Special feature article

Research Topics at the Environmental Engineering Research Laboratory

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Abstract
The Environmental Engineering Research Laboratory aims to achieve energy management and energy efficient railway systems. In this paper, topics of research done in the laboratory are described in five categories: next-generation energy grid, energy-conserving train control by coordination between onboard and wayside equipment, utilization of batteries, utilization of hydrogen energy, and improving energy efficiency of equipment.

●***Keywords*:** Energy grid, Battery post, Energy-conserving train control, Battery, Hydrogen energy, Fuel cell, Energy-efficient equipment

1. Introduction

The Environmental Engineering Research Laboratory has been conducting R&D centering on the field of energy in the 10 years since its launch in April 2009 in order to establish energy management and apply energy-conserving technologies to JR East railway business.

When considering JR East's energy flow, it is important for achieving energy saving that we reduce energy consumption for train operation and buildings and use energy efficiently by introducing energy storage systems and employing supply and demand management. It is also important to realize diversification of energy use by studying use of hydrogen energy and other forms of energy that are not yet well utilized.

JR East has set high targets of reducing energy consumption for railway operation by 25% and CO_2 emissions by 40% by fiscal 2030 compared with fiscal 2013. And the "Mid-to-Long term Vision for Technological Innovation: Energy and Environment" established in 2017 proposes technical targets such as a next-generation energy grid, automated energy-conserving train control by coordination between wayside and onboard equipment, utilization of storage batteries, utilization of hydrogen energy, and improving energy efficiency of equipment. Herein, we introduce case examples of R&D at the Environmental Engineering Research Laboratory for achieving those targets.

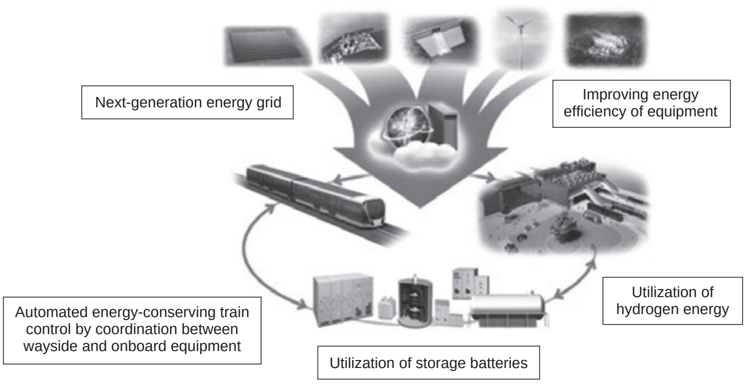

Fig. 1 Efforts of the Environmental Engineering Research Laboratory

2. Next-generation Energy Grid

We are proceeding with R&D related to energy management on electric power grids in order to utilize energy effectively. Recently, focus has been put on setting up energy storage systems at the wayside to utilize energy effectively.

2.1 Regenerative Energy Storage System (Battery Post)

A battery post is a system to store regenerative energy generated when trains brake in an energy storage device set up at the wayside and supply that to trains at powered running. If substations can be replaced with battery posts, a reduction in maintenance labor can be achieved by simplifying transforming equipment. We performed proving tests to verify energy storage system performance on the Uchibo Line Onuki substation in fiscal 2017 and 2018, proving that necessary power can be supplied to trains from the energy storage system.

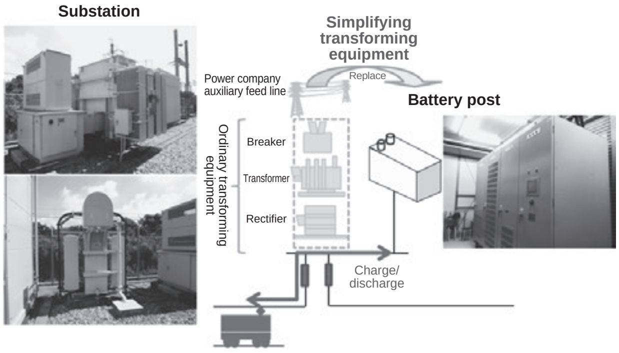

Fig. 2 Overview of Battery Post

2.2 Flywheel Storage System

A flywheel storage system is a system that rotates a disc (flywheel) to store electric power as kinetic energy (charge) and convert that kinetic energy back to electric power as needed (discharge). Features of flywheels include that they have long-term durability and do not degrade in performance with repeated charging and discharging, have excellent responsiveness and maintainability, and their power and stored energy capacity can be designed independently.

2.2.1 Superconducting Flywheel Energy Storage System

We are developing a superconducting flywheel energy storage system that stores regenerative energy generated at train braking. In that, a large flywheel is made to levitate by superconducting technology in order to minimize energy decrease due to friction loss as well as eliminate bearing wear, thereby eliminating the need for periodic large-scale maintenance.

