Smart Battery Systems
for Energy Storage

Lithium-ion
Optimized Battery Solutions for ESS Applications

Samsung SDI provides a variety of solutions from residential to utility-scale energy storage.

Applications

**Generation**
- Ancillary Services
  - Spinning reserves
  - Non-spinning reserves
  - Voltage support
  - Black start

**Bulk Energy Services**
- Electric energy time-shift (Arbitrage)
- Electric supply capacity

**T&D (Transmission & Distribution)**
- T&D Infrastructure Services
  - Frequency regulation
  - Transmission upgrade deferral
  - Transmission congestion relief
  - Distribution upgrade deferral
  - Voltage support

**Demand**
- Customer Energy Management Services
  - Power quality
  - Power reliability
  - Retail electric energy time-shift
  - Demand charge management

Product Line-up

- **Prismatic Lithium-ion Cells**
- **Battery Modules & Trays**
- **Battery Systems for Utility-Scale, Commercial and UPS**
Reliable Samsung SDI
Continuous Innovation

Based on excellent cell technology, our innovations make your ESS more enhanced and valuable.

Safety First
Multi-layered protection on cell
1. OSD (Overcharge Safety Device)
2. Vent
3. Fuse
4. SFL (Safety Functional Layer)
5. NSD (Nail Safety Device)*

Long Cycle Life
Key Advantages of Samsung SDI’s Cell
- Longer expected cycle life
- Slow, linear capacity degradation even for lower SOH levels
- Components design for longer durability (30 years+)

Cycle Life of 68Ah Cell
- Capacity (%): 80, 90, 100
- Cycle: 2000, 4000, 6000, 8000

6,000 Cycle Life
* Samsung SDI’s lab test (DOD100%, 1C/1C at 25°C)

Higher Energy Density
[Module]
- 177kWh/L
- 236kWh/L

[Max 40ft ISO Container]
- 3.3MWh
- 4.8MWh

Innovative Changes for 2016
- High energy & high power cell
- Compact module
- Multiple arrangement

Unique Samsung SDI’s LTS (Life-Time Simulation) Technology
- Customer’s Needs → Samsung SDI’s LTS → Optimal Battery Sizing
- Big data: Customer load profiles
- Mathematical modeling: Arrhenius
- Aging parameters: Temperature, C-rate, DOD, SOC, SOH, etc.
- Highly accurate and reliable simulation results on multi-use and multi-cell levels

Key Advantages of Samsung SDI’s Cell
- Longer expected cycle life
- Slow, linear capacity degradation even for lower SOH levels
- Components design for longer durability (30 years+)

Cycle Life of 68Ah Cell
- Capacity (%): 80, 90, 100
- Cycle: 2000, 4000, 6000, 8000

6,000 Cycle Life
* Samsung SDI’s lab test (DOD100%, 1C/1C at 25°C)
Battery Module & Tray

Module

<table>
<thead>
<tr>
<th>Specification</th>
<th>M2994</th>
<th>M2963 / M2968</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell type</td>
<td>Prismatic</td>
<td>Prismatic</td>
</tr>
<tr>
<td>Energy kWh</td>
<td>2.8</td>
<td>2.0</td>
</tr>
<tr>
<td>Nominal voltage V</td>
<td>29.6</td>
<td>29.2</td>
</tr>
<tr>
<td>Operating voltage V</td>
<td>25.6 ~ 33.2</td>
<td>24.0 ~ 32.8</td>
</tr>
<tr>
<td>Peak discharge C-rate</td>
<td>0.5 / 6</td>
<td>6 / 4</td>
</tr>
<tr>
<td>Dimension (W x D x H) mm</td>
<td>457 x 185 x 154</td>
<td>214 x 414 x 163</td>
</tr>
<tr>
<td>Weight kg</td>
<td>22</td>
<td>17</td>
</tr>
</tbody>
</table>

2016 Module*

<table>
<thead>
<tr>
<th>Specification</th>
<th>M8994 E2</th>
<th>M8194 M2</th>
<th>M8068 P2</th>
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</thead>
<tbody>
<tr>
<td>Cell type</td>
<td>Prismatic</td>
<td>Prismatic</td>
<td>Prismatic</td>
</tr>
<tr>
<td>Cell capacity Ah</td>
<td>94</td>
<td>94</td>
<td>68</td>
</tr>
<tr>
<td>Energy kWh</td>
<td>8.39</td>
<td>7.65</td>
<td>5.46</td>
</tr>
<tr>
<td>Nominal voltage V</td>
<td>89.3</td>
<td>81.4</td>
<td>80.3</td>
</tr>
<tr>
<td>Operating voltage V</td>
<td>76.8 ~ 99.6</td>
<td>70.4 ~ 91.3</td>
<td>68.2 ~ 90.2</td>
</tr>
<tr>
<td>Dimension (W x D x H) mm</td>
<td>370 x 588 x 160</td>
<td>370 x 588 x 160</td>
<td>370 x 650 x 160</td>
</tr>
<tr>
<td>Weight kg</td>
<td>&lt; 60</td>
<td>&lt; 55</td>
<td>&lt; 50</td>
</tr>
</tbody>
</table>

