Technotalk

Advanced Technologies and System Integration for More Environmentally Conscious Railway Systems

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Because railways have higher energy efficiency than other forms of transportation and impose less of a burden on the environment, their value has come to be recognized anew in recent years both in Japan and elsewhere. Meanwhile, factors such as global environmental problems and the changing energy situation in Japan have been driving demand for even higher energy efficiency. As a total system integrator for the railway industry, Hitachi is continually working to develop the advanced technologies that underpin the evolution of railway systems. Hitachi is drawing on its accumulated experience and technology to advance on energy efficiency on a variety of fronts and to contribute to a next generation of railway systems that will be even kinder to the environment.

Batteries and Control Systems Hold the Key to Energy Efficiency

Yokose: While railways are known as a form of transportation that consumes relatively little energy and is kind to the environment, background factors such as increasing global warming and a changing energy environment are behind the demand for further improvements in energy efficiency. I would like to discuss how Hitachi, as a supplier of railway systems, can contribute to achieving this objective in terms of current technology and the prospects for the future.

Takahashi: Batteries are a key technology for achieving energy efficiency. Hitachi already supplies the energy storage technology for traction power supply systems in Japan and elsewhere. These systems store excess regenerative electric power in wayside lithium-ion batteries and then supply it to trains that require traction power.

Developed to improve the energy efficiency of trains by making use of the regenerative electric power they produce, recent progress in battery technology means it has reached a level of technical maturity. Installation of the energy storage for traction power supply systems has achieved power savings of approximately 20% at some sites compared with previous systems that used an inverter to return regenerative electric power to the grid.

Tokuyama: For systems in which the batteries are located on the train, Hitachi has also developed a

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hybrid drive system (incorporating an electric motor and lithium-ion batteries) for diesel locomotives that operate on non-electrified railway lines. By enabling the use of regenerative electric power on non-electrified railway lines, this system helps reduce the load on the environment by improving energy efficiency and reducing carbon dioxide (CO_2) emissions. For railway lines that include both electrified and non-electrified sections, Hitachi is expediting development aimed at commercializing battery-powered trains that can operate on electric power from the overhead lines when traveling on electrified sections and on battery power alone when traveling on non-electrified sections. Development is also progressing on a system in which batteries are used in conventional locomotives to assist with traction in much the same way as in a hybrid car.

The energy efficiency of trains is also being improved by enhancing the efficiency and reducing the losses of electric motors, inverters, and other equipment. We are also starting to adopt a philosophy of using control systems to operate this equipment efficiently on both existing and newly developed trains.

Miwa: An emerging trend in recent years, both in Japan and overseas, has been the use of traffic management, power management, and other control systems for energy management. Although optimizing the power consumption of onboard electrical machinery, wayside substations, and other individual systems is comparatively easy, management by a supervisory system is needed to for overall optimization at the level of an entire railway line. For example, an ideal balance of power consumption would be achieved if traction drive could be operated on one train while another is braking. Control systems monitor machinery and equipment and control their operation in accordance with the directives of the railway operations staff. Current practice is to perform control in ways that prioritize passenger convenience, such as quickly restoring normal operation after a schedule disruption. There is also the potential to extend the functions of these systems so that they can control the operation of the railway to maximize energy efficiency based on data such as the operational status of rolling stock and substations.

Miyauchi: To make progress on energy efficiency, we need to understand on when high energy consumption occurs and to what extent countermeasures can be expected to help. At Hitachi Research Laboratory, we have developed an integrated railway analysis system that can perform coupled analyses by modeling the different elements that make up a railway system, including the rolling stock, signals, traffic management system, and feeder power supply. By allowing the operation of a large railway system to be simulated on a personal computer (PC), the analysis system can be used to study such things as how much power is consumed by trains in operation and how substation output changes over time. It can also be used to study the operation of trains with disruptions and their influence on power consumption. Because the system provides quantitative information on the efficient and effective siting of substations, batteries, and other equipment in terms of energy efficiency, and on how power consumption changes with different operating practices, it can also be used to devise solutions that will improve energy efficiency.

Unanticipated Power Consumption Revealed in Actual Data

Yokose: A challenge when it comes to improving the energy efficiency of railway systems is to come to grips with power consumption. This means determining not only overall consumption but also the power consumed by each device, train, and section of railway line, and

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also the factors that cause their power consumptions to change. While simulation naturally plays an important role, being able to visualize the details of actual consumption is also essential for assessing the benefits of investment.

Takahashi: While the only way to do this at present is to infer power consumption from data or other status information, we have also made one very interesting inference. When we looked at the year-long results of measuring the benefits of energy storage for a traction power supply system in collaboration with the railway operator, we found that trains running above ground have excess regenerative electric power during spring and fall, but that the amount of excess returned to the energy storage for traction power supply system falls in mid-summer and mid-winter. In contrast, measurements from systems installed on underground trains showed little evidence of this seasonal variation. We believe the reason why regenerative electric power generated when the temperature is high or low is consumed within the train is because most of it is being used by auxiliary systems such as air conditioning. We hadn't anticipated that the amount of power consumed by these auxiliary systems would be so high. Given that the weather has a major influence on the power consumption of trains that run above ground, significant energy savings should be possible by performing detailed control of the auxiliary power supplies used on trains for air conditioning and other purposes.

