3. Infrastructure Systems

3.1 Multi-Power Conditioner Enabling Use of Vehicle Batteries as Distributed Power Sources

Multi-power conditioner (left) and electrified vehicle charging station (right)

As part of its goal to achieve carbon neutrality by 2050, the Japanese government has set a goal of having electrified vehicles (xEV) account for 100% of new car sales by 2035.

With this in mind, Toshiba Infrastructure Systems & Solutions Corporation has commercialized a multi-power conditioner compatible with vehicle-to-everything (V2X) communication, which uses DC to connect an xEV charging station to a non-V2X-compatible system composed of a stationary battery and solar panels. The multi-power conditioner is so called because it consolidates multiple power conditioners into a single enclosure based on required functions.

The multi-power conditioner can export electricity from the vehicle battery to buildings through an xEV charging station and is thus expected to be utilized for peak shaving and in the event of power failure.

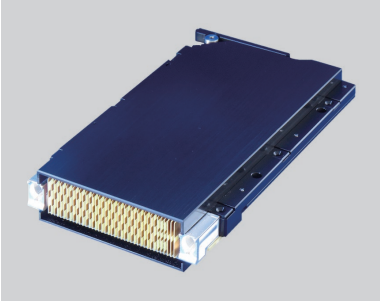
Furthermore, the multi-power conditioner connects a stationary battery, solar panels, and an xEV charging station via DC, improving energy conversion efficiency by approximately 13.7% in comparison with AC(*).

We will leverage the multi-power conditioner to promote the use of xEVs as distributed power sources and thereby contribute to the goal of carbon neutrality.

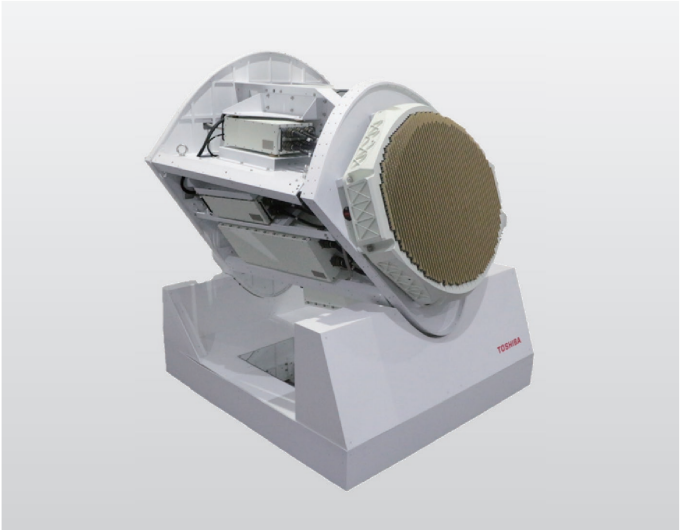
(*) When electricity generated by a solar panel is stored in a stationary battery and then transferred from a stationary battery to an xEV

3.2 Compact Digital Active Electronically Scanned Array for Next-Generation Airborne Radar

X-band array unit



Digital conversion unit



Digital AESA for next-generation airborne radar (actual-size model)

Toshiba Infrastructure Systems & Solutions Corporation has developed an active electronically scanned array (AESA) incorporating high-speed digital technology for next-generation airborne radar systems. Although digitally processing a large amount of data significantly improves AESA performance, the resulting increase in components makes it necessary to reduce the AESA size considerably for practical applications. We therefore reduced the size of two digital AESA main units by leveraging cutting-edge civilian technologies:

(1) X-band array unit(*)

We implemented frequency conversion circuits as a standalone chip using internal semiconductor manufacturing processes, reducing the size of the X-band array unit to less than one-fourth of the conventional unit.

