High-Current Recharging Systems for Electric Vehicle Batteries

Nobuyuki Kamiya, NISSAN MOTOR CO., LTD.
Takafumi Anegawa, TOKYO ELECTRIC POWER COMPANY
Noboru Itoh, Electric Power Development Co., Ltd.
Tatsuo Horiba, Shin-Kobe Electric Machinery Co., Ltd.
Kazuo Chiba, NISSAN MOTOR CO., LTD.
Chiaki Harada, NISSAN MOTOR CO., LTD.
Shinya Ogata, NISSAN MOTOR CO., LTD.
Tsuyoshi Morita, NISSAN MOTOR CO., LTD.

The main issues about the electric vehicle are the length at which the EV can be driven and the time needed to charge the batteries.
If the battery can be recharged in several minutes for a minimum necessary amount of electric energy, such problems will be greatly reduced, resulting in much greater ease of use.
By studying the high-current recharging systems, we were able to understand the basic technology.

1. Status of EVs

(1) Driving mileage during normal use

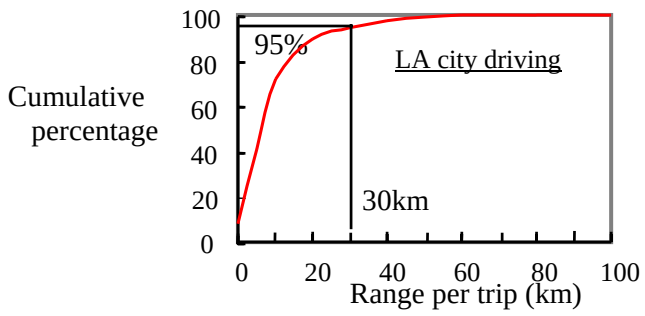


Fig. 1: Survey results on actual mileage in traffic

Establishment of goals

64 km (40 mile) driving range (2 trips + a little extra)

with a 10 minute recharge (the driver's waiting time should be at most 10 minutes at a recharging station.)

High-Current Charger Specifications

Output：50 kW (average)
10 minutes

>the vehicle batteries need:
45.6 kW
= 119 Wh/km x 64km / (10/60)h
>the recharging efficiency from the charger to the vehicle batteries: 0.9
>The charger output power:
50 kW = 45.6 kW / 0.9

(2) Vehicle Specification

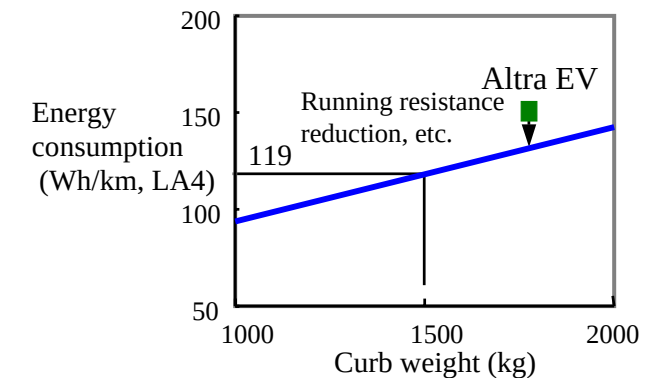


Fig. 2: Vehicle weight and power consumption rate

Vehicle Specifications
(planned values)

