Future Vision of Railway EMS with "Serendie"

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Abstract

Mitsubishi Electric Corporation is leveraging its proprietary digital platform "Serendie" to advance comprehensive optimization of energy operations for railway systems by beginning with providing data analysis services, as well as introducing optimal placement and optimal control of railway operator assets, controlling train operations for multiple trainsets, and further integrating these initiatives to maximize their benefits. Data from railway systems will be analyzed and utilized in the future, and collaboration with communities along railway corridors will enable optimization of energy supply throughout the entire region. The deployment of this series of Railway Energy Management Solutions (EMS) will contribute to achieving carbon neutrality.

1. Introduction

Global warming is a major social issue which must be addressed urgently. Reports by the Intergovernmental Panel on Climate Change project serious impacts on the global environment into the future, such as extreme weather and rising sea levels, due to the increasing average temperature on the planet. Accordingly, the Paris Agreement adopted in 2015 established an international framework for measures to combat global warming, and efforts toward achieving carbon neutrality are accelerating worldwide.

In the energy sector, expanding the use of renewable energy sources such as photovoltaics (PV) and improving energy efficiency are key pillars. Initiatives are also underway in the railway industry toward achieving carbon neutrality, including the use of renewable energy and the introduction of eco-friendly rolling stock. To accelerate these efforts, it is also effective to utilize various operational data related to railways, such as operational information, and optimize energy use across the entire line by coordinating railway assets at electrical substations and railway stations with train operations (Fig. 1).

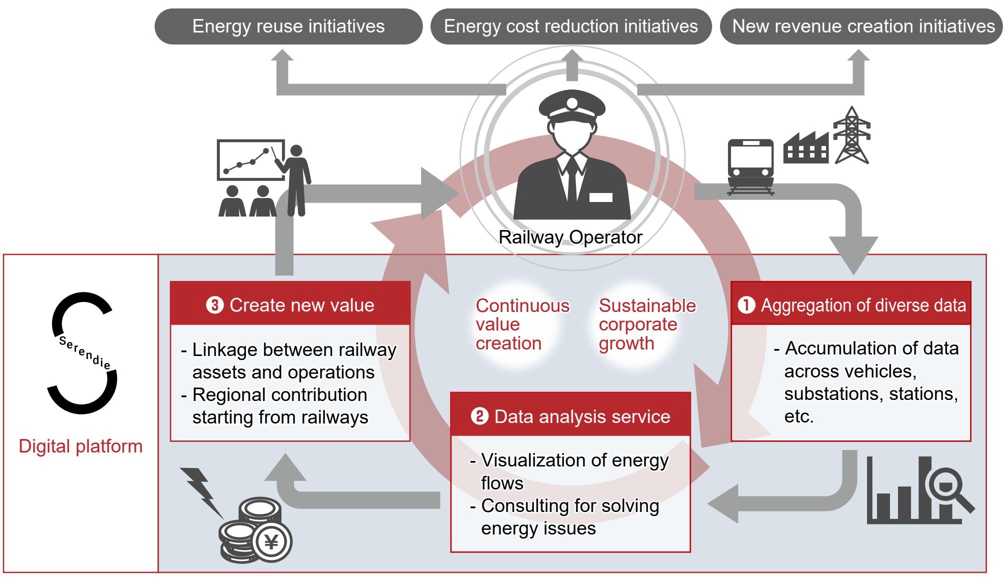


Fig. 1 System diagram of the Railway Data Analysis Service

This paper presents a vision for deploying solutions that contribute to energy optimization across all railway lines and to the optimization of communities along them, starting with data analytics services.

2. Data Analysis of Railway Systems Using Serendie

We have long been working on data analysis and optimization in the railway sector using rolling stock data. An example of this is optimizing the design of control equipment and control parameters using data acquired from rolling stock in operation—we have achieved energy savings such as improving the efficiency of onboard electrical equipment and increasing the amount of regenerative power generated during braking(1).

However, to further achieve carbon neutrality, conventional individual optimization has limitations, and optimizing energy operations across the entire railway system is desirable. Therefore, as the first step, we launched the “Railway Data Analysis Service,” which proposes overall optimization by rapidly analyzing operational data for railway systems (including rolling stock data, substation data, station power usage, and the status of train operations) using the digital platform Serendie (Fig. 2).