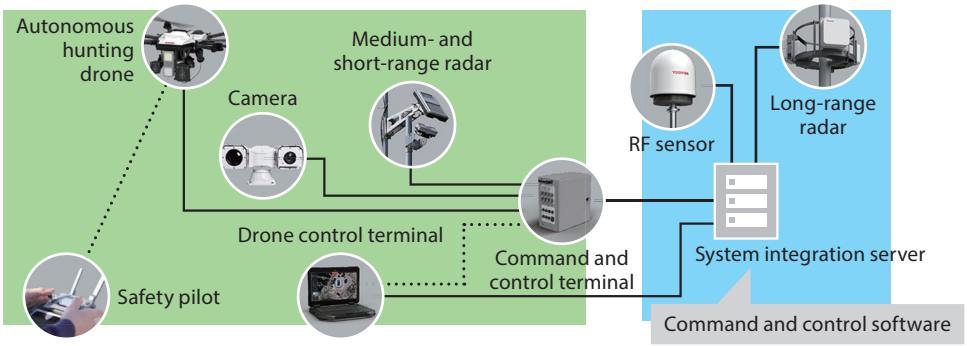
(2) Digital conversion unit

We increased the high-speed digital conversion IC mounting density to reduce the size of the digital conversion unit to less than one-tenth of the conventional unit.

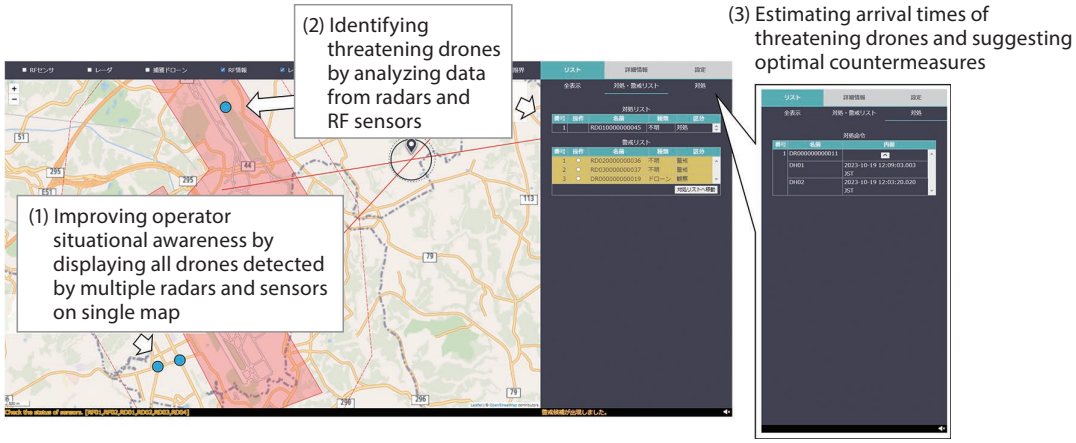
We also created an actual-size model of an airborne radar system using these units and verified its effectiveness. As a next step, we will leverage these achievements to contribute to the enhancement of critical infrastructure responsible for Japan's national security.

(*) An X-band array unit integrates multiple antenna elements and is capable of both transmitting and receiving radio signals.

3.3 Counter-Unmanned Aerial System



Overview of C-UAS solutions



Situational awareness image from integrated system software

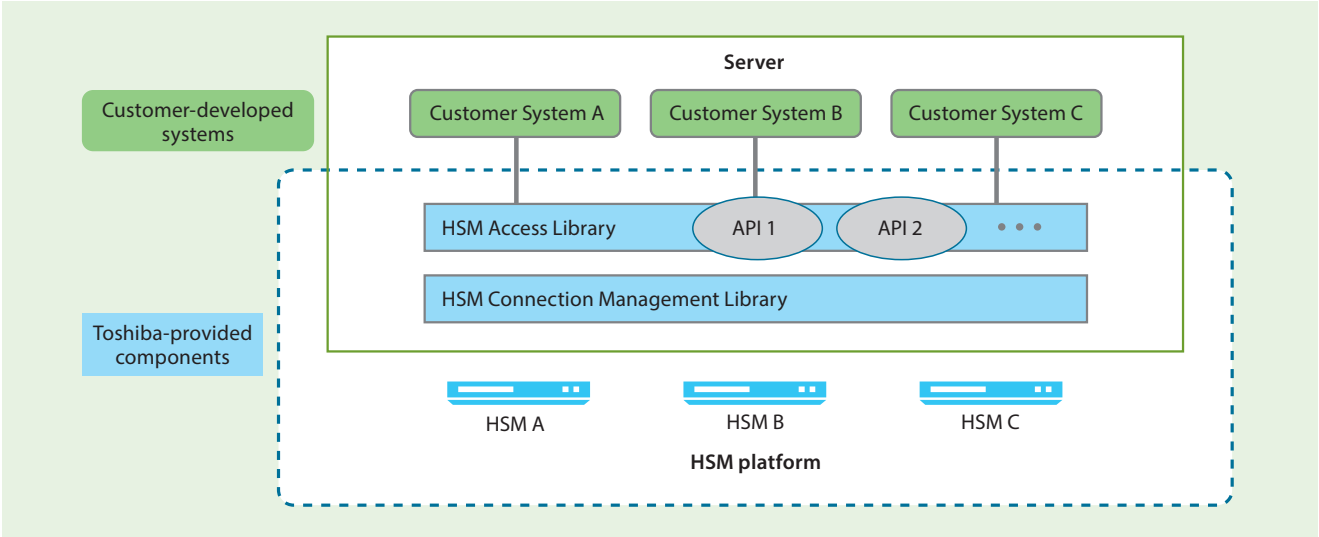
In recent years, the use of drones for logistics and infrastructure inspections has increased, however, the growing threat of illegal drones underscores the importance of counter-unmanned aerial systems (C-UAS).