Energy consumption rates for LA4 mode driving：119 Wh/km

vehicle weight of 1500 kg with 8 batteries

2. High-Current Charger Specifications

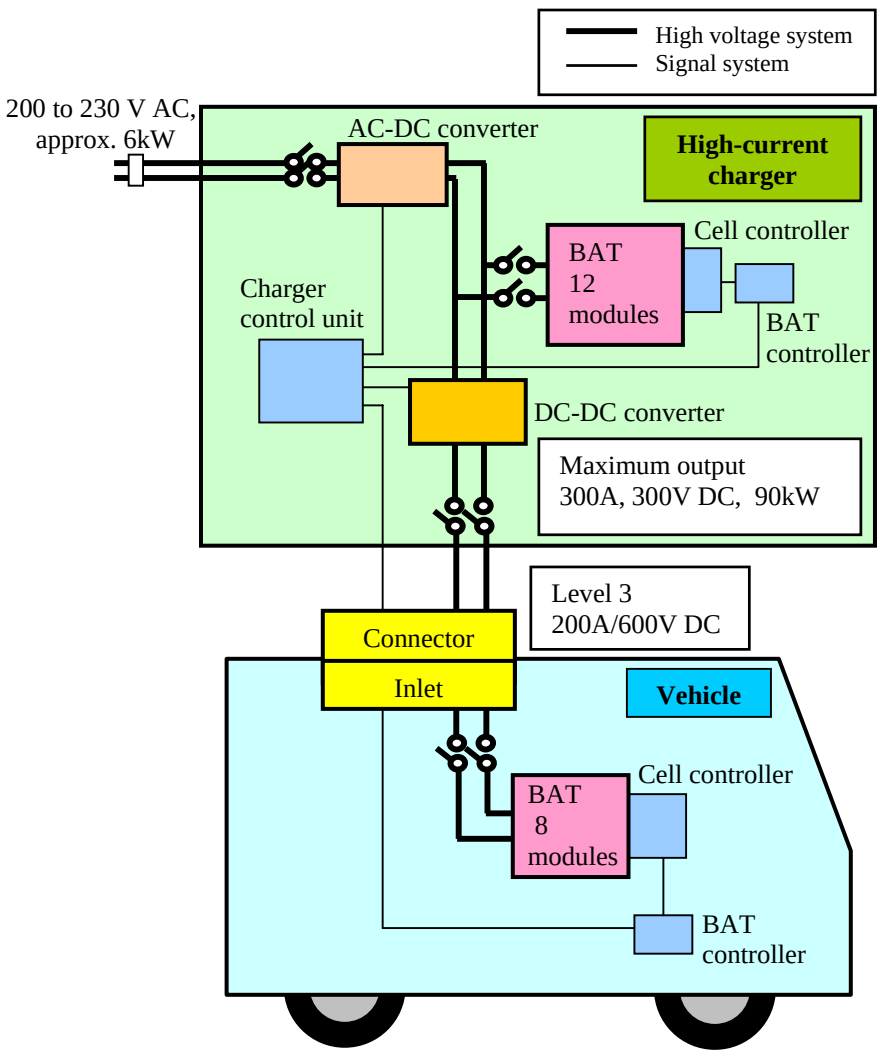


Fig. 3: High-current recharging system configuration

Table 1. High-current charger

Item		Specification
Input	Rated input voltage	200 V AC
	Input voltage range	180 ~ 264 V AC
	Frequency	50 / 60 Hz ±5%
	Input current	30 A MAX
	Rush current	30 A MIN
	Power factor	90%
Output	Electric power	90 kW
	Output voltage range	140 ~ 300 V DC
	Continuous current range	300 A MAX
Control system	AC-DC converter	PWM increase power factor converter + PFM current resonance converter
	DC-DC converter	PWM chopper system
Others	Cooling system	Forced-air-cooling system
	Environmental conditions Temperature / humidity	-10 ~ 40 degree C / 30 ~ 90 %
	Connector & Inlet (on vehicle) (SAE J1772 & UL2256 compliant)	Level 3: Mixed charge: 200A / 600V DC 40A / 300V AC Level 1, 2 & 3: 200A / 600V DC 40A / 300V, 15A / 120V AC

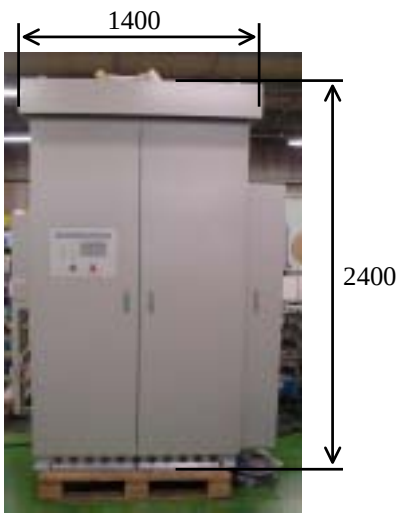


Photo 1: External view of high-current charger prototype technical study

Photo 2: Test vehicle and connector used in laboratory experiment with high-current charger

3. Experiments and results

(1) Evaluations of performance —to the batteries built into charger

2.5 hours was found to be required to fully recharge the batteries built in the charger.