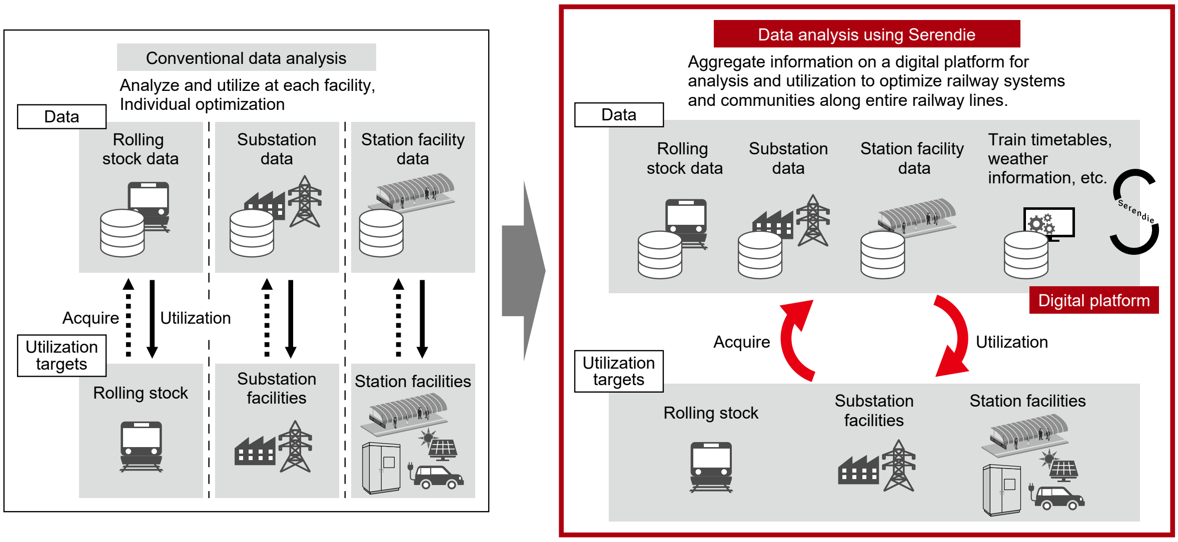


Fig. 2 Conceptual diagram of Railway Data Analysis Service with Serendie

The Railway Data Analysis Service enables analyses that contribute to optimization for the entire railway system; for example, by combining data from multiple rolling stock classes, it can quantitatively identify actual wasted energy across the entire power system. For issues specific to railway operators, the service is able to propose appropriate locations for railway assets such as station energy saving inverters (S-EIV), which are energy-saving equipment that absorb surplus regenerative electric power for use in the railway station, and to propose optimal operational methods for railway assets according to station congestion levels, train timetables, and operational status.

3. Optimization of Railway Systems

Utilizing data analysis, optimal placement and control of railway assets, as well as energy-efficient train operation, can significantly improve efficiency and further reduce the carbon footprint of a railway system.

3.1 Optimal placement of assets

To effectively utilize regenerative electric power, it is important to identify the locations of ground-based facilities and areas where surplus regenerative electric power is generated. To this end, we visualized surplus regenerative electric power using data. Figures 3 and 4 show examples of the analysis of surplus regenerative electric power. In Fig. 3 and 4, the surplus regenerative electric power being concentrated at Stations A and D can be confirmed visually. When surplus regenerative electric power is concentrated at specific points, the installation of ground-based energy-saving equipment at those locations can be effective. By implementing localized measures such as installing an S-EIV which transfers surplus regenerative electric power from rolling stock to ground facilities, and installing energy storage systems that absorb and reuse surplus regenerative electric power, improvements in power consumption can be expected.