In FY2023, Toshiba Infrastructure Systems & Solutions Corporation developed radars and radio frequency (RF) sensors to detect radio waves emitted by drones. We have developed new integrated system software, which uses data acquired by radars and RF sensors, to display a map showing the positions of drones and other information. The integrated system software incorporates a specialized algorithm with functions to (1) improve the situational awareness of operators by displaying data from all radars and RF sensors on a single map, (2) identify threatening drones by analyzing the data, and (3) estimate arrival times and suggest optimal countermeasures.

Combined with the radars and RF sensors, these functions provide a new counter-UAS solution which we will sell to customers around the world.

Next, we will link this system to unmanned aircraft system traffic management (UTM) systems and various sensors to enable even more accurate situational awareness and safer countermeasures.

3.4 HSM Platform to Ensure Cybersecurity for IoT and DX Advancement



HSM platform system configuration

As the Internet of Things (IoT) and digital transformation (DX) advance, cybersecurity is attracting more attention. Secure key generation and management are the cornerstone of cybersecurity, necessitating a hardware security module (HSM), a tamper-resistant(*) hardware device that securely stores cryptographic keys used for encryption and digital signatures.

There is increasing demand in various industries for HSMs compliant with the U.S. Federal Information Processing Standard (FIPS) 140, particularly for verifying encryption modules during system development. However, because interface specifications HSM security features are complicated, customers often find it difficult to select the right HSM and understand its specifications, incurring extra costs.

With this in mind, drawing on our experience in system development using multiple HSMs, Toshiba Infrastructure Systems & Solutions Corporation has developed an HSM platform that simplifies optimal HSM selection and development. It consists of the following three components:

(1) HSM Access Library: This library serves as an interface for higher-level applications, allowing commands to be issued to the HSM without requiring in-depth knowledge of HSM specifications.

(2) HSM Connection Management Library: This library accommodates differences in HSM specifications, enabling the execution of HSM access operations.

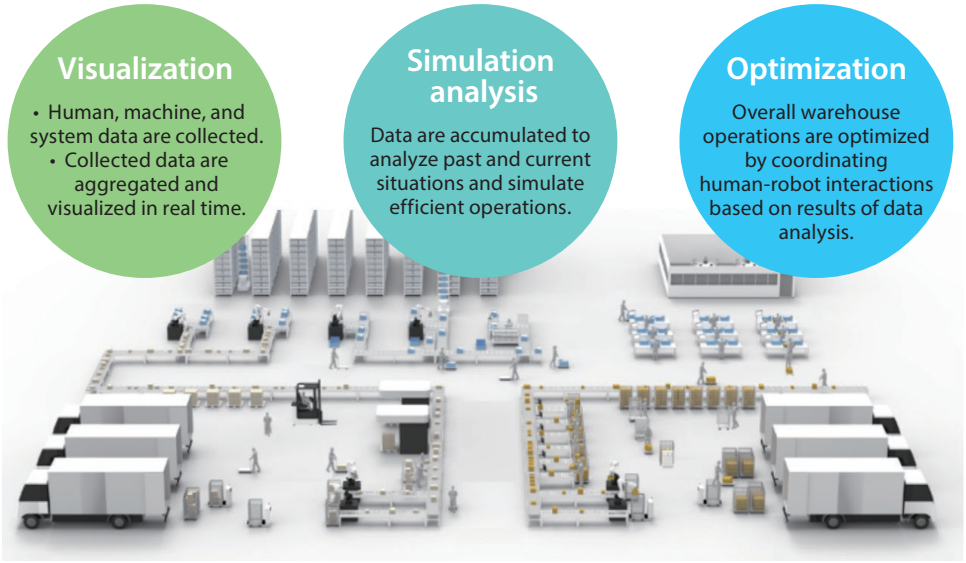
(3) Multiple HSMs: The HSM platform supports various types of HSMs.