Miyauchi: Something we have discovered only recently is that the power consumed by the static inverters (SIVs) used to supply air conditioning and other auxiliary equipment has a much bigger impact on the energy savings achieved by energy storage systems than was previously thought. Assuming that the power used by SIVs is about 10% of the traction drive power consumption, and that the regeneration rate is 40% (regeneration produces 40% of the power consumed by traction), then the proportion of regenerative electric power consumed by SIVs is only about 25%. If SIV power consumption increases further, however, less excess regenerative electric power will be available because a growing proportion will be used by the SIVs, and this can be expected to affect the level of power savings achieved.

Takahashi: That's right. This tendency is particularly evident when there is a long distance of railway line between substations.

Use of Control Systems to Support Energy-efficient Operation

Miyauchi: Overall train power consumption depends on operating conditions, with running resistance and the drive system believed to have particularly significant influences. Because running resistance is a function of the speed at which a train is traveling, operating practices that minimize variations in speed will help save energy. In particular, when schedule disruptions occur, control techniques that can minimize acceleration and deceleration and allow trains to run at a slow speed as needed will reduce power consumption. Given that achieving this requires techniques for obtaining accurate location and movement data about trains on the railway line, it should be possible to use traffic management system technology for this purpose.

Tokuyama: As you say, accelerating from a halt uses a large amount of energy and therefore allowing trains to proceed at a slow speed will reduce power consumption. Because trains are able to obtain information such as passenger load factors and how long to stop at stations, it should be possible to achieve even greater energy savings by using this information in the supervisory traffic management system to coordinate operations in realtime, including departure times and modifying the speed of following trains.

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Miwa: As traffic management systems are designed with an emphasis on how quickly trains can get from station to station and how close together trains can run, there is no system-level definition of how to operate for energy efficiency. While this is a natural consequence of giving precedence to ensuring the transportation capabilities of the railway in its role as public infrastructure, I believe we also need to be concerned with electric power in the future. Furthermore, an important aspect of doing this will be how a system-based approach to minimizing power consumption can be made to support operations in a way that is compatible with the instincts of the train drivers. On the other hand, combining this with automatic train operation (ATO) and implementing operating schedules that are designed for optimal energy efficiency offers an alternative approach, and I believe we need to continue collecting data and identifying the technical possibilities.
Yokose: In terms of supporting energy-efficient operation, it is also important to consider what capabilities control systems can offer.
Miwa: Since the driver cannot see the train ahead, unlike in a car, a key point will be how the supervisory traffic management system can make this information available and use it to support operations or to automate the operational coordination of multiple trains.

Integrating Technologies for Innovation in Railway Systems

Takahashi: The pursuit of energy efficiency also requires measures for dealing with losses on feeder power lines. I believe that using substations to control the voltage supplied to feeder lines is one effective technique for achieving this.

However, because few substations are currently able to control the feeder line voltage, it is anticipated that the ideal method will be to perform realtime control of feeder line voltage in conjunction with the use of wireless technology and batteries. This will likely involve the deployment of train control system technology that uses radio communications, like that in the communications-based train control system (CBTC).
Tokuyama: Batteries installed on the wayside can also be used in that way. Along with using them for energy efficiency, we are also trialing their use as an emergency power supply so that trains can reach the next station when a major power outage occurs. The fact that Hitachi's business encompasses both batteries and railway systems can be seen as a major technical strength. While battery technology still requires further technical innovations in areas such as weight and cost, the technology will be essential for future railway systems that impose less of a load on the environment and therefore our aim is to contribute by developing models that successfully combine batteries with equipment and control systems.
Miyauchi: Hitachi is engaged in the broad-based development and supply of railway system technologies that extend from rolling stock, signaling systems, traffic management systems, and substations to hybrid drive systems that combine engines, electric motors, and batteries, and has a variety of energy efficiency technologies that are based on the experience and knowledge built up through this work. While the benefits of new energy-saving systems that utilize these technologies can be estimated by using collected data and the simulations described earlier, we still want to verify them on actual railways.
Miwa: Most past developments have been undertaken to fulfill customer requirements, but to deliver the sort of value represented by energy efficiency, I believe we first need to build our own models that will indicate a certain level of benefits and then to prove them in demonstration projects. To achieve this, we should further enhance our technology in-house and expedite measures aimed at moving to the next stage, such as enhancing interoperation between systems.
Yokose: It is now possible in the railway industry to collect large amounts of diverse forms of data from numerous subsystems. Key factors to success will be our ability to apply the know-how we have accumulated through our railway business to the analysis of this big data, and whether we will be able to utilize it to improve energy efficiency.

We are approaching a period of transition to more sophisticated systems in which the railway systems that in the past have been developed to ensure safe and punctual operation will need also to take account of energy efficiency. Along with railway technology, other technologies with an important role in this transition will include wireless communications and the global positioning system (GPS) for obtaining accurate train locations, and data transmission techniques for the precise control of substations.

The Social Innovation Business that Hitachi is pursuing on a group-wide basis seeks to create new value through infrastructure innovation in collaboration with customers. Likewise with railway systems, our aim is to combine the comprehensive capabilities we have built up in the railway industry with technology and knowledge from elsewhere in the group to contribute to innovations that will help develop the next generation of railway systems so that they impose less of a load on the environment.