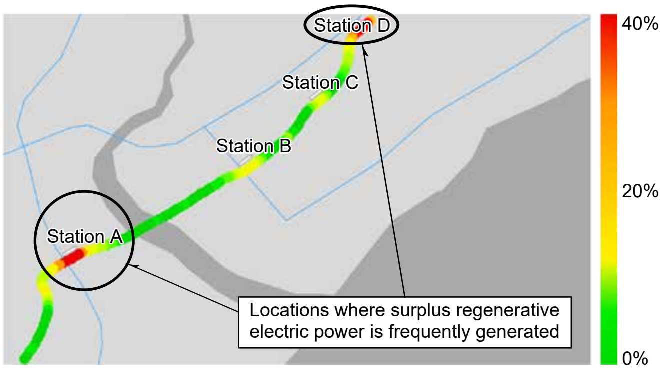
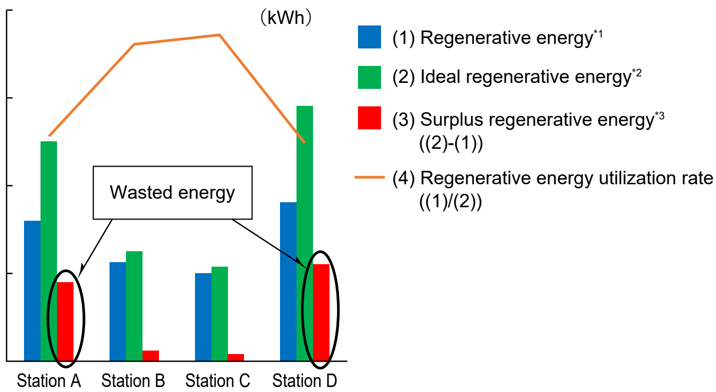


Fig. 3 Geographic mapping of surplus regenerative electric power



*1 Indicates the amount of regenerative electric power that was actually made available to other rolling stock, etc.
*2 Regenerative energy in the case where all braking energy could be converted into electric power
*3 Regenerative energy that is converted into thermal energy by air brakes, etc., and is not being effectively utilized

Fig. 4 Analytical schematic of regenerative energy

3.2 Feeder voltage control for substations

As a further energy-saving measure using existing facilities, we are currently advancing studies on optimal feeder voltage control.

In general, railway traffic density varies depending on the time of day, such as peak and off-peak service schedules. Train density is low during off-peak hours, and regenerative electric power returned to the overhead line during braking cannot be sufficiently shared among powered rolling stock, resulting in frequent regenerative power suppression that limits regenerative electric power output. Because the supply distance of regenerative electric power becomes longer as feeder voltage decreases, lowering the substation feeder voltage is expected to further increase the amount of regenerative power made available. On the other hand, train density is high during rush hours, so regenerative electric power is shared between rolling stock and regenerative power suppression decreases. In such situations, setting the substation feeder voltage higher can reduce losses in substations and overhead lines, and improve the efficiency of onboard traction inverters and motors.

Therefore, it is effective to adjust and optimize the substation feeder voltage by time of day as shown in Fig. 5. However, current substation facilities are not designed on the premise of changing feeder voltage by time of day, and they output feeder voltage at a fixed voltage ratio relative to the receiving voltage throughout the day. In addition, given that the facility capacity, number of units, and supply distance differ by substation, it is ideal to identify and apply the optimal feeder voltage for each substation.

