Creative Energy & Materials Solution Leader

Samsung SDI is creating a future energy world on the foundation of technology and innovation. As a global leading provider of lithium-ion batteries and electronic materials, Samsung SDI’s innovation and excellence is part of our customers’ lives around the world.

Samsung SDI businesses

- **Small-Sized Li-ion Battery**: IT devices / Power devices / Transportation devices
- **Automotive Battery**: Pure Electric Vehicle (EV) / Hybrid Electric Vehicle (HEV) / Plug-in HEV / Micro-/Mild HEV
- **Electronic Materials**: Semiconductor / LCD / OLED / Photovoltaic

ESS history

1970 ○ Established Samsung SDI
2000 ○ Started LiB (Lithium-ion battery) business
2008 ○ Started LiB business for automotives
2010 ○ Started LiB business for ESS
2011 ○ Entered residential ESS market in Japan
2012 ○ Supplied UPS batteries to bank data centers
2013 ○ Residential ESS achievements - No.1 market share in Japan - Obtain VDE certifications
2014.5 ○ 2014 Frost & Sullivan award for ESS in Europe
2014.9 ○ Supplied utility-scale energy storage to Schwerin project in Germany
2014.12 ○ No.1 global market share in batteries for ESS (B3 research, 2014)
2015.5 ○ Hybrid UPS system (UPS+ESS) started operation in Uiwang, Korea
2015.6 ○ Supplied batteries to 1st frequency regulation ESS project in Korea
2015.12 ○ No.1 global market share in batteries for ESS for two years in a row (B3 research, 2015)
2016.8 ○ Awarded the world’s largest ESS project in USA
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

1. OVER (Overcharge Safety Device)
2. Vent
3. Fuse
4. SFL (Safety Functional Layer)
5. NSD (Nail Safety Device)*

Multi-layered protection on cell

Longer expected cycle life
Slow, linear capacity degradation even for lower SOH levels
Components design for longer durability (30 years+)

Higher Energy Density

[Module]

- Previous: 221 Wh/L
- 2016*: +25% 227 Wh/L

[Max 40ft ISO Container]

- Previous: 3.3 MWh
- 2016*: +45% 4.8 MWh

Innovative Changes for 2016

- High energy & high power cell
- Compact module
- Multiple arrangement

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+)

Unique Samsung SDI’s LTS (Life-Time Simulation) Technology

- 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

Cycle Life of 68Ah Cell

- Capacity (%): 80, 90, 100
- Cycle Life: 2,000, 4,000, 6,000, 8,000 cycles

*In case of 68Ah cell

Customer’s Needs

Samsung SDI’s LTS

Optimal Battery Sizing
Battery Module & Tray

Module

**Specification**

<table>
<thead>
<tr>
<th>Item</th>
<th>M2994</th>
<th>M2968</th>
<th>M2967</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell type</td>
<td>Prismatic</td>
<td>Prismatic</td>
<td>Prismatic</td>
</tr>
<tr>
<td>Energy kWh</td>
<td>2.8</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Operating voltage V</td>
<td>25.6 – 33.2</td>
<td>24.0 – 32.8</td>
<td>24.0 – 33.6</td>
</tr>
<tr>
<td>Peak discharge C-rate</td>
<td>0.5</td>
<td>4.0</td>
<td>6.0</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>
<td>214 x 414 x 163</td>
</tr>
<tr>
<td>Weight kg</td>
<td>22</td>
<td>17</td>
<td>17</td>
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</table>

2016 Module

**Specification**

<table>
<thead>
<tr>
<th>Item</th>
<th>M8194 E2</th>
<th>M8194 M2</th>
<th>M8068 P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-rate</td>
<td>&lt; 0.5</td>
<td>&lt; 1.0</td>
<td>1.0 – &lt; 2.5</td>
</tr>
<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>7.6</td>
<td>7.6</td>
<td>5.5</td>
</tr>
<tr>
<td>Operating voltage V</td>
<td>70.4 – 91.3</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 650 x 160</td>
<td>370 x 650 x 160</td>
</tr>
<tr>
<td>Weight kg</td>
<td>52.5</td>
<td>53</td>
<td>49</td>
</tr>
</tbody>
</table>

100V / 48V Solution

**100V Solution _M10023**
- Advanced cylindrical 21700 cell
- High conversion efficiency (DC to AC)
- Optimized for high voltage PCS
- Wide temperature range

**48V Solution_M5194**
- High energy prismatic 94Ah cell
- High energy density
- Long cycle life
- Available up to 1C-rate

**100V Solution _M10023**

*Compatible with 100V – 200V PCS*

**48V Solution_M5194**

*Compatible with 48V PCS*

**Specification**

<table>
<thead>
<tr>
<th>Item</th>
<th>M10023</th>
<th>M5194</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
<td>Battery Module, BMS</td>
<td>Battery Module*, BMS</td>
</tr>
<tr>
<td>Cell type</td>
<td>Cylindrical</td>
<td>Prismatic</td>
</tr>
<tr>
<td>Energy (Rated/Usable) kWh</td>
<td>2.3 / 2.0</td>
<td>4.84 / 4.84</td>
</tr>
<tr>
<td>Scalability (Usable) kWh</td>
<td>321(16ea)</td>
<td>188 (39ea)</td>
</tr>
<tr>
<td>Operating voltage V</td>
<td>84 – 112</td>
<td>44.8 – 58.1</td>
</tr>
<tr>
<td>Charging method</td>
<td>CC-CV</td>
<td>CC-CV</td>
</tr>
<tr>
<td>Dimension (W x D x H) mm</td>
<td>454 x 200 x 173</td>
<td>484 x 450 x 163</td>
</tr>
<tr>
<td>Weight kg</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Operating temperature °C</td>
<td>-10 – 60</td>
<td>-10 – 50</td>
</tr>
<tr>
<td>Life cycle ** Cycle</td>
<td>4,000</td>
<td>5,000</td>
</tr>
</tbody>
</table>

