Current Situation and Integration Potential in Transport Area in Japan

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(East Japan Railway Company)
1  Introduction
2  Electric Energy Utilization in Railway Transportation
3  Utilization of Regenerative Energy
4  Examples of Other Projects
5  Conclusions
Japan National Railway was privatized and divided into 6 railway company in 1987.
Voltage categories of TPS in Japan

High Speed Railway
- A.C. 25kV

Conventional Railway
- D.C. 1.5kV
- A.C. 20kV

[Map of Japan showing voltage categories and train routes]
CO2 emission from each transportation mode

- Car: 172g-CO2
- Airplane: 111g-CO2
- Bus: 51g-CO2
- Railway: 18g-CO2

Reported by Ministry of Land, Infrastructure, Transport and Tourism in 2007
Share in Transportation

Ratio of Each Transportation Mode (passenger km)
Total Energy Consumption is not Small

**ENERGY CONSUMPTION AND TRANSPORTATION MARKET SHARE**

(FY2012 results)

- **Automobiles**: 65.8%
- **Railways**: 29.0%
- **Airways**: 5.2%

**MARKET SHARE BY PASSENGER TRANSPORTATION MODE**

**ENERGY CONSUMPTION BY PASSENGER TRANSPORTATION MODE**

- **Automobiles**: 90.6%
- **Railways**: 3.4%
- **Airways**: 6.0%

Source: Compiled based on data from The Energy Conservation Center, Japan (ECCJ)'s Handbook of Energy & Economic Statistics in Japan
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Total Energy Consumption is not Small

Energy Consumption of JR East

Total Electric Energy Consumption for Railway Transportation

(JR East)
about 5TWh/year

(Railway Total)
18.073TWh/year
(2009 FY)

= 1.6%
of total electric energy in Japan
**d.c. Traction Power Supply System**

- 1.5kV d.c. for trains and 6.6kV a.c. for station and signaling.
- Interval Length of traction substations is about 3-5km around city area and about 10km in country side.
d.c. Traction Load Curves

Current (A) (at 1.5kV d.c.) (average values per minute)

Time
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What is regenerative power?

- Regenerative power is utilized by the other powering train simultaneously.
- Inverse power flow from d.c. to a.c. is impossible by diode rectifier.
- Residual regenerative power is canceled and kinetic power is dispersed as heat.

Ex. 1000A, 2km at most
What is regenerative power?

Assumption:
10 cars (25-30t/car)
150 passengers/car
90km/h

Kinetic energy
25m/s, 376t
= 117MJ = 33kWh

Electric energy and power
13kWh, 1568kW

Assumption:
Utilization ratio 40%
Regeneration time 30s
- Tie feeding between upward and downward feeders
- Regenerative inverter
- Self-commutation (PWM) inverter
- Energy Storage system (ESS)
Tie-feeding

- Upward feeder and downward feeder are connected in the middle of traction substations.

- Opportunities to utilize regenerative power increase.

- JR West reported about 3.4% energy saving in suburban line.
• Regenerative power is converted from d.c. 1.5kV to a.c. 6.6kV and utilized at station or signaling system.

• Realized since 1970’s
• Function of regenerative inverter is combined to conventional diode rectifier.

• Realized in 2005 at TSUKUBA Express Line.

• They have started selling electricity from regenerative energy since December in 2013.
Energy storage system

- First Lithium-ion battery in 2006 by JR West for compensation for voltage drop.

- Storage medium: Lithium-ion battery, Ni-MH battery, Electric double layer capacitor
General requirement for energy storage system for regenerative energy utilization

<table>
<thead>
<tr>
<th>Electric power:</th>
<th>500kW – 2MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage capacity:</td>
<td>10kWh – 400kWh</td>
</tr>
<tr>
<td>Voltage:</td>
<td>d.c. 1.5kV (or 750V)</td>
</tr>
</tbody>
</table>

Price of battery decreases drastically and application of ESS to traction PSS is promoted during last a few years.
More than 10 energy storage systems have already installed in d.c. 1.5kV or d.c. 750V traction PSS (power supply system)
Purpose of ESS in d.c. traction PSS

- **Compensation for voltage drop**: MW order electric power transmission causes large voltage drop.
  - JR West, Tobu Railway etc.

- **Avoiding regenerative brake cancelation**: Large voltage drop causes regenerative brake cancelation.
  - Seibu Railway, Kobe City, Kagoshima City etc.

- **Utilization of regenerative energy**: Canceled power was conventionally lost as heat generation at brake friction pad.
  - JR East

- **Emergency power supply**: D.c. traction power can be supplied even when black out of utility company happens.
  - Tokyo Monorail
Practical installation of Li-ion battery at Haijima SS in 2013 and Okegawa SS in 2014.

Energy saving effect of ESS

Haijima SS
400MWh/year

Okegawa SS
700MWh/year
Effect of Energy Storage System at OKEGAWA


After installation (2014/3/25-2014/9/30)
Effect of Energy Storage System at HAIJIMA

Reduction ratio to total traction energy of HAIJIMA SS
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Railway Static Power Conditioner (RPC)

Railway is single phase load and causes three phase unbalance in grid.

By introducing RPC, three phase unbalance problem is solved by ac/dc/ac link.
All electric power are supplied from PV system on the sunny day from 78kW, 500m² PV panel and 240kWh Lithium-ion battery.

During the daytime, residual power is stored at Li-ion battery.

During the night, station power is supplied from stored battery.
Rooftop PV System at TOKYO Station

453kW, 3846m², 300MWh/year
KEIYO Depot “Mega-Solar Plant”

1050kW, 6600m², 1000MWh/year

To SHIN-NARASHINO Station (for TOKYO)

To KAIHIN-MAKUHARI Station (for CHIBA)

PV Panels

KEIYO Depot

KEIYO Line

KEIYO Depot

PV Panels
# Comparison between ESS and PV

<table>
<thead>
<tr>
<th></th>
<th>Energy Storage System for Regenerative Power</th>
<th>Photovoltaic System around Railway Premises</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HAIJIMA SS</td>
<td>OKEGAWA SS</td>
</tr>
<tr>
<td>Capacity</td>
<td>78kWh, 2000kW</td>
<td>137kWh, 2000kW</td>
</tr>
<tr>
<td>Effect</td>
<td>400 MWh/year</td>
<td>700 MWh/year</td>
</tr>
<tr>
<td>Area</td>
<td>100m²</td>
<td>100m²</td>
</tr>
<tr>
<td>CO₂ Reduction / Cost (normalized)</td>
<td>1.0</td>
<td>1.7</td>
</tr>
</tbody>
</table>
• Started operation on March 2014 at KARASUYAMA Line.
• 190kWh on-board Li-ion battery.
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Integration potential in railway transportation area?

- Electric railway is unstable and unbalanced load.
- Changing regenerative energy is utilized within d.c. traction power supply system now.

Possibility

- On ground energy storage system can realize peak cut of changing traction load and may contribute to stabilization of power grid in the future.
- Reduction of system cost, not battery cost, will be a key in the future for more introduction.
New HSR from NAGANO to KANAZAWA

will start operation in March 2015

Thank you indeed for kind attention!