JR East has so-far concluded a "Basic Agreement on Technology Development of Superconducting Flywheel Power Storage System for Railways" with Yamanashi Prefecture and the Railway Technical Research Institute (RTRI). The parties are coordinating efforts and moving forward with development to put a superconducting flywheel energy storage system for railways into practical use for the first time in the world, and we plan to set up a test device at Anayama substation on the Chuo Line and conduct proving tests with that.

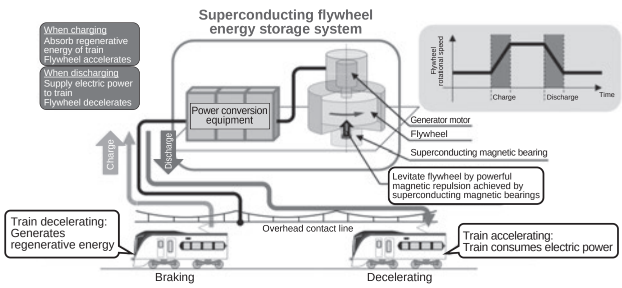

Fig. 3 Overview of Superconducting Flywheel Energy Storage System

2.2.2 Small Flywheel

By introducing an energy storage system, we will be able to utilize energy effectively and avoid introducing additional power distribution equipment for station equipment such as newly added platform doors. We are focusing on small flywheels with output of a few tens of kilowatts as the energy storage system, and we have confirmed good performance in field tests such as for platform door opening and closing.

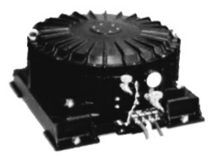

Fig. 4 External View of Small Flywheel

3. Automated Energy-conserving Train Control by Coordination Between Wayside and Onboard Equipment

We believe that we can conserve energy by coordinating train operation and wayside equipment control. We are currently conducting development of basic technology for that, and we are aiming to conserve energy in the railway system as a whole in the future by technology for combining onboard and wayside systems, energy-conserving driving, wayside storage systems, and onboard storage systems.

3.1 Energy-conserving Driving

It is known that energy consumption of trains differs considerably, even at the same operating time, depending on driving operations such as timing of powered running and braking. We found that energy conservation of up to 25% is achieved when driving according to most energy-conserving running patterns, which were found by extracting the most energy-conserving train performance curves of those measured for rolling stock such as the Series E257 on the Chuo Line and Series E231 on the Utsunomiya Line. And later we developed tools with which drivers learn energy-conserving driving so they could perform that task, and we held trials on efforts in energy-conserving driving at various field depots. Energy-conserving driving is a method effective in achieving much energy saving without large-scale capital investment. In the future, this can be applied to automated driving in addition to manual driving by drivers, so we intend to develop systems in order that energy saving driving can be achieved automatically.

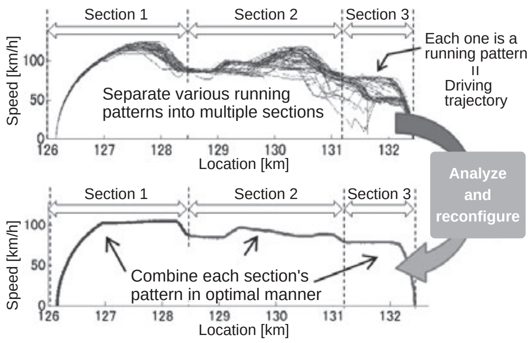

Fig. 5 Generation of Energy-conserving Running Patterns

3.2 Energy-conserving Control

If traction motors of rolling stock can be controlled at a highly efficient range, greater energy saving can be achieved. Torque can be uniquely determined if the point with highest efficiency is selected at a certain speed. However, total torque may be excessively large or small for the train set when all motors are driven at that point. By varying the number of motors being driven in a train set, the train can run at the desired speed while operating motors at the point with highest efficiency. We have been conducting running tests by controlling under that concept and confirmed energy saving effects and are proceeding with development for putting it into practical use.

3.3 Regenerative Energy Storage System (Battery Post)

In proving tests of the battery post introduced in 2.1, we performed tests on coordination between wayside and onboard equipment where energy storage system control is done using train location information. If train location and charge/discharge voltage control are linked, unnecessary charge/discharge operations such as discharging when a train is not present can be reduced, thereby lengthening the life of storage batteries. Those tests showed that equipment could be simplified (30% reduction of volume) and lifespan lengthened.

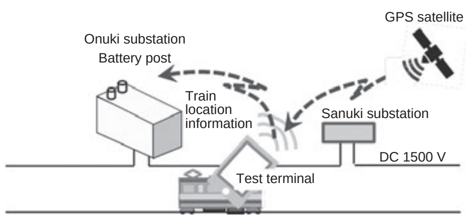

Fig. 6 Tests of Coordination Between Wayside and Onboard Equipment for Battery Post

4. Utilization of Storage Batteries

For efficient use of electricity, technology to utilize storage batteries that can absorb the time difference between generation and consumption is imperative. Battery posts have already been covered, so here we introduce examples of development for battery devices that can be mounted on rolling stock.