This platform allows customers to choose the optimal HSM according to their system requirements and reduce development costs.

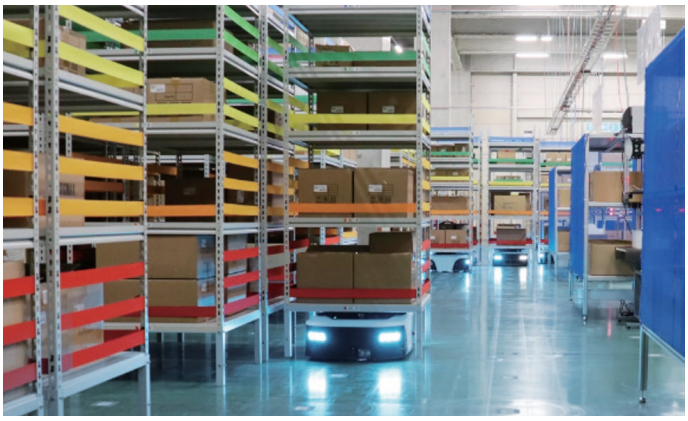
Next, we will enhance the HSM platform and apply it to various commercial systems and services to support social infrastructure cybersecurity.

(*) Inherently resistant to unauthorized attempts to analyze, read, or modify the internal structure, data processing mechanisms, or stored data from external sources

3.5 Warehouse Execution System to Improve Efficiency of Logistics Operations



WES functions



Autonomous mobile robots for warehouse operations

Facing escalating labor shortages, the logistics industry is using automation to improve warehouse operational efficiency. It is difficult, however, for automated robots to handle all warehouse tasks, so manual labor is still necessary. To help resolve this, Toshiba Infrastructure Systems & Solutions Corporation has developed a warehouse execution system (WES) which coordinates human actions with autonomous mobile robots to improve the efficiency of outbound delivery work that accounts for more than 50% of the workload in a warehouse. The new WES provides an optimization function to reduce the workload by consolidating the delivery of the same goods while rearranging the order of outbound goods to meet delivery deadlines.

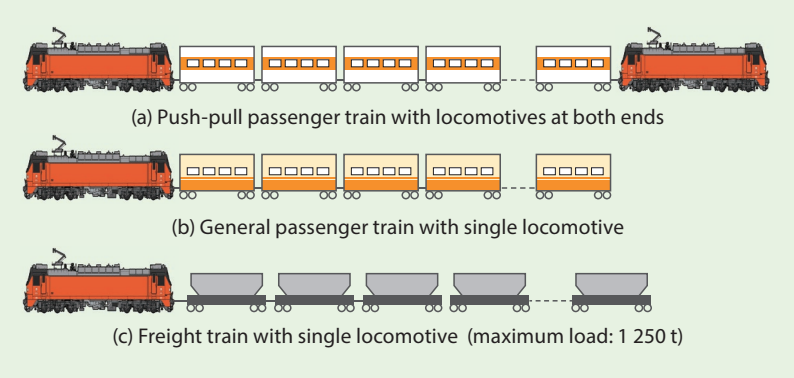
3. Infrastructure Systems

Goods that are difficult to handle for autonomous mobile robots are handled manually. The new WES predicts the daily workload based on the analysis of past delivery records and visualizes the progress of the delivery work. We have also developed a function to assist personnel from other work groups when it is difficult to meet deadlines.

