Power Supply Technologies Contribute to Sustainable Railway Network

Power Supply Technology Division engages in the research and development of railway power supply systems, which in turn also includes the current collection systems. In recent years, we have been focusing on establishing a sustainable railway power system that would help us move towards a sustainable society. We aim to achieve "reduction in CO_2 gas emission by railways" and "reduction in labor and cost for maintenance of railway infrastructures." I introduce the research done by our division on these initiatives recently.

Dr. Hidenori Shigeeda
Director,
Head of Power Supply Technology Division

Introduction

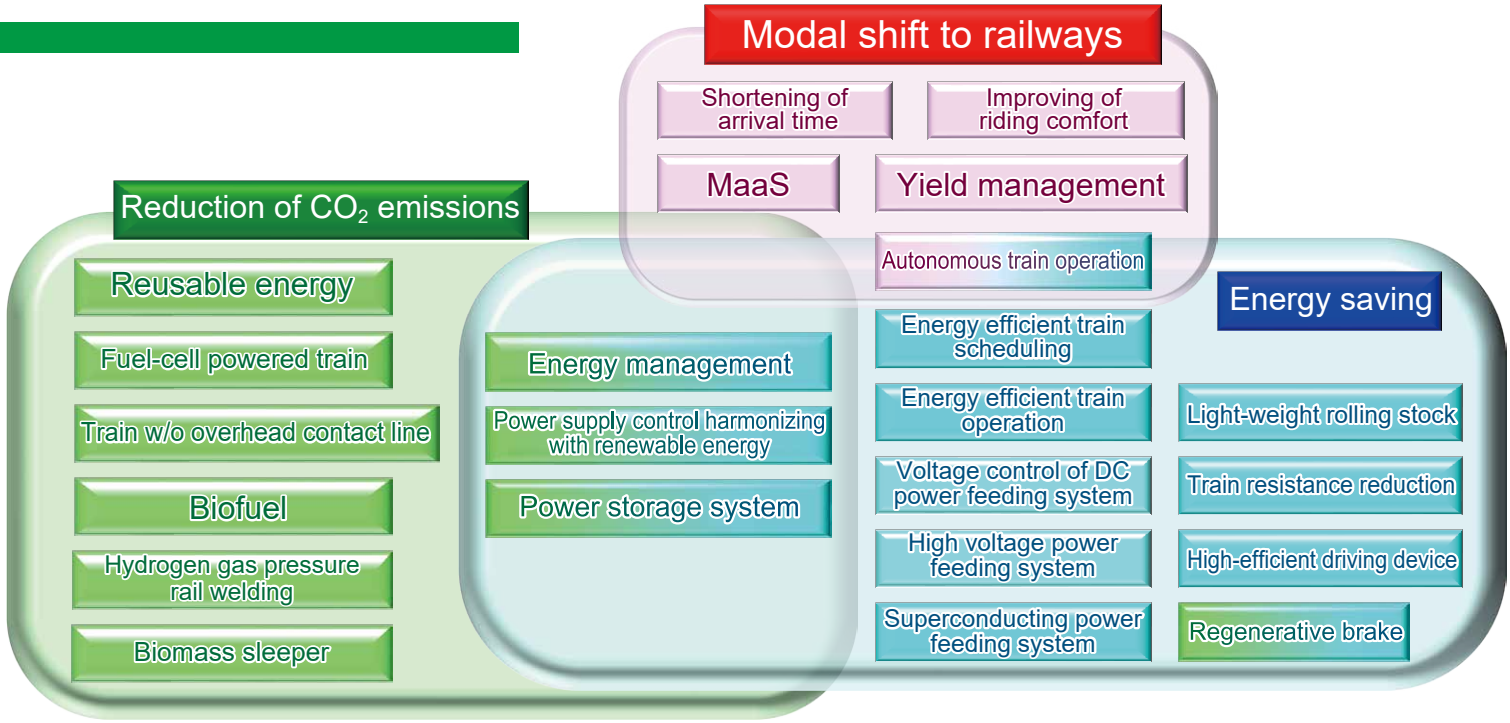
Power Supply Technology Division has three laboratories, "Power Supply Systems," "Current Collection Maintenance " and "Contact Line Structures," where research and development is being conducted with the principle aim of establishing a railway power supply system for the realization of a sustainable society. This initiative has two objectives: one is a socially sustainable effort to fight global warming by utilizing railway assets and the other is to create a sustainable national railway network and reducing cost of railway infrastructure maintenance. Both these issues require immediate attention. In this paper , the latest information regarding the research and development we have been conducting in this field is explained.