The recharging efficiency from the AC power source to the charger batteries was 92 % (η_1)

(2) Discharging from charger batteries

The charger with an output power of 50kW was found to be able to discharge in 10 minutes.

The discharging efficiency from the charger batteries to the charger outlet was 98 % (η_2)

(3) Recharging the vehicle batteries (4 modules)

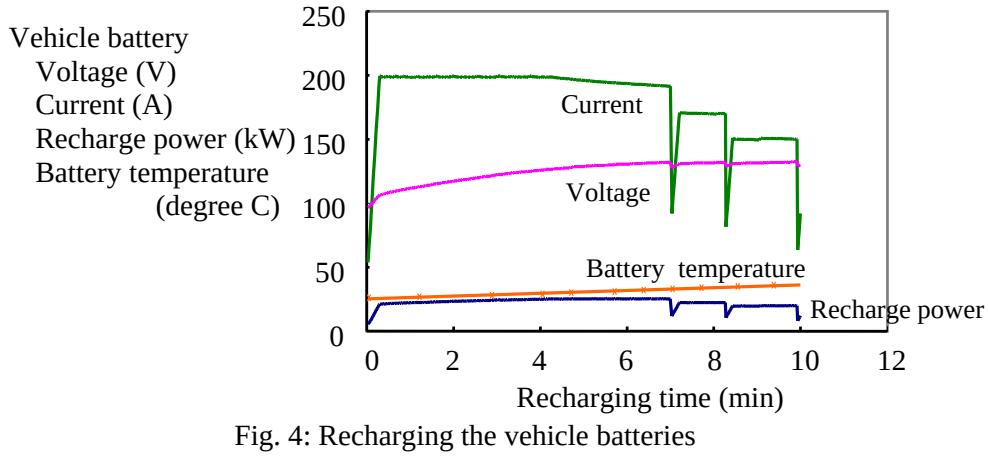
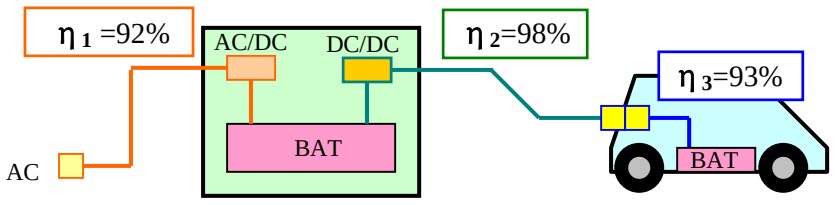


Fig. 4: Recharging the vehicle batteries

The recharging 3.8kWh was found to be attainable in 10 minutes when 4 on-board batteries were used.

The charger outlet power and the recharging efficiency of the on-board batteries was 93 % (η_3)



1) The goal of recharging 7.6kWh was found to be attainable in 10 minutes when 8 on-board batteries were used.

2) The total efficiency from the AC power source of the high-current recharging system to the on-board batteries is defined by the following:

$$\eta_0 = \eta_1 \times \eta_2 \times \eta_3 = 84\ \%$$

(4) Continuous recharging (simulation)

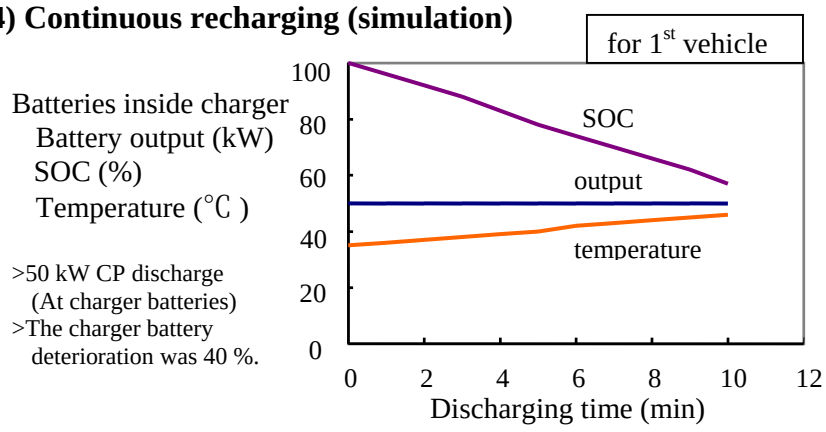


Fig. 5: Output simulation results of charger batteries for 1st high-current recharging

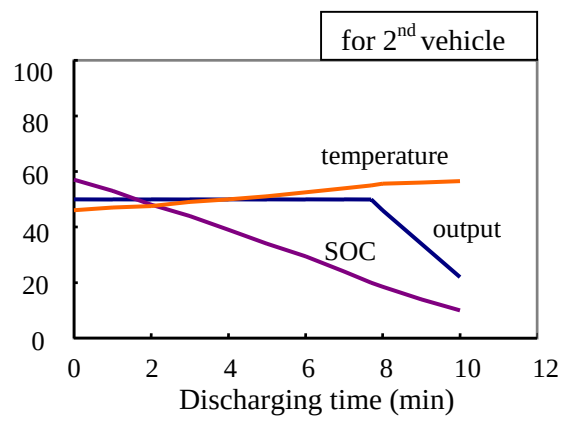


Fig. 6: Output simulation results of charger batteries for 2nd high-current recharging

1) **The first vehicle was completely recharged.**

2) **The second vehicle was charged to 94% of the required energy.**

3) **The third unit could not be recharged.**

(5) Recharging in low-temperature environment (simulation)

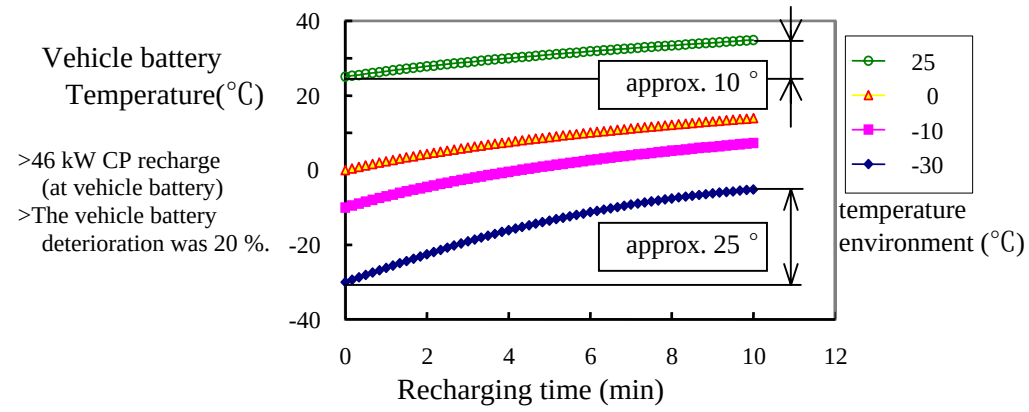


Fig. 7: Vehicle battery temperature changes during high-current recharging in low-temperature environment

1) **The on-board battery temperature increased 25 ° .**
Initial temperature : –30 ℃

2) **The on-board battery temperature increased 10 ° .**
Initial temperature : 25 ℃

4. Summary and discussion

(1) The results of this study showed that a system that can recharge on-board batteries in 10 minutes for 64km driving.

(2) 10 minute high-current recharging is limited to once every 2.5 hours for a charger with 12 storage batteries.

(3) The advantages of high-current recharging in a low-temperature environment are that it can recharge the batteries for warm-up.

5. Technical challenges and observations

Challenges:

(1) Study lifetime evaluation techniques for the reused lithium ion batteries.

(2) Study the reliability, durability and vehicle installation layout of the conductive connectors.

Observations:

We have found that significant cost reduction is feasible for the storage batteries inside the current charger by reusing the batteries mounted on EVs. However, financial assistance using public funding is required for developing alternative energy usage technologies.

< If you have any questions, please contact us via our web-site. http://www.itsev.com/ >