Development of Advanced Energy-efficient Transportation Systems Using High-Performance Batteries

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Mitsubishi Heavy Industries, Ltd. (MHI) is involved in the development of transportation systems such as automated people movers (APMs) and light rail transit (LRT). These systems have attracted great public enthusiasm as effective means of transport that are friendly to both people and the environment. MHI is currently developing a new environmentally friendly battery-powered transportation system. The use of high-performance, high-capacity batteries will not only improve electrical power efficiency but also contribute to a less-cluttered urban landscape and simplified operation by eliminating catenary wires. The system is completing its final operational testing on MHI's own test track and is in the final productions stages, with demonstrations for potential customers to follow shortly.

1. Features of battery-powered transportation systems

1.1 Battery-powered transportation systems

With environmental issues attracting increasing attention worldwide, MHI has been developing automated people mover (APM; **Fig. 1**) and light rail transit (LRT) systems (**Fig. 2**) to solve traffic problems such as congestion, noise, and various other environmental issues. Major cities around the globe are welcoming APMs and LRT as means of people-friendly transportation that are also environmentally sound. APMs are an effective means of public transit used between terminals in an airport or within a metropolitan area. They almost operate unattended and are equipped with rubber tires to reduce noise and vibration.

LRT vehicles are a new generation of streetcar with high performance and stylish appearance. Their barrier-free design with extremely low floor levels makes them easily accessible to all. These features contribute to LRT's favorable acceptance as an effective means of public transit.

Using battery power for vehicles in a guideway transport system to eliminate the conventional catenary lines offers the following features:

- energy savings due to the efficient regeneration of power during braking, and elimination of power transmission loss;
- uncluttered space by eliminating the catenary wires and utility poles that would otherwise spoil the view;
- reduction in construction time and cost;
- reduction in maintenance costs and improvement in occupational safety by eliminating catenary wires and associated maintenance work involving high voltages and elevated work platforms.

The system is highly energy efficient and thus environmentally friendly; no power transmission loss occurs because no catenary lines are involved, and power is recovered for reuse during

Fig. 1 APM : Automated people mover

Fig. 2 LRT : Light rail transit

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efficient regenerative braking. The contribution to preserving scenic city views by eliminating catenary wires is a major advantage.

Many research organizations and vehicle manufacturers have been studying battery-powered transportation systems. Since its early development stages, MHI's work has focused on lithium-ion batteries as the vehicle-mounted power source.

1.2 Application of high-capacity batteries

Among the various types of high-performance, high-capacity batteries being developed for automotive applications, lithium ion stands out as being capable of storing and instantaneously supplying high power, and allowing stable continuous charging and discharging at high currents. Lithium-ion batteries are the most suitable for APM and LRT vehicles with their operating patterns of repeated and frequent high rates of acceleration and deceleration. Approximately 40–50% of the energy consumed when accelerating can be recovered during braking and then reused. In addition, while parked at a terminal or a station at the end of a route, for example, up to half the total energy required for the next recharging can be quickly transferred in less than 5 minutes depending on the route characteristics and the vehicle operation schedules. Because of their high-energy density, lithium-ion batteries are small and compact enough to fit into the limited space available in the vehicle. Once recharged, a lithium-ion battery is capable of running the vehicle for a distance of 10 kilometers or longer without recharging.

2. Development outline

2.1 System configuration

Figure 3 shows examples of battery-powered transportation system configurations. Fed by the direct-current electric power from the battery, the variable voltage variable frequency (VVVF) inverter drives the induction motor. The VVVF inverter also efficiently returns regenerative energy to the battery during braking. The same battery supplies electrical power for air conditioning, fluorescent lighting, and other vehicle devices through the static inverter (SIV) that converts the direct current into alternating current.

MHI is studying several different and flexible configurations as shown in the following examples. **Figure 3(a)** presents a configuration suited to new railway construction in which no catenary wires are used. Quick recharging takes place while the vehicle is at rest. **Figure 3(b)** is applicable to a route in which part of the track is under catenary wires, but the

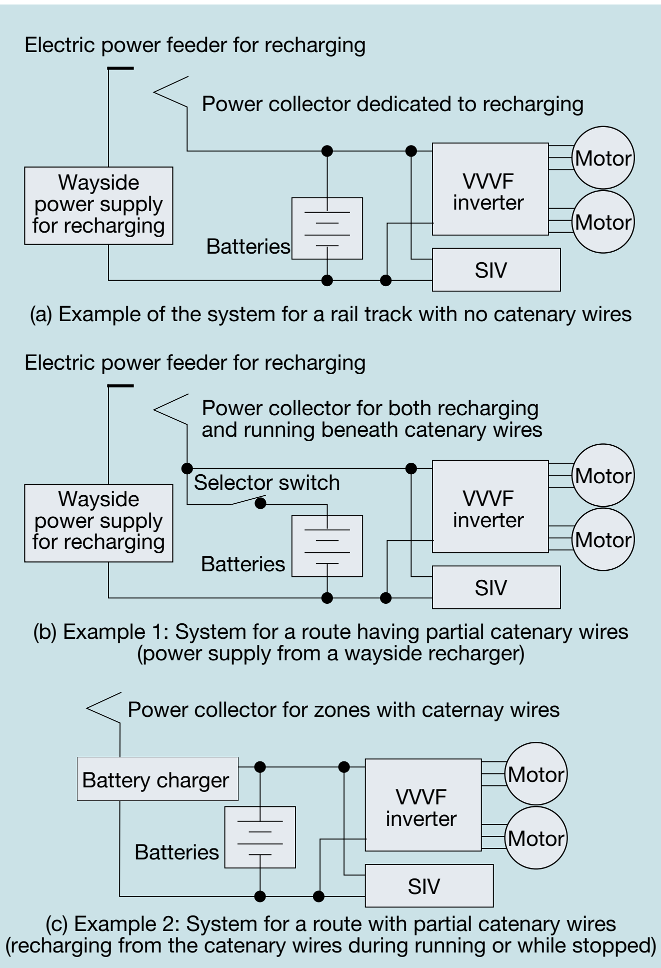

Fig. 3 Examples of system configurations for battery-powered LRT

Fig. 4 Operational testing of a battery-powered APM vehicle

Fig. 5 Operational testing of a battery-powered LRT vehicle

operation has been extended to a new section that has no overhead wires. The power supply switches back and forth between the pantographs/catenaries and the batteries as required. Quick recharging also takes place during stops. **Figure 3(c)** shows a configuration in which the vehicle is equipped with an internal battery charger that charges the battery while the vehicle is running under the catenary wires.

2.2 Operational testing

Figures 4 and 5 are photographs of the operational testing of battery-powered APM and LRT vehicles on MHI's test track. The range of running tests includes operation at very low temperatures to improve the commercial viability of the products under realistic operating conditions. Collecting and verifying the data obtained from the running tests enables simulation of the power consumption of battery-powered vehicles while taking into account the battery characteristics. The simulated results are used to study the layout of a power recharging system along an actual track as well as to evaluate the capacity, life, and other parameters of the batteries installed on the vehicles.

3. Conclusions

This paper has briefly described MHI's development of next-generation transportation systems using high-capacity batteries. MHI is currently in the process of producing a new demonstration vehicle. In addition to the ongoing comprehensive system tests, customer demonstrations are also scheduled. MHI wishes to promote the production of these products as environmentally friendly transportation systems that are attractive to both transit authorities and passengers.

References

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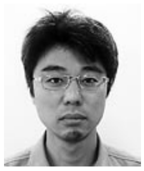
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