Efforts towards reduction of greenhouse gas emissions

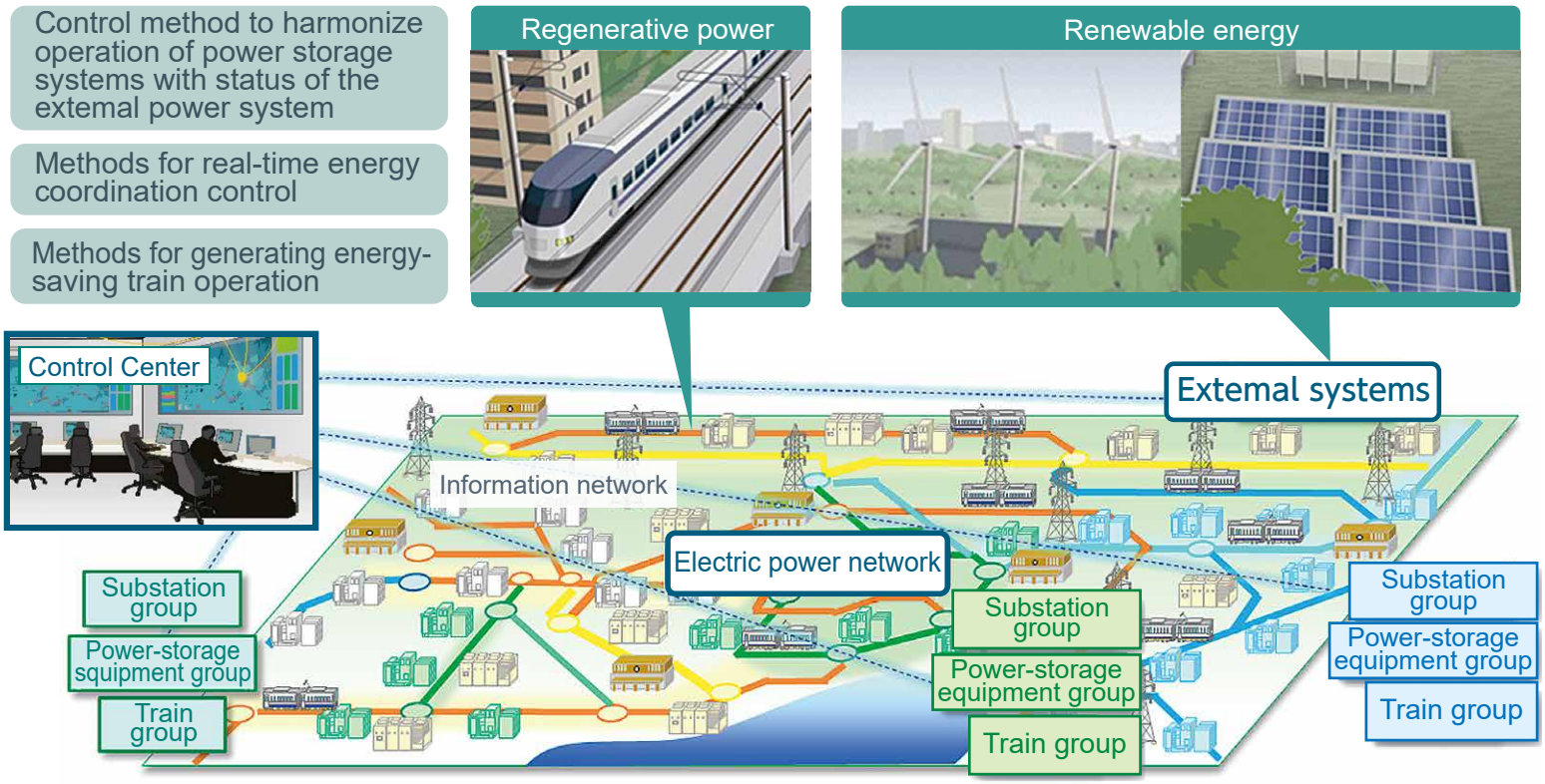
Approach adopted for CO_2 reduction

Japan has announced a policy to achieve carbon neutrality by 2050, and to this effect, by FY2030, the country has set an ambitious goal of reducing greenhouse gas emissions by 46% of those produced in FY2013. Since carbon dioxide (CO_2) emitted from energy sources accounts for most of greenhouse gas emissions in Japan, it is important to reduce these emissions . The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is pushing forward a project with the following three objectives for the railway sector:

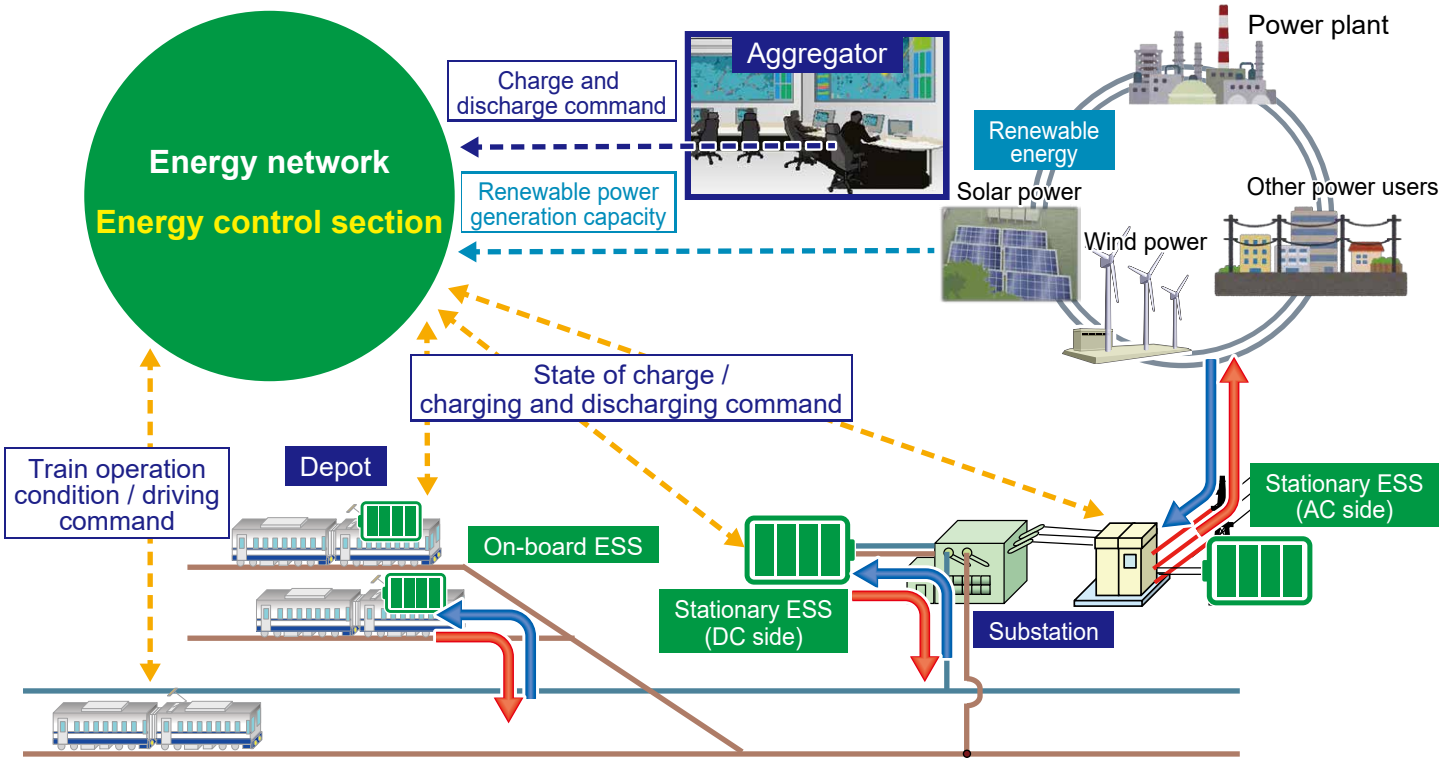
- "Decarbonization of railways" to reduce CO_2 emissions through energy conservation and electrification of diesel railcars.
- "Decarbonization by railways" to generate, transport and store renewable electric power or hydrogen energy by utilizing railway assets.
- "Decarbonization supported by railways" to reduce CO_2 emissions by promoting the use of railway services among people.



