Commitment to Developing Solutions to Energy Issues

Railway systems have been superior to other transport modes in resolving energy issues due to their advantageous features: higher energy efficiency and lower CO_2 emissions. However, the automobile and aircraft industries have performed systematic and proactive research and development to find solutions to energy issues and have made breakthroughs. The railway sector needs to make more effort to conduct research and development to further upgrade its features of higher energy efficiency and lower CO_2 emissions. Mr. Hiroyuki Nozawa, General Manager of International Division gives an outline of RTRI's R&D activities on energy issues.

Implications of COP21

As you may remember well, the twenty-first session of the Conference of the Parties (COP21) was held in Paris last year (December 2015) , where the Paris Agreement was adopted to set out a framework for global warming countermeasures, following the Kyoto Protocol of 1997. In Europe, the International Union of Railways (UIC) held an event named "TRAIN to Paris" in conjunction with COP21, and had a series of trains run to Paris from different parts of the world to highlight how effective energy efficient rails are in the prevention of global warming.

Meanwhile, the Japanese government has established a two-pillar program for CO_2 emission reduction in response to the outcome of the COP21: 1) further promotion of energy saving and 2) choice of an energy source that emits less CO_2. In the transportation field, we are also required to commit ourselves to further energy saving and CO_2 emission reduction.

In recent years, many of the Japanese railway operators have been operating an environmental management system (EMS) conforming to the ISO 14001 standard. The EMS has established specific environmental goals including energy issues, and the PDCA (Plan-Do-Check-Act) cycle is employed for management to reach the goals.

Commitment to solutions to energy issues in the railway field

Compared to other modes of transport, railway systems have the advantage of being able to transport passengers and freight with higher energy efficiency and lower CO_2 emissions. Railways by their nature are energy efficient due to little rolling resistance of wheels on rails and technological developments have brought about the reduction of vehicle weight, introduction of regenerative brakes and other advancements, all of which have contributed to the current high level of energy savings.

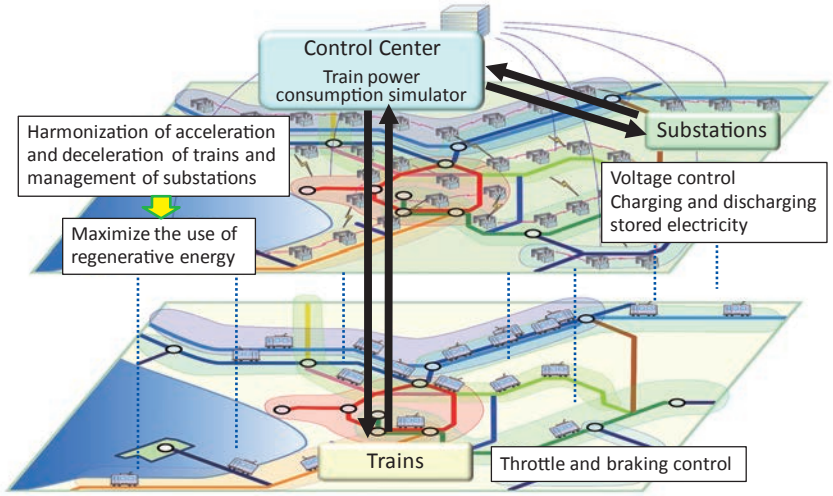
-25.4%

Japan's intention of greenhouse gas reduction by 2030 compared to 2005

"We will mobilize all measures to promote thorough energy conservation and introduce renewable energies to the greatest possible extent."

(Japan's Prime Minister Shinzo Abe stated in his policy speech to the 189th session of the Diet on Feb.12, 2015.)

Concerning the other target of having an energy source emitting less CO_2, the railway industry has made efforts to generate in-house power for their system operations by hydroelectric power generation for a long time. Additionally in recent years,



Concept of networked energy conservation
where the control center, trains and substations work cooperatively

photovoltaic power and wind-power generation systems have been installed on railway property including station roofs and railway land.

In recent years, hybrid-driven vehicles using diesel electric power and storage batteries have been developed and are in practical use in railways all over the world. In Japan, hybrid-driven passenger diesel cars and shunting diesel locomotives are in practical use and have started to replace the existing diesel vehicles for energy saving.

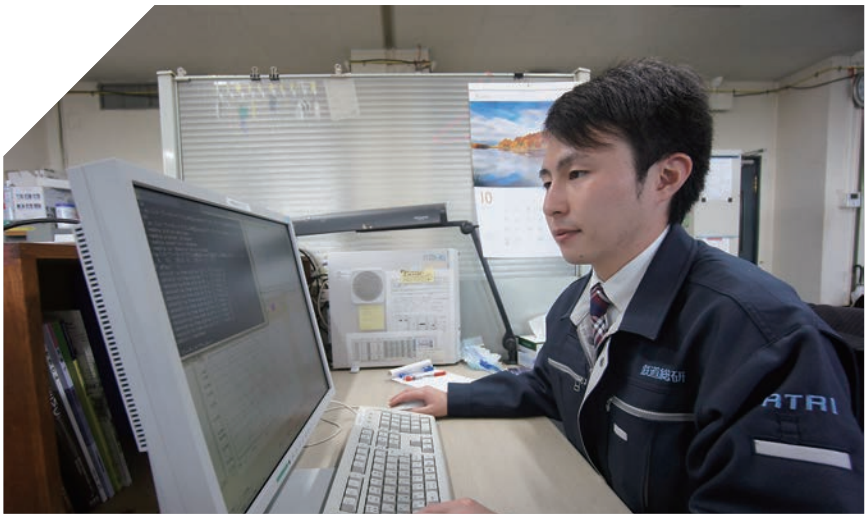
Around urban areas, the sections between urban centers and major stations are often electrified, and the sections beyond them are sometimes non-electrified. To achieve energy saving in such cases, battery-powered vehicles are in practical use. Electric storage vehicles can run in non-electrified sections, using the energy of their power storage devices which are either charged during running in electrified sections or by using chargers installed at the stations in non-electrified sections. In Japan, battery-powered EMUs available for DC feeding systems were put into actual operation and electric storage vehicles available for AC feeding systems has just been put into operation in October 2016. In Europe as well, electric storage vehicles were put into practical use and are used for trams, etc.

Thus energy issues have been addressed in railway systems, but other means of transport have also proactively introduced new technologies and started to greatly enhance their environmental performance. Accordingly, railway systems need to further upgrade their environmental features, which are high energy efficiency and low CO_2 emissions, and continuously keep their energy advantages in the future. This requires the railway industry to advance to the next level. The following sections introduce the directions of research and development for that purpose.

Replacement by energy source emitting less CO_2

Replacement of internal combustion engines by fuel cells as an energy source emitting less CO_2 is one of the most promising technologies. A fuel cell is a device to generate electrical energy and water by chemical reaction of hydrogen and oxygen. Since no CO_2 emits from a fuel cell vehicle, the device is known to be greatly effective in achieving reduction of CO_2 emissions. In the automobile field, vehicles loaded with fuel cells are already commercially available.

As described elsewhere in this magazine, RTRI started making efforts to develop fuel-cell vehicles about 10 years ago and is currently performing a running test to determine the long-term degradation characteristics of fuel cells and is advancing the technological developments toward



Simulating changes of energy consumption of trains in accordance with the change in train schedule

practical application.

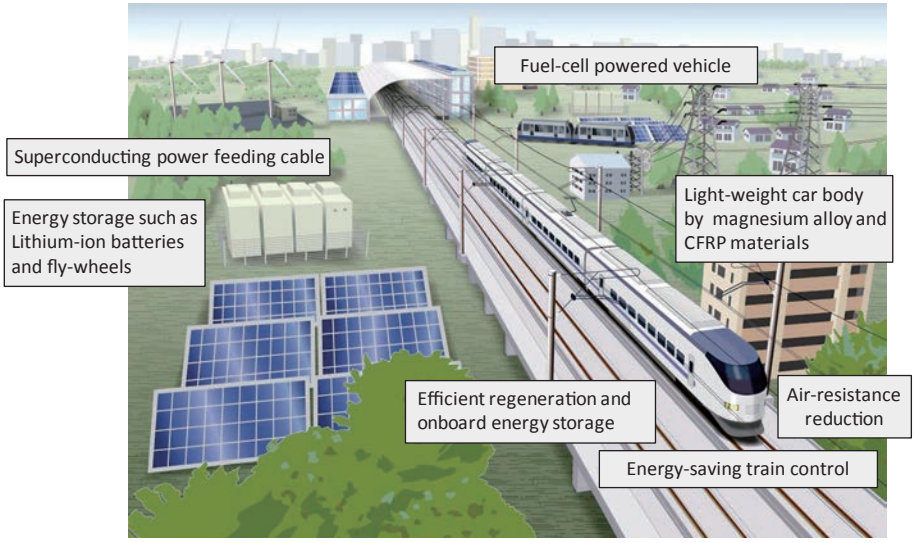
Expectations for further technological innovation

For further technological innovation, development of silicon carbide (SiC), which is a next-generation semiconductor element, is progressing in many countries. In Japan, research and development is being advanced to adopt silicon carbide (SiC) in traction inverters. Achieving further energy savings is expected by reduction of semiconductor loss and the decrease of vehicle weight due to reducing the size and weight of the inverters.

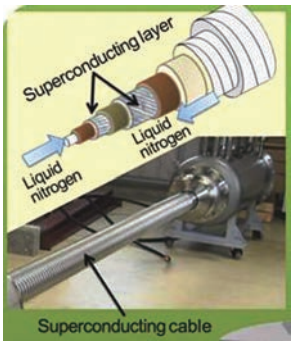
RTRI is also conducting research and development of superconductive feeder cables that enable power transmission without electrical resistance by applying superconductive material to feeder cables. DC feeding systems have issues such as transmission loss and voltage drop, which are attributable to the electrical resistance of feeder cables. If superconductive feeder cables are put into practical use, these issues will be reduced. These cables will be effective in load leveling at substations in addition to energy saving due to reduction of transmission loss and regeneration canceled.

Smart grids are being studied worldwide to develop an electric power network that performs communication and control functions and proactively utilizes an energy source emitting less CO_2. RTRI is also proceeding with research and development for further energy savings by transforming the railway power network into a smart grid. If we are able to construct a smart grid that can control the power networks of an electric power company and railways integrally in the future, it is expected to be extremely effective in achieving energy saving and utilization of an energy source emitting less CO_2.

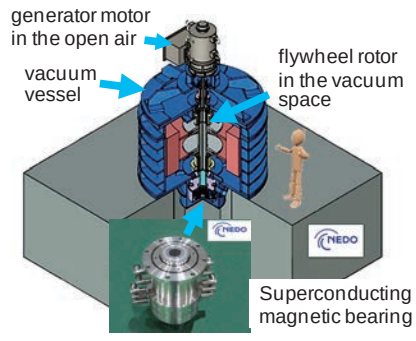
Mixing chemicals in a mortar to prepare a compound for a ceramic superconductor



Technological innovations addressing energy issues



Superconducting power feeding cable



100 kWh flywheel with superconducting magnetic bearing