We will continue to expand the functions for human-robot interactions to further improve the efficiency of warehouse operations.

3.6 First Delivery of E500 Electric Locomotive to Taiwan

E500 electric locomotive



Various train formations supported by E500

Toshiba Infrastructure Systems & Solutions Corporation received an order for 68 E500 electric locomotives from the Taiwan Railway Administration in October 2019 and made the first delivery in August 2023. The Taiwan Railway Administration will replace all the aging E200, E300, E400, and E1000 electric locomotives manufactured in the 1970s to 1990s with the E500 to avoid the complex task of operating multiple types of locomotives.

While leveraging our vehicle system technologies, we employed a modular locomotive design platform for developing the E500 as doing so allows flexible customization and excellent maintainability required for long-term operation. The most notable feature of the E500 is that it provides all the functions and performance available with the electric locomotives currently operated by the Taiwan Railway Administration. With all functions integrated into a single locomotive, the E500 will considerably improve operability and maintainability. In addition, we applied our size reduction technology to improve the performance of various functions and devices without increasing the vehicle size.

The main features of the E500 are as follows. The first, third, and fifth features improve maintainability whereas the first, second, and fourth features improve operability.

(1) The E500 can be connected to both passenger and freight cars currently in operation.
(2) The high-output and highly redundant main circuit, and the auxiliary power supply system provide excellent reliability. The auxiliary power supply system has four converters per locomotive, so even if one fails, another serves as a backup to allow the train to continue operating without any reduction in performance.
(3) With the electric equipment and vehicle body subdivided into modules, they can be replaced quickly during inspection and maintenance.
(4) In addition to the conventional traction force command, the E500 can send speed control commands from the master controller. A holding brake provides improved operability for starting on an uphill slope, which otherwise requires considerable operating skill.
(5) Regenerative and electro-pneumatic blended braking provides improved energy efficiency and helps to reduce brake shoe wear.
(6) The E500 is compliant with the EN45545 European railway fire safety standards.
(7) The E500 combines sufficient cooling performance and noise reduction. The E500 reduces the rotation speeds of the noisy motor blower and cooling tower when it is not running.

3.7 Establishment of Method for Upgrading Taiwan High Speed Rail Control and Relay Panels

New control and relay panel for Taiwan High Speed Rail

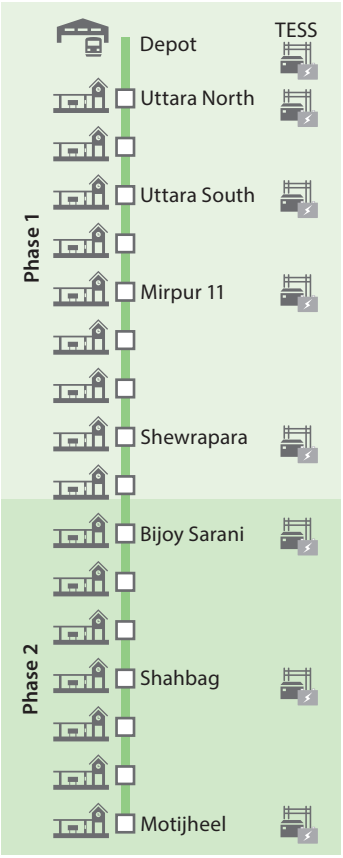
The Taiwan High Speed Rail (THSR) commenced commercial service in 2007 between Taipei and Kaohsiung, and has been in operation for more than 15 years. The electronic components of control and relay panels (CRPs) are reaching the end of their life cycle, so Toshiba Infrastructure Systems & Solutions Corporation is currently replacing the CRPs at all 30 electrical posts with new ones.

The CRPs, which are essential to protecting and controlling power supply facilities, must be upgraded without affecting the commercial operation of the THSR, so we modify the existing system and test the new CRPs while trains are not in service and bring the existing CRPs back online before service resumes.

The challenge is to finish the changeover promptly to ensure sufficient work time. Because this project will last for years to come, we have established a method to solve this challenge first. Specifically, we have prepared (1) a dedicated panel to reduce the time required for changeover and (2) a supervisory control and data acquisition (SCADA) system for testing purposes in the operation control center to minimize the impact on existing system and facilitate testing.

We