*2016.3Q mass production  **Fan is optional, dimension with fan is equal to M8068 P2

48V Tray

Special Benefits

- Investment cost down
- Operation & maintenance convenience
- Lead-acid battery replacement
- No additional switchgear box
- Expandable up to ~234kWh
- Fit on 19 inch standard rack
- Automatic balancing between trays
- Compatible with 48V PCS

<table>
<thead>
<tr>
<th>Specification</th>
<th>T4835</th>
<th>T4894</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
<td>Battery Module, BMS, Switchgear</td>
<td>Battery Module*, BMS, Switchgear</td>
</tr>
<tr>
<td>Cell type</td>
<td>Cylindrical</td>
<td>Prismatic</td>
</tr>
<tr>
<td>Energy (Rated/Usable) kWh</td>
<td>2.2 / 1.7</td>
<td>4.5 / 4.5</td>
</tr>
<tr>
<td>Scalability (Usable) kWh</td>
<td>28.3 (16ea)</td>
<td>234 (52ea)</td>
</tr>
<tr>
<td>Nominal voltage V</td>
<td>50.4</td>
<td>47.8</td>
</tr>
<tr>
<td>Operating voltage V</td>
<td>42.0 ~ 56.0</td>
<td>40.3 ~ 53.9</td>
</tr>
<tr>
<td>Charging method</td>
<td>CC-CV, Floating</td>
<td>CC-CV, Floating</td>
</tr>
<tr>
<td>Dimension (W x D x H) mm</td>
<td>482 x 433 x 96</td>
<td>482 x 510 x 161</td>
</tr>
<tr>
<td>Weight kg</td>
<td>18.5</td>
<td>45</td>
</tr>
<tr>
<td>Operating temperature °C</td>
<td>-20 ~ 60</td>
<td>0 ~ 40</td>
</tr>
<tr>
<td>Life cycle ** Cycle</td>
<td>3,150</td>
<td>3,500</td>
</tr>
</tbody>
</table>

*Module base, tray type is optional  **Under the condition at 25°C, DOD 80%
Battery System for Utility-Scale & Commercial

2016 Innovations
- High energy and high power in the same form factor
- All line-up based on single module with compact size
- Multiple arrangement for space optimization

<table>
<thead>
<tr>
<th>Cell</th>
<th>Module</th>
<th>Arrangement</th>
</tr>
</thead>
<tbody>
<tr>
<td>94 Ah</td>
<td>2451P</td>
<td>Vertical</td>
</tr>
<tr>
<td>68 Ah</td>
<td>2251P</td>
<td>Horizontal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>24MWh case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only 5 containers</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Multiple arrangement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical</td>
</tr>
</tbody>
</table>

- Customized combination for optimized ESS
- 24MWh case
- Multiple arrangement

<table>
<thead>
<tr>
<th>Specification (Rack@1,000V)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item</strong></td>
</tr>
<tr>
<td><strong>Module</strong></td>
</tr>
<tr>
<td><strong>Arrangement type</strong></td>
</tr>
<tr>
<td><strong>Configuration of rack</strong></td>
</tr>
<tr>
<td><strong>Cell capacity Ah</strong></td>
</tr>
<tr>
<td><strong>Energy kWh</strong></td>
</tr>
<tr>
<td><strong>Continuous power kW</strong></td>
</tr>
<tr>
<td><strong>Nominal voltage V</strong></td>
</tr>
<tr>
<td><strong>Operating voltage V</strong></td>
</tr>
<tr>
<td><strong>Dimension (WxDxH) mm</strong></td>
</tr>
<tr>
<td><strong>Rack energy density Wh/L</strong></td>
</tr>
</tbody>
</table>

- Product Line-up
  - **Energy**
    - Power output: ~0.5C
    - Duration: ~0.5C
  - **Medium**
    - Power output: ~1.0C
    - Duration: ~1.0C
  - **Power**
    - Duration: ~3.0C

- **Configuration**
  - Energy shift, Peak Cut
  - Curtailment

- **Max 40ft ISO container**
  - 4.8MWh
  - 4.4MWh
  - 3.2MWh

2016 Innovations
- High energy and high power in the same form factor
- All line-up based on single module with compact size
- Multiple arrangement for space optimization

- Customized combination for optimized ESS
- 24MWh case
- Multiple arrangement

- Specification (Rack@1,000V)

- **Energy**
  - Power output: ~0.5C
  - Duration: ~0.5C
- **Medium**
  - Power output: ~1.0C
  - Duration: ~1.0C
- **Power**
  - Duration: ~3.0C

- **Configuration**
  - Energy shift, Peak Cut
  - Curtailment

- **Max 40ft ISO container**
  - 4.8MWh
  - 4.4MWh
  - 3.2MWh
Battery System for UPS (Uninterruptible Power Supply)

Benefits of Lithium-ion Battery for UPS

<table>
<thead>
<tr>
<th>Less Space / Weight</th>
<th>Longer Life</th>
<th>Fast Charge / Discharge Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead-acid</td>
<td>3–7 years</td>
<td>+ Less space for battery room</td>
</tr>
<tr>
<td>Lithium-ion</td>
<td>15 months</td>
<td>+ Battery replacement deferral</td>
</tr>
<tr>
<td>(Equal capacity)</td>
<td></td>
<td>+ Enhanced reliability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ No oversizing required</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ Shorter charging time</td>
</tr>
</tbody>
</table>

Product Line-up

- **DC UPS**
  - Power output: 6C
  - Back-up time: (2hrs~)
  - Substation, Electric power station

- **AC UPS: 4C**
  - Power output: 4C
  - Back-up time: (15min~)
  - Data center, Factory

- **AC UPS: 6C**
  - Power output: 6C
  - Back-up time: (~10min)
  - Data center, Factory

Specification (Single Rack)

<table>
<thead>
<tr>
<th>Item</th>
<th>DC UPS (120V)</th>
<th>UPS 4C (600V)</th>
<th>UPS 6C (600V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module</td>
<td>M2968</td>
<td>M2968</td>
<td>M2963</td>
</tr>
<tr>
<td>Configuration of rack</td>
<td></td>
<td>3253P</td>
<td>14451P</td>
</tr>
<tr>
<td>Cell capacity Ah</td>
<td>68</td>
<td>68</td>
<td>68</td>
</tr>
<tr>
<td>Energy kWh</td>
<td>23.8</td>
<td>35.7</td>
<td>35.7</td>
</tr>
<tr>
<td>Continuous power kW</td>
<td>11.9</td>
<td>143</td>
<td>214</td>
</tr>
<tr>
<td>Nominal voltage V</td>
<td>117</td>
<td>526</td>
<td>526</td>
</tr>
<tr>
<td>Operating voltage V</td>
<td>96~131</td>
<td>432~590</td>
<td>432~590</td>
</tr>
<tr>
<td>Dimension (WxDxH) mm</td>
<td>650 x 600 x 1,500</td>
<td>650 x 600 x 2,000</td>
<td>650 x 600 x 2,000</td>
</tr>
</tbody>
</table>

Battery System for Hybrid UPS

New Business Model: Samsung SDI's UES(UPS+ESS)

UES solution provides both UPS and ESS function. It works as backup power in the event of power outage, while it functions as ESS for energy saving.

Concept

UES controller

Grid → UPS

For UPS

Lithium-ion battery

Start operation from April, 2015 in Uiwang, Korea

Benefits of Lithium-ion Battery for UPS

- Less space / weight
- Longer life
- Fast charge / discharge rate

Product Line-up

- **DC UPS**
  - Power output: 6C
  - Back-up time: (2hrs~)
  - Substation, Electric power station

- **AC UPS: 4C**
  - Power output: 4C
  - Back-up time: (15min~)
  - Data center, Factory

- **AC UPS: 6C**
  - Power output: 6C
  - Back-up time: (~10min)
  - Data center, Factory
Battery Solutions, Opening the Future Energy World

Technology Leadership

Samsung SDI having 6,645 patents in total leads future business energy market based on world-class technology leadership. As a lithium-ion battery solution provider, Samsung SDI has acquired a number of safety-related certifications from unit cell to battery system in Korea, USA, Europe, Japan, Australia, etc.

Patent status*

<table>
<thead>
<tr>
<th>Region</th>
<th>Total</th>
<th>Energy business</th>
<th>Material business</th>
</tr>
</thead>
<tbody>
<tr>
<td>America</td>
<td>2,687</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td>835</td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>1,382</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>1,308</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rest of world</td>
<td>433</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Overseas patent registration status (as of Jan, 2016)

Global Track Record

Since 2010, Samsung SDI’s lithium-ion battery systems are being successfully operated in over 20 countries worldwide.

Total Installation by 2015

500+ MWh

over 20 countries
ESS GLOBAL SALES NETWORK

GERMANY
Munich office
TEL +49-89-9292-7799(19)
FAX +49-89-9292-7799(99)
sintaek.yim@samsung.com

USA
San Jose office
TEL +1-408-544-4491
FAX +1-408-544-4991
mirah.kang@samsung.com

CHINA
Hefei office
TEL +86-551-6532-7653
shuqi.zheng@samsung.com

JAPAN
Tokyo office
TEL +81-3-6369-6414
FAX +81-3-6369-6388
m.goto@samsung.com

HEADQUARTERS
150-20 Gongse-dong, Giheung-gu,
Yongin-city, Gyeonggi-do 17084, Korea
energy.storage@samsung.com

www.samsungsdi.com

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