Example factors to be considered by the RTRI for decarbonization



Main tasks involved in "Low-carbon power feeding networks by coordinated power control"



Smart energy storage system

Activities of Power Supply Technology Division

Example factors to be considered by the RTRI for decarbonization shows the factors related to the decarbonization aspects that RTRI has been working on. Under the category of "decarbonization of railways," we are aiming for energy saving and energy conversion programs. We are also promoting R&D in energy management and energy storage system (ESS) under the category "Decarbonization by railways," and reducing the time of commute and improving the riding comfort under "Decarbonization supported by railways."

Power Supply Technology Division is also working towards reducing CO_2 emitted from the use of electricity that accounts for most of the CO_2 emissions from railways. This is achieved by focusing on "low-carbon power feeding networks by coordinated power control" (*Main tasks involved in "Low-carbon power feeding networks by coordinated power control"*), which is one of our R&D tasks set for the future. The main feature of this task is to develop a new method for coordinated control of railway ESSs and power grids through the active use of power derived from renewable energy sources, in addition to energy conservation that we have been working on for some time in order to promote decarbonization in railways. The "smart energy storage system" under study as part of this project is shown in *Smart energy storage system*.

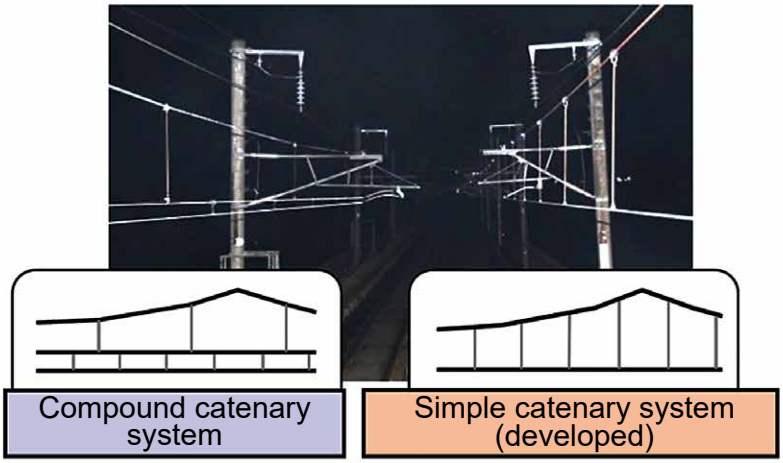
This smart energy storage system allows us to control each energy storage device in a well-coordinated manner and usually works independently in the railway power grid. In this way, regenerative electric power is utilized more efficiently, enhancing the energy-saving effect. In addition, by coordination between the renewable energy and ESSs, we aim to improve the utilization rate of renewable energy in railway operations and introduce renewable energy to the power grid system, which has the ability to deal with the fluctuation in power supply. We are currently developing an algorithm to control multiple energy storage devices in a coordinated manner, and improving the existing simulator to test its effectiveness and determine the battery life when used for several cycles of charging and discharging.

Labor efficiency and cost reduction for maintenance work

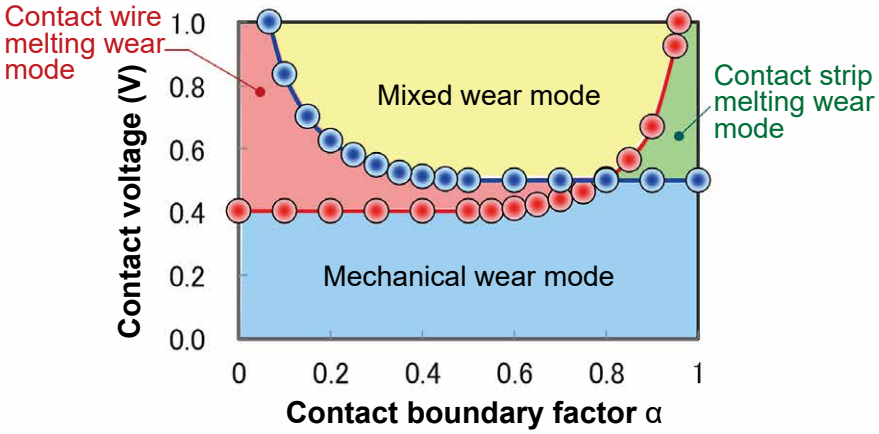
As Japan's birthrate declines and the population ages, it is expected to become increasingly difficult to secure maintenance personnel for railway infrastructure. Moreover, the recent decrease in passenger traffic caused by the spread of the new variant of coronavirus has significantly impacted the financial situation of railway service businesses. Given this background, research and development to reduce labor and maintenance costs associated with the power supply systems, especially train tracks, is desired. Hence, we are working on projects such as "streamlining of maintenance works" to reduce inspection check items for facilities, "prolonging facility service life" to extend the renewal cycle of facilities, and "mechanization and automation" for maintenance works. It is important that these activities are conducted without safety and reliability being compromised.

