  4. Optimisation

SDA-Methodology
SDA-Methodology

Focus on 'Specification'

- Analysis of Field of Application
  - Functional Requirements
  - Load-Profile Synthesis
    - Generic Loadprofile
    - Dimensioning
      - Specific Requirements

- Design
  - Technology Decision
  - Energy Storage
    - Properties Energy Storage

- Operational Strategy

- Assessment
  - Modeling & Simulation
    - Operating Behaviour
      - Assessment

  - Iteration / Optimisation
    - Quality Energy Storage System
    - Properties Energy Storage System
    - Specific Requirements

Symposium Energieinnovation Graz 2014 | Institute for Mechatronic Systems | TU Darmstadt | Maximilian Schneider | 6
Specification Process

‘Specification’:
- In-depth analysis of the field of application
- Identification of storage operator needs
- Assumption of ideal storage

Results from ‘Specification’:
- Nominal electrical power
- Usable storage capacity
- Goals for the ‘Design’ process
  - Efficiencies
  - Cycle life
  - Safety
  - Total costs
  - Specific energy and power densities

Criteria also basis for the ‘Assessment’ and ‘Optimization’
Application Example: Industrian Plant
Application load profile

Generating an application load profile

\[ t_{\text{set-up}}^{1,1} \rightarrow \text{Machine 1} \rightarrow t_{\text{set-up}}^{1,2} \rightarrow \text{Machine 1} \rightarrow t_{\text{set-up}}^{1,3} \rightarrow \text{Machine 1} \]

- Machine 2
- Machine 2
- Machine 2
- Machine 2
- Machine 2

\[ \cdots \]

- Machine n
- Machine n

Time
Application Example: Industrian Plant
Synthesis of generic application load profile

Aim of the EESS: smoothen the load profile

Determination of ideal Generic Load Profile with EESS: zero-phase digital low-pass filter
Application Example: Industrian Plant
Synthesis of generic application load profile

Calculation of the generic storage profile (unbalanced):

\[
P_{st,\text{gen},\text{ub}} = P_{\text{load,gen}} - P_{\text{app}}
\]

\[
E_{\text{st}}(\tau) = \sum_{t=1}^{\tau} P_{t} \cdot \Delta t
\]
Application Example: Industrian Plant
Operational Strategy

- Operational strategy is necessary to balance the EESS
- Power and SoC controller parameters must be set

Application Example: Industrian Plant
Synthesis of balanced storage profile
Application Example: Industrian Plant
Analysis and Specification

Power distribution

59 kW @ 96%
Application Example: Industrian Plant
Analysis and Specification

Energy distribution

Anzahl

Frequency in %

Energieinhalt in kWh

Frequency in %

Energy in kWh

Application Example: Industrian Plant
Analysis and Specification

Energy distribution

Anzahl

Frequency in %

Energieinhalt in kWh

Frequency in %

Energy in kWh

- 6.5 kWh @ 46%

5.6 kWh @ 44%

12.1 kWh @ 90.2%
Application Example: Industrian Plant
Analysis and Specification

Additional information can be gained from the balanced storage profile:

<table>
<thead>
<tr>
<th></th>
<th>Per Profile (≈8 h)</th>
<th>Per Year (200 workdays)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power ramp rate</td>
<td>71.8 kW/s</td>
<td>71.8 kW/s</td>
</tr>
<tr>
<td>Number of load reversals</td>
<td>17,415</td>
<td>3,483,000</td>
</tr>
<tr>
<td>Number of load cycles (100% DoD and 100 % Capacity)</td>
<td>10.7</td>
<td>2,133</td>
</tr>
</tbody>
</table>
Discussion and Conclusion

- Sizing of EESS is important
- No standardized methods available
- SDA Methodology as overall approach to size, design and optimize energy storage systems
- 'Specification' process allows for technology neutral definition of requirements

- Detailed information about the field of application necessary
- Consideration of losses later in the process can affect the storage performance

- Uncertainties should be integrated into the procedure
Thank you very much for your attention!

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