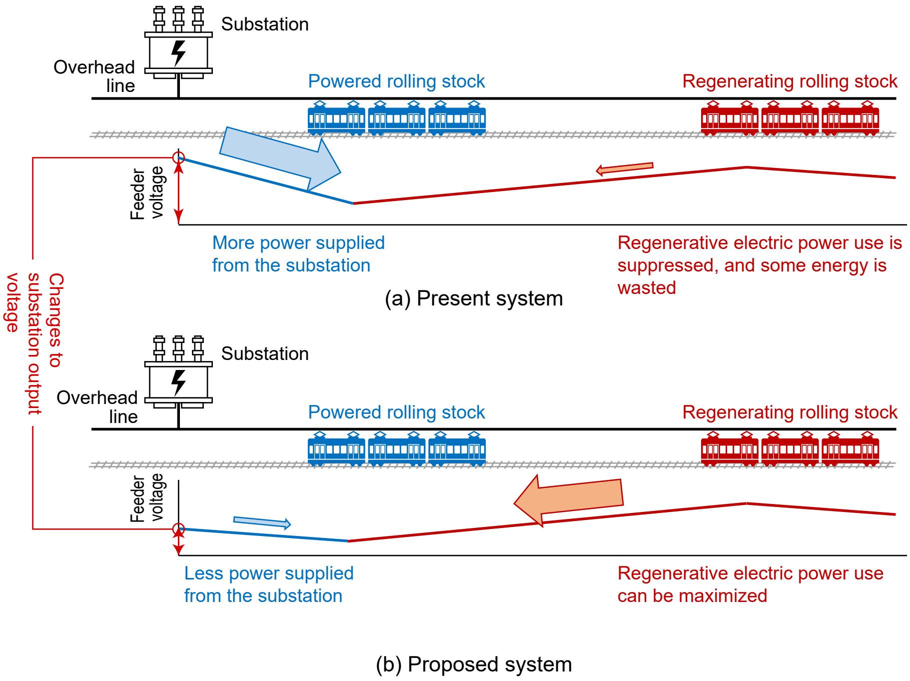


Fig. 5 Optimization of feeder voltage control

To achieve these operations, we devised the "Optimal Feeder Voltage Control Architecture" shown in Fig. 6.

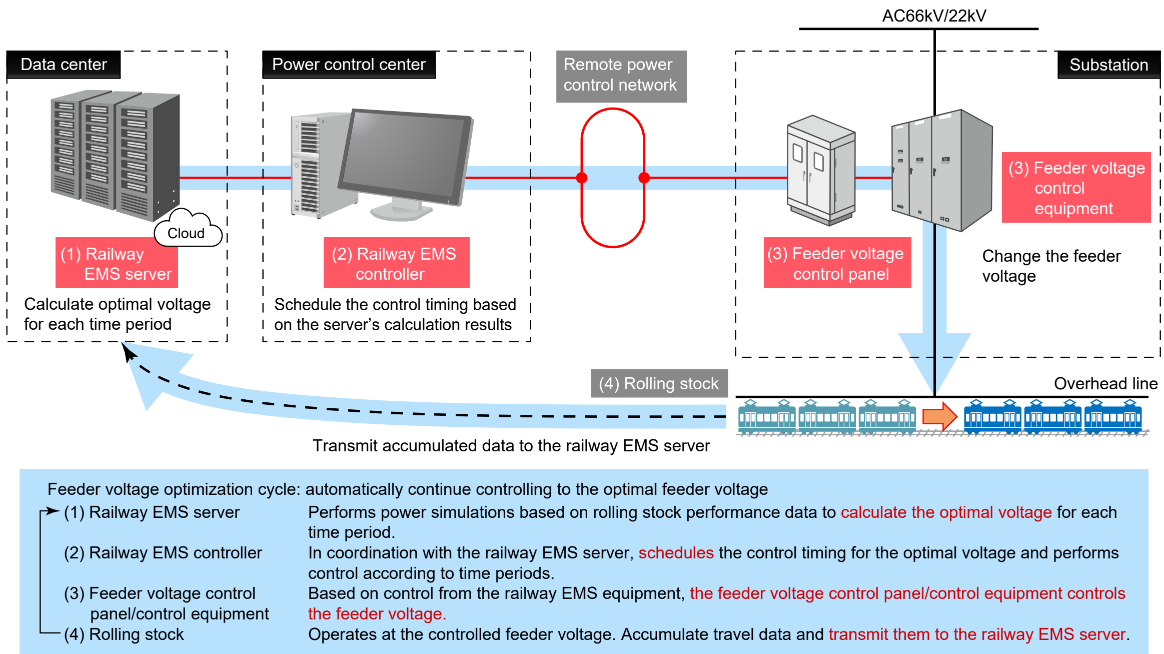
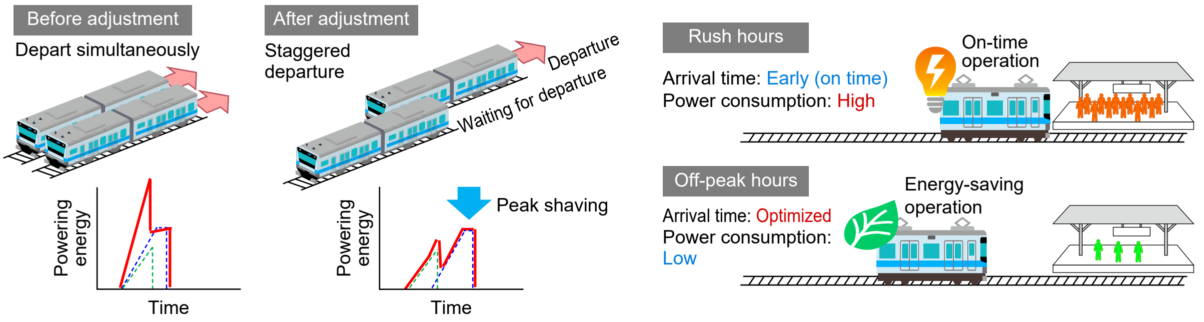