In streamlining of maintenance works, we have developed a simple catenary system for Shinkansen lines to replace an existing compound catenary system comprising a messenger wire, an auxiliary messenger wire and a contact wire. The new system works without the auxiliary messenger wire and supports speeds of over 300 km/h (*Installation situation of overhead contact lines*).

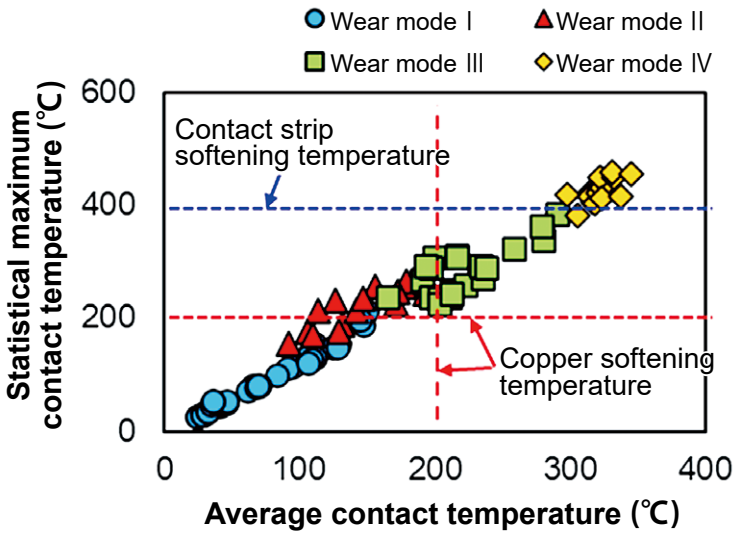
To improve the service life of facilities, we conducted basic research on current collecting materials. We are investigating their wear mechanism with a view to develop long service-life current collecting materials in the future (contact wire and contact strip). In our previous research, we revealed the electrical wear mechanism caused by Joule heat, the mechanical wear mechanism caused by frictional heat as well as heat transition characteristics of each wear mode (*Wear mode map under the effect of flowing electric current* & *Mechanical wear mode with respect to contact temperature*). We intend to continue



