Smart Battery Systems for Energy Storage
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

- **Energy Storage Systems (ESS)**
  - Utility-Scale Energy Storage
  - Commercial Energy Storage
  - Residential Energy Storage
  - UPS battery
  - Telecom battery

- **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

- **Multi-layered protection on cell**
  - OSD (Overcharge Safety Device)
  - Vent
  - Fuse
  - SFL (Safety Functional Layer)
  - NSD (Nail Safety Device)*

* In case of 94Ah cell

### 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](chart)

* Samsung SDI’s lab test (DOD100%, 1C/1C at 25℃)

### Higher Energy Density

- **[Module]**
  - [Max 40ft ISO Container]

- 177 Wh/L → 221 Wh/L
  - Previous → 2016*

- 3.3MWh → 4.8MWh
  - Previous → 2016*

* Energy Line-up

### 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

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**NSD (Nail Safety Device)**

**Fuse**

**SFL (Safety Functional Layer)**

**Vent**

**OSD (Overcharge Safety Device)**
Battery Module & Tray

Module

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

2016 Module

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<tr>
<th>Item</th>
<th>M8194 E2</th>
<th>M8194 M2</th>
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<td>C-rate C</td>
<td>&lt; 0.5</td>
<td>&lt; 1.0</td>
<td>1.0 – &lt; 2.5</td>
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<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>
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<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

- 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

Specification

<table>
<thead>
<tr>
<th>Item</th>
<th>M10023</th>
<th>M5194</th>
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<tbody>
<tr>
<td>Component</td>
<td>Battery Module, BMS</td>
<td>Battery Module*, BMS</td>
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<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>
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<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>Cycle Life **</td>
<td>4,000</td>
<td>5,000</td>
</tr>
</tbody>
</table>

*Module base, tray type is optional
**Under the condition at 25°C, 10%
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
- Cell: 94 Ah, 68 Ah
- Module: 2251P
- Arrangement: Vertical, Horizontal

Multiple arrangement
- Vertical: 242S1P, 264S1P, 242S1P, 264S1P, 242S1P, 264S1P
- Horizontal: 242S1P, 264S1P, 242S1P, 264S1P, 242S1P, 264S1P

Cell Module Arrangement
- Power output: ~1.0C
- Power: ~2.5C
- Peak cut
- Peak shift
- Duration
- Ancillary services: Frequency regulation, Voltage support

Specification
<table>
<thead>
<tr>
<th>Item</th>
<th>Energy</th>
<th>Medium</th>
<th>Power</th>
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<tbody>
<tr>
<td>Configuration of rack</td>
<td>Module</td>
<td>MB194 E2</td>
<td>MB194 M2</td>
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<tr>
<td></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>
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<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 kWh: 83.7, 91.3, 83.7, 91.3, 60.0, 65.5
- Operating voltage V: 774 ~ 1,004, 845 ~ 1,096, 774 ~ 1,004, 845 ~ 1,096, 750 ~ 992, 818 ~ 1,082
- Dimension (WxDxH) mm: 442 x 640 x 2,124, 442 x 640 x 2,290, 442 x 702 x 2,124, 442 x 702 x 2,290, 442 x 702 x 2,124, 442 x 702 x 2,290
- Weight kg: 659, 718, 665, 724, 618, 673

124MWh case
- Only 5 containers

Max 40ft ISO container
- 4.8MWh

*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>Lithium-ion</td>
<td>15 years</td>
<td>+ No oversizing required</td>
</tr>
<tr>
<td>Lead-acid</td>
<td>3-7 years</td>
<td>+ Battery replacement deferral</td>
</tr>
<tr>
<td>(Equal capacity)</td>
<td></td>
<td>+ Enhanced reliability</td>
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</table>

Product Line-up

<table>
<thead>
<tr>
<th>AC UPS : 4C</th>
<th>AC UPS : 6C</th>
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<tbody>
<tr>
<td>Power output</td>
<td>Power output</td>
</tr>
<tr>
<td>Back-up time (15min~)</td>
<td>Back-up time (~10min)</td>
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</table>

Data center, Factory

Specification

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<thead>
<tr>
<th>Item</th>
<th>UPS 4C (600V)</th>
<th>UPS 6C (6000V)</th>
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</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>
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<tr>
<td>Cell capacity</td>
<td>Ah</td>
<td>Ah</td>
</tr>
<tr>
<td>Energy</td>
<td>kWh</td>
<td>kWh</td>
</tr>
<tr>
<td>Operating voltage</td>
<td>V</td>
<td>V</td>
</tr>
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<td>mm</td>
<td>mm</td>
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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

UESS controller

For ESS

For UPS

General load

Critical load

Outage

Lithium-ion battery

Start operation from April, 2015 in Uiwang, Korea

Lithium-ion battery

- Less space for battery room
- No structure reinforcement required
- Battery replacement deferral
- Enhanced reliability
- No oversizing required
- Shorter charging time

**This comparison above is based on each material's characteristic.

- Less space for battery room
- No structure reinforcement required
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- Enhanced reliability

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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*

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<tr>
<th>Region</th>
<th>Energy business</th>
<th>Material business</th>
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<td>2,687</td>
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<tr>
<td>Europe</td>
<td>835</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>1,382</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>1,308</td>
<td></td>
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<td>Rest of world</td>
<td>433</td>
<td></td>
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<td><strong>Total</strong></td>
<td><strong>6,645</strong></td>
<td></td>
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* 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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Yongin-city, Gyeonggi-do 17084, Korea
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