Fig. 6 Example of the optimal feeder voltage control architecture and optimization cycle

This architecture enables calculation and control of optimal feeder voltage for each time period, promoting effective use of surplus regenerative electric power. This achieves a balance between minimizing energy used for railway operations and reducing electricity charges, contributing to achieving carbon neutrality. We are currently building our proprietary feeder voltage optimization algorithm and are working to calculate the optimal voltage more efficiently.

3.3 Energy-efficient train operation control

In the past, we worked on energy-saving measures for individual trainsets, such as studying energy-saving run curves; however, we are currently also advancing efforts to develop energy-saving solutions based on overall optimization that takes into account operation control for multiple trainsets. For example, we are studying powering timing adjustment control to suppress the voltage drops in overhead lines, as well as arrival time adjustment control based on congestion level, which are shown in Fig. 7.



(a) Powering timing adjustment control

(b) Arrival time adjustment control based on congestion level

Fig. 7 Energy-efficient train operation control

For powering timing adjustment control, the timetable is adjusted to minimize or eliminate overlapping powering activities by multiple trainsets within each substation section. As a result, given that the current flowing through overhead lines can be leveled and peak current can be suppressed, transmission losses in overhead lines can be reduced. This also suppresses any decreases in the efficiency of onboard equipment and acceleration performance due to voltage drops, contributing to energy savings.

For arrival time adjustment control based on congestion level, whether to adopt energy-saving-priority operation or operation according to the timetable is determined within a range that does not impair passenger convenience. For example, in time periods and sections with fewer passengers, there is sufficient margin in boarding and alighting times at stations, so a run curve with even greater energy savings is adopted to reduce energy consumption.

In this way, we are advancing initiatives that add an energy-reduction perspective to train operations.

4. Energy Optimization for the Entire Railway Business

Combining all solutions described above – using data to select the most efficient solutions for each location – our vision is to achieve both overall power optimization for the entire railway (as shown in Fig. 8) and operation optimization which also leads to improved passenger convenience.