4.1 Trains Equipped with Storage Device

Regenerative energy is generated at train braking, and in the greater Tokyo area that is used well for acceleration of other trains. However, in provincial lines, the number of train runs is small, so that regenerative energy cannot be completely used and is consumed as heat by resistors onboard trains. In order to improve energy efficiency, a system that stores regenerative energy in storage devices and consumes it at the next instance of powered running is desirable. We are thus studying a train system using storage devices that fits the characteristics of trains where rapidly generated regenerative energy can be stored and rapidly released at powered running.

4.2 Increasing Lifespan of Storage Batteries of Diesel Hybrid Trains

Diesel hybrid trains are equipped with storage batteries, but it is useful to increase the lifespan of the batteries in order to reduce lifecycle cost of the rolling stock. Research up to now has shown that battery lifespan can probably be lengthened by modifying charging and discharging control. Into the future we plan to conduct detailed verification of that.

5. Utilization of Hydrogen Energy

As part of efforts to diversify utilization of energy, we are going forward with elemental development of fuel cell rolling stock that uses hydrogen energy.

The hydrogen for fuel cell rolling stock is stored as high-pressure gas. The High Pressure Gas Safety Act and other related rules are applied to high-pressure gas in Japan, but those rules are not taken into much consideration for moving bodies like railway rolling stock, so overcoming legal issues is imperative in order to use hydrogen. Up to now, we have studied safety verification tests and verified risks, and we have performed these tests on hydrogen storage units in which high-pressure hydrogen is stored. For future, we plan to advance the design of hydrogen systems and traction systems and apply the results of that in design of fuel cell railway rolling stock.

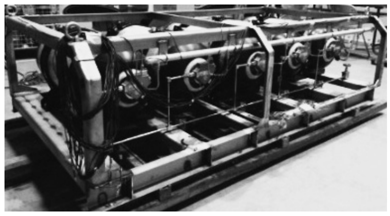

Fig. 7 Hydrogen Storage Unit Developed

6. Improving Energy Efficiency of Equipment and Other Efforts

6.1 High Efficiency Water-sprinkler Snow Melting Equipment

For stable Shinkansen transport, water-sprinkler snow melting equipment is installed along lines in areas with heavy snowfall. But even though that is only used in winter, its energy consumption is large, making up more than 1% of energy consumed by the company as a whole per year. We thus have developed high efficiency water-sprinkler snow melting equipment. To make equipment conserve energy better, we adopted functions that determine the priority of operation by and that enable fine control of output, comparing operating efficiency of multiple types of heating equipment. And in consideration of actual introduction, we improved output per unit in order to reduce the number installed and adopted a space-saving design. By introducing this system, we expect to reduce fuel consumption and CO_2 emissions by 10%, and we plan to continue verifying its effect.

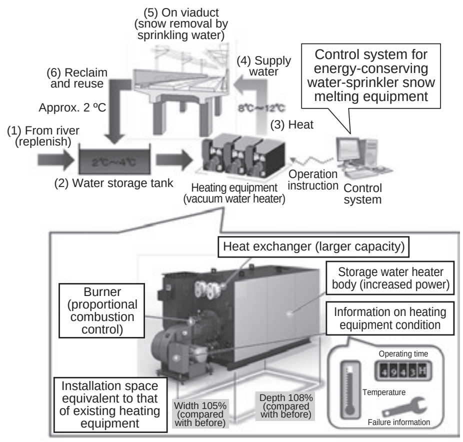

Fig. 8 High Efficiency Water-sprinkler Snow Melting Equipment

6.2 Supply and Demand Coordination System

By adjusting supply (electricity, heating oil, gas, etc.) of energy consumed in a certain area in accordance with demand (electricity, steam, etc.), waste can be reduced. In the past, we verified if we can predict energy consumption by using actual data on an area that includes a station and buildings around the station in an urban area. Simulations showed that we could conserve energy if we supply energy according to those predictions. Into the future, we will introduce that method on a trial basis and verify its effects.

6.3 Optimizing Station Thermal Environment and Conserving Energy

Providing the optimum thermal environment is effective in making station spaces comfortable, but air conditioning for large station spaces requires tremendous amounts of energy. Efforts up to now have included development of simulation tools for designing optimum thermal environments for underground station spaces. Currently we are studying methods of partial air conditioning that increase customer satisfaction in the thermal environment with small amounts of energy. And for provincial stations, we are studying how to achieve zero-energy houses (ZEH) for station buildings.

7. Conclusion

This paper introduced efforts of the Environmental Engineering Research Laboratory in line with the Mid-to-Long term Vision for Technological Innovation. We will continue with R&D for energy management and energy saving, and we would appreciate the continued guidance and support of all those involved.