Simulation Study

To better tend to customer’s needs, Toshiba offers a more customer-oriented engineering which includes a simulation study using Toshiba’s advanced traction power simulation software engines. With this, Toshiba can offer a more suitable solution.

Ratings and Specifications

<table>
<thead>
<tr>
<th>Item</th>
<th>Rating / Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Line Voltage</td>
<td>DC 750V (DC 600V and DC 825V are also available)</td>
</tr>
<tr>
<td>Rated Power</td>
<td>500kW - 2000kW</td>
</tr>
<tr>
<td>Applicable Load Pattern</td>
<td>Class I - IX (IEC 62924)</td>
</tr>
<tr>
<td>Applicable Standard</td>
<td>IEC / JEC</td>
</tr>
</tbody>
</table>

Find out more about Toshiba transportation solutions on [http://toshiba-railway.com](http://toshiba-railway.com)

Toshiba Infrastructure Systems & Solutions Corporation

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Toshiba Infrastructure Systems & Solutions Corporation
Traction Energy Storage System with SCiB™

When a train set is braking, it generates energy which can be used by the adjacent accelerating trains. But in most cases, this regenerative energy is not efficiently utilized by the next train and is wasted as heat through onboard or wayside resistors. Such cases do not only incur energy wastage but also likely to cause abrupt shift from regenerative braking to mechanical braking. This sudden change may further cause passenger ride discomfort and degradation of the brake shoe due to abrasion.

Toshiba's Traction Energy Storage System (TESS) efficiently stores surplus regenerative energy in the SCiB™ and discharges it to another accelerating train. TESS is installed with Toshiba's patented advance control system which allows flexible control of charge-discharge cycles in accordance to the battery’s State-of-Charge (SOC). This allows significant increase in battery lifetime.

Toshiba developed Traction Energy Storage System (TESS) with SCiB™, a new energy saving solution with Toshiba’s own battery technology of high quality.

Key Benefits

- Better Regenerative Braking Operation
- Energy Saving
- Line Voltage Stabilization
- Emergency Power Supply

SCiB™’s remarkable charge-discharge efficiency characteristics can reduce energy wastage and ultimately, promote power demand peak cut.

System Outline

<table>
<thead>
<tr>
<th>Control Panel</th>
<th>Converter</th>
<th>Battery Panel</th>
<th>DC Switchgear</th>
</tr>
</thead>
<tbody>
<tr>
<td>500W x 600D + 2100H (2 Panel)</td>
<td>600W x 1700D x 2200H (1000W x 2200D x 2200H for 1000kW - DC 1500V)</td>
<td>500W x 600D x 2100H (8 Panel)</td>
<td>600W x 1700D x 2100H (2 Panel)</td>
</tr>
</tbody>
</table>

Advanced V-SOC Battery Control

Toshiba also developed a completely new and advanced Charge-Discharge algorithm for the efficient control of TESS.

For conventional energy storage systems, battery is charged and discharged to keep specified SOC (State of Charge). Thus, battery is charged and discharged regardless of the feeding voltage. There will be instances when the battery will be unnecessarily charged/discharged even at rated line voltage (area between the Charge Start Voltage and Discharge Start Voltage). Thus causing feeding voltage imbalance and shortened battery lifetime.

As for Toshiba’s advance V-SOC control method, charge and discharge characteristics automatically shifts depending on SOC. When SOC is high, charge-discharge characteristic will shift to the higher voltage side, hence the battery shall be easily discharged. On the other hand, when SOC is low, charge-discharge characteristic will shift to the lower voltage side thus, battery shall perform more charging. The lifetime of a battery strongly depends on the charge-discharge times and current. By using this control algorithm, unnecessary charge and discharge can be greatly reduced.

Toshiba’s system does not define any certain SOC which means that charge and discharge will be performed dynamically within a wide range of SOC.

In addition, Toshiba’s TESS is equipped with the following functions:

- 1. V-SOC Control
- 2. Monitoring
- 3. Sequence Control
- 4. Adjusting Charge and Discharge

Toshiba’s advanced traction power simulation software engines.

TESS utilizes Toshiba’s own high performance SCiB™

This battery has various outstanding characteristics. By using unique oxide materials, SCiB™ holds high resistance against thermal runaway caused by internal short circuiting brought about by physical stresses.

- High performance SCiB™
- Safe Usage Highly safe Lithium Titanium oxide (LTO)
- Low Temperature Operation Can be used at temperature as low as -30°C
- Wide Effective SOC Range Proved to be large available capacity
- Rapid Charging / Discharging can be operated up to 13,000 charge-discharge cycles
- Long Life can be operated up to 13,000 charge-discharge cycles
- High Input / Output

Toshiba’s system does not define any certain SOC which means that charge and discharge will be performed dynamically within a wide range of SOC.