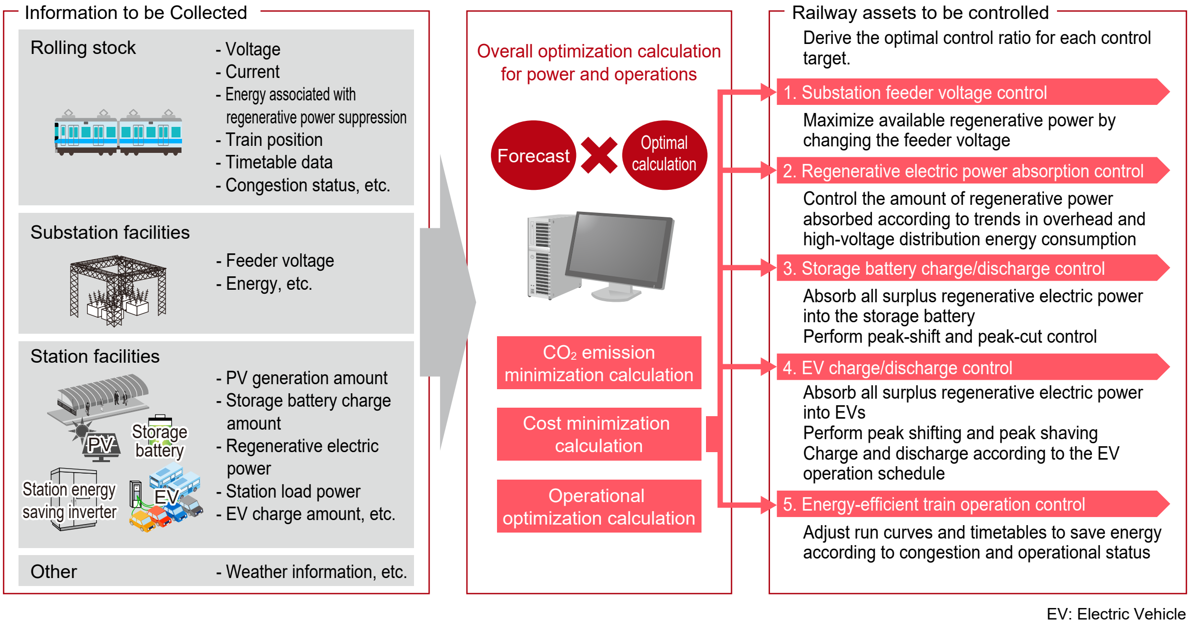


Fig. 8 Energy optimization for the entire railway business

From a medium-term perspective of several years, operation plans and the associated power demand change due to factors such as the introduction of new rolling stock and changes in passenger flow due to urban development. From a short-term perspective of about one year, operation plans and power demand also fluctuate due to timetable revisions, weather conditions, and various special events. To respond to these changes while maintaining passenger convenience, simulations are conducted to optimize power use by utilizing data on rolling stock, substations, stations, weather, and other factors.

In this way, we are aiming to establish simulation technology that achieves overall optimization by combining individual energy-saving solutions.

5. Future Outlook

In the future, as shown in Fig. 9, we aim to achieve further energy optimization through rail-based initiatives in collaboration with communities along the railway network. For example, the development of station-centered microgrids in communities along railway lines will enable energy optimization beyond the railway sector. In addition, leveraging railway assets during emergencies such as large-scale disasters enables the supply of emergency power to communities along railway lines, strengthening power resilience and increasing the value of the railway corridor. Furthermore, given the high level of power consumption in the railway business domain, suppressing railway power demand as needed and using railway assets as adjustment resources makes it possible to respond to power shortages in the electricity market. Through these initiatives, we aim for energy optimization beyond the railway business domain.

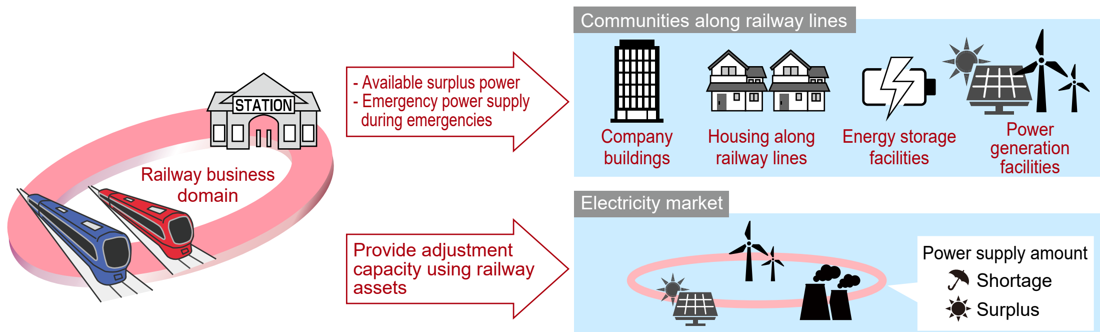


Fig. 9 Collaboration with non-railway business domains

6. Conclusion

Preventing global warming is an important issue in achieving a sustainable society, and efforts to achieve carbon neutrality are underway worldwide. This paper outlined our specific solutions for decarbonization, starting with data analysis using the digital platform Serendie.

Going forward, we will contribute to further accelerating the achievement of carbon neutrality by applying insights gained through various solutions to new solutions and by working to develop solutions in collaboration with various business domains beyond the railway domain.

Reference

(1) Ubukata, N., et al.: Initiatives Toward Energy-saving Optimal Rolling Stock Systems, Railway Cybernetics Symposium Papers, No. 48, 503 (2012)