Development of Contact-Wire/Battery Hybrid LRV

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Contact-wire/battery hybrid vehicles run on a hybrid power source that enables energy to be fed from contact wires and/or onboard batteries. Regenerated energy is returned to the contact wires and/or onboard batteries during braking in track sections, thereby ensuring the effective utilization of energy (Fig. 1). In track sections where no contact wires are installed, such vehicles can run using energy supplied only from the onboard batteries (Fig. 2).
In electrified track sections, hybrid running saves energy because regeneration cancellation does not occur, thereby improving the reliability of the regenerating brake. Additionally, running in non-electrified track sections (which offer savings in terms of contact wire installation and maintenance costs) prevents the degradation of urban landscapes to preserve the value of sightseeing resources and improves passenger convenience by enabling through-operation to/from electrified track sections.
As one of the targets of this study, the Traction Control Laboratory developed a contact-wire hybrid car and had it manufactured. The data of running distance after one spell of charging using only energy from the onboard batteries, and energy consumption during hybrid running in actual track sections compared with that of existing inverter vehicles was acquired. And the battery performance in low-temperature areas was also checked.
As another target, the laboratory developed a method of charging to quickly supply energy to the vehicles in midway stations distributed at intervals of several kilometers, while aiming at continuous running in non-electrified track sections using only energy from the onboard batteries.
The purposes and results of the study are outlined below.

(1) The Traction Control Laboratory developed the various element technologies required to enable continuous battery driving. It adopted, for example, a system for contact charging through a pantograph from rigid contact wires, and conducted a stationary test at a charging current of 1,000 A to confirm that the contact point would not melt. It also developed a structure to cool the onboard lithium ion batteries (thereby suppressing increases in their temperature), determined the interval between the cells in the battery module, and ascertained the required volume of cooling air through tests and thermal simulation. The laboratory then installed a cooling fan with a maximum capacity of 5 m/sec on the vehicle. It also developed a dual-voltage contact-wire hybrid exchanger with a quick-charge function and a capacity of 600 kW, suitable for application both to 1,500 V and 600 V DC voltages.

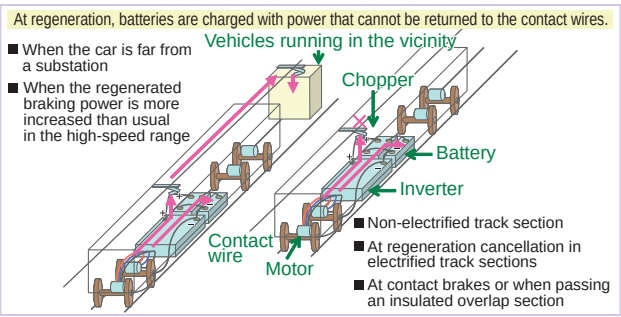

Fig. 1 Contact-wire/hybrid power flow (at regeneration)

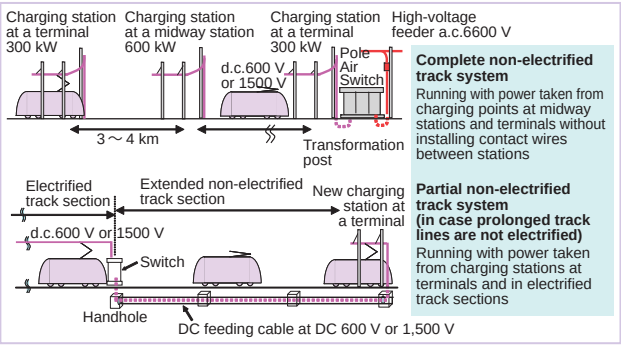

Fig. 2 Running in non-electrified track sections

(2) The Laboratory had a contact-wire/battery-type hybrid car manufactured that reflected the element technologies developed, including those introduced above, in its design (Fig. 3).
In consideration of the number of batteries to be mounted for running in non-electrified track sections, the car was designed with an onboard battery system featuring a nominal capacity of 72 kWh at a nominal voltage of 600 V. It was demonstrated that batteries and a charger could be mounted in a compact formation on the LRV carbody with the smallest dimensions of all LRV cars in Japan.

(3) The laboratory implemented a test on quick charging from rigid contact wires for the LRV car developed (Fig. 4). In this test, the onboard batteries were charged over a period of about 60 seconds at a charging current of 1,000 A with enough energy to run 4 km or more (Table 1). The test therefore proved the feasibility of quick charging with no melting at the contact point and restriction of the temperature increase in the onboard batteries to 3° C.

(4) The LRV car developed was put into test on a commercial service line of Sapporo City's Transport Bureau. It ran 25.8 km on an actual operation diagram while heating the passenger room without power from external sources, and recorded a regeneration ratio of 41% (the volume of regenerated power divided by the power consumed in running) (Fig. 5). During running in electrified track sections while charging the batteries, energy consumption was cut by 30% over that of existing inverter cars.

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Fig. 3 Contact-wire/battery hybrid LRV

Fig. 4 Quick charging from rigid contact wires

Table 1 Energy obtained by quick charging

Battery charging current and duration	Power charged at battery terminals	Running distance after a one short time of quick charging (without air conditioning)	Running distance after a one short time of quick charging (at the maximum air conditioning load)
1,000 A x 61 sec	13.7% of the capacity	Equivalent to 7.9 km	4.0 km or over
500 A x 3 min and 16 sec	21.9% of the capacity	Equivalent to 12.7 km	6.4 km or over

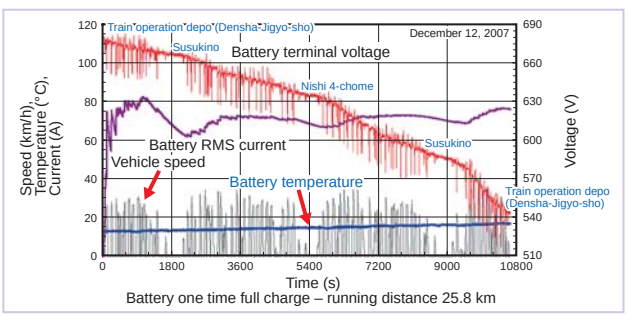

Fig. 5 Running with batteries after a spell of charging