Charge-Discharge characteristic with Feeder Voltage

<table>
<thead>
<tr>
<th>Feeder Voltage (V)</th>
<th>Charge / Discharge Power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1030</td>
<td>0</td>
</tr>
<tr>
<td>1050</td>
<td>0.5</td>
</tr>
<tr>
<td>1070</td>
<td>1.0</td>
</tr>
<tr>
<td>1090</td>
<td>1.5</td>
</tr>
<tr>
<td>1110</td>
<td>2.0</td>
</tr>
<tr>
<td>1130</td>
<td>2.5</td>
</tr>
<tr>
<td>1150</td>
<td>3.0</td>
</tr>
<tr>
<td>1170</td>
<td>3.5</td>
</tr>
<tr>
<td>1190</td>
<td>4.0</td>
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<tr>
<td>1210</td>
<td>4.5</td>
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<tr>
<td>1230</td>
<td>5.0</td>
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<tr>
<td>1250</td>
<td>5.5</td>
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<tr>
<td>1270</td>
<td>6.0</td>
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<tr>
<td>1290</td>
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<td>7.0</td>
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<tr>
<td>1430</td>
<td>10.0</td>
</tr>
</tbody>
</table>

*Results of cell level tests under certain conditions. Not a guaranteed performance.
Performance Record

TESS for Line Voltage Stabilization

Tobu Railway - Unga Battery Post

During the adaptation of new type of cars, significant loss in line voltage was expected to occur between Noda Substation and Toyoshiki Substation (11.65km distance). To stabilize line voltage in this section and avoid building new substation, 1000kW TESS was installed as a battery post.

DC Switchgear

Converter

Battery Panel

Control Panel

TESS was able to stabilize line voltage fluctuation without having to build a new substation. Furthermore, power peak cut was also achieved through the effective use of regenerative energy.

Voltage Fluctuation Stabilization Results during Morning Rush Hour

TESS for Energy Saving

Okinawa Urban Monorail - Sueyoshi Substation Field Test Result

500kW TESS was installed in Sueyoshi Substation of Okinawa City Monorail. With TESS operation, 10% power peak cut was achieved in Sueyoshi SS power consumption alone. Significant power peak cut was also achieved in total power consumption in all substations.

With TESS, daily traction energy consumption was reduced to 575kWh/day (-37%) during weekday and 885kWh/day (-32%) during weekend while reducing the adjacent substation energy consumption as well.

Power Peak Cut

Total Traction Energy Consumption

Day

Weekend

TESS for Emergency Power Supply

Tokyo Metro - Ayase Substation Field Test Results

500kW TESS was installed in Ayase Substation of Tokyo Metro for energy saving and emergency power supply. TESS was able to independently power a 10-Car Train including all its auxiliary equipment (air conditioners, etc.) through a 2.4 kilometer distance from Ayase Station to Kita-Senju Station. This distance has a section with steep gradient of up to +33‰. Even at this stringent condition, TESS was able to safely power the train in a power failure condition.

Field Test Conditions

TESS Capacity

500kW

TESS Output

194kWh

Train Speed

15km/h

Auxiliary Power

In Use

Voltage Fluctuation Stabilization Results

Sueyoshi SS

All SS (Total)

Voltage Fluctuation Stabilization Results during Morning Rush Hour

Ajinomoto SS

Mekashi SS

Sueyoshi SS

Location

Peak Value (without TESS) in Use

Peak Value (with TESS) in Use

Peak Cut Effect

Sueyoshi SS

530 kWh/0.5h

280 kWh/0.5h

10%

All SS (Total)

830 kWh/0.5h

600 kWh/0.5h

3.6%

600W × 650D × 2100H

750kg × 1 Panel

500W × 600D × 2100H × 2 Panel

250kg × 2 Panels

500W × 600D × 2100H × 2 Panel

250kg × 2 Panels

600W × 650D × 2100H × 2 Panel

1235V

1741V

5,000kg × 2 Panels

600W × 650D × 2100H × 2 Panel

250kg × 2 Panels

1117V

1678V

600W × 650D × 2100H × 2 Panel

250kg × 2 Panels

1691V

1768V

600W × 650D × 2100H × 2 Panel

250kg × 2 Panels

1592V

1707V

600W × 650D × 2100H × 2 Panel

250kg × 2 Panels

1587V

1702V

600W × 650D × 2100H × 2 Panel

250kg × 2 Panels

1582V

1698V