*Module base, tray type is optional  **Under the condition at 25°C, EOL 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

### Customized combination for optimized ESS

<table>
<thead>
<tr>
<th>Cell</th>
<th>Module</th>
<th>Arrangement</th>
</tr>
</thead>
<tbody>
<tr>
<td>94 Ah</td>
<td>22S1P</td>
<td>Vertical</td>
</tr>
<tr>
<td>68 Ah</td>
<td></td>
<td>Horizontal</td>
</tr>
</tbody>
</table>

### Multiple arrangement

<table>
<thead>
<tr>
<th>Vertical</th>
<th>Horizontal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

24MWh case

*Max capacity of energy line-up in 40ft ISO container

### Specification

<table>
<thead>
<tr>
<th>Item</th>
<th>Energy</th>
<th>Medium</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module</td>
<td>M8194 E2</td>
<td>M8194 M2</td>
<td>M8068 P2</td>
</tr>
<tr>
<td>Configuration of rack</td>
<td>242S1P</td>
<td>264S1P</td>
<td>242S1P</td>
</tr>
<tr>
<td>Cell capacity Ah</td>
<td>94</td>
<td>94</td>
<td>94</td>
</tr>
<tr>
<td>Energy kWh</td>
<td>83.7</td>
<td>91.3</td>
<td>83.7</td>
</tr>
<tr>
<td>Operating voltage V</td>
<td>774 ~ 1,004</td>
<td>845 ~ 1,096</td>
<td>774 ~ 1,004</td>
</tr>
<tr>
<td>Dimension (WxDxH) mm</td>
<td>442 x 640 x 2,124</td>
<td>442 x 640 x 2,290</td>
<td>442 x 702 x 2,124</td>
</tr>
<tr>
<td>Weight kg</td>
<td>659</td>
<td>718</td>
<td>665</td>
</tr>
</tbody>
</table>

Product Line-up

Energy

- 10C
- 25C

Medium

- Peak cut
- Peak shift
- Ancillary services: Frequency regulation, Voltage support

Power

- 3C
- 2.5C
- 2.3C

Ancillary services: Frequency regulation, Voltage support

Configuration

<table>
<thead>
<tr>
<th>Cell</th>
<th>Switchgear</th>
<th>Module</th>
<th>Rack</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Max 40ft ISO container

4.8MWh

3.4MWh

*Max capacity of energy line-up in 40ft ISO container

I 24MWh case

Only 5 containers

*Max capacity of energy line-up in 40ft ISO container
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>+ Less space for battery room</td>
<td>+ Battery replacement deferral</td>
<td>+ No oversizing required</td>
</tr>
<tr>
<td>+ No structure reinforcement required</td>
<td>+ Enhanced reliability</td>
<td>+ Shorter charging time</td>
</tr>
</tbody>
</table>

*This comparison above is based on each material's characteristics

Product Line-up

<table>
<thead>
<tr>
<th>Product Line-up</th>
<th>AC UPS : 4C</th>
<th>AC UPS : 6C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power output</td>
<td>4C</td>
<td>6C</td>
</tr>
<tr>
<td>Back-up time (15min-)</td>
<td>Data center, Factory</td>
<td>Data center, Factory</td>
</tr>
</tbody>
</table>

Specification

<table>
<thead>
<tr>
<th>Item</th>
<th>UPS 4C (600V)</th>
<th>UPS 6C (6000V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module</td>
<td>M2968</td>
<td>M2967</td>
</tr>
<tr>
<td>Configuration of rack</td>
<td>144S1P</td>
<td>136S1P</td>
</tr>
<tr>
<td>Cell capacity Ah</td>
<td>68</td>
<td>67</td>
</tr>
<tr>
<td>Energy kWh</td>
<td>35.7</td>
<td>34.6</td>
</tr>
<tr>
<td>Operating voltage V</td>
<td>432 – 590</td>
<td>408 – 571</td>
</tr>
<tr>
<td>Dimension (WxDxH) mm</td>
<td>650 x 600 x 2,000</td>
<td>650 x 600 x 2,055</td>
</tr>
<tr>
<td>Weight kg</td>
<td>500</td>
<td>480</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

Start operation from April, 2015 in Uijeong, Korea
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>Patent Status</th>
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</thead>
<tbody>
<tr>
<td>America</td>
<td>2,687</td>
</tr>
<tr>
<td>Europe</td>
<td>835</td>
</tr>
<tr>
<td>China</td>
<td>1,382</td>
</tr>
<tr>
<td>Japan</td>
<td>1,308</td>
</tr>
<tr>
<td>Rest of world</td>
<td>433</td>
</tr>
</tbody>
</table>

Total 6,645

* 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 2016

Over 1+ GWh

over 20 countries
SAMSUNG SDI
Energy Storage System

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