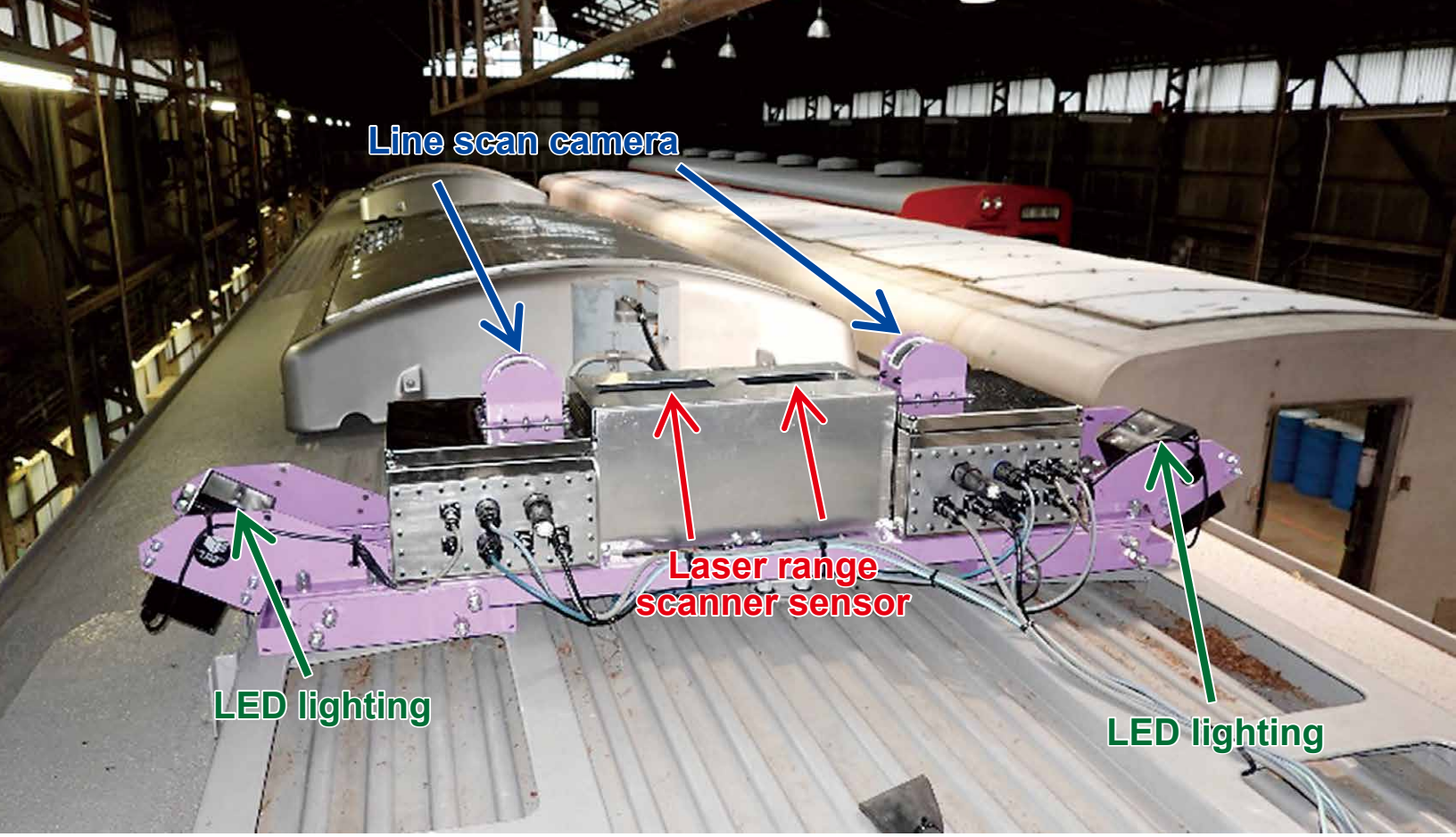
Installation situation of overhead contact lines



Wear mode map under the effect of flowing electric current



Mechanical wear mode with respect to contact temperature



Contactless OCL measuring device

material research with respect to bulk temperature.

For mechanization and automation of maintenance operations, we are working on inspection and diagnosis practices for overhead contact lines (OCL) using digital technologies. We have already developed a *contactless OCL measuring device* that enables 3-dimensional measurement of OCL wire positions（*Contactless OCL measuring device*）. Furthermore, we are conducting research on detecting OCL fittings using machine learning techniques from OCL images acquired by the measuring device to determine the condition of the fittings.

Conclusions

Introducing an electrical power system with clean energy is an effective way to help reduce greenhouse gas emissions. It is also important to reduce labor and costs involved to maintain and promote the electric railway systems. Our division will continue to work to identify effective solutions for these issues.

References

1) Atsushi Furukawa, “Railway Technologies required for Decarbonization,” Proceedings of the 34th Railway Technical Research Institute Lecture Forum, pp.11-18, 2021 (in Japanese) .
2) Atsushi Furukawa, Hidenori Shigeeda and Katsumi Muramoto, “Research and Development at RTRI toward the Achievement of Net-Zero by 2050,” Ascent, No.11, pp. 3-8, 2022.
3) Mizuki Tsunemoto, et al., “Development of Simple Catenary System for Operation over 300 km/h,” Quarterly Report of RTRI, Vol. 61, No. 1, pp. 47-53, 2020.
4) Chikara Yamashita, “Wear Mechanism of Current Collecting Materials under the Effect of Flowing Electric Current,” Quarterly Report of RTRI, Vol. 58, No. 4, pp. 264-269, 2017.
5) Chikara Yamashita and Koki Nemoto, “Classification of Mechanical Wear Modes of Contact Wire and Contact Strip caused by Frictional Heat,” RTRI Report, Vol. 35, No. 12, pp. 11-16, 2021 (in Japanese) .
6) Itaru Matsumura, et al., “Measurement Accuracy Verification of OCL Contactless Measurement Device by On-board Test Run in Conventional Line,” RTRI Report, Vol. 34, No. 9, pp. 11-16, 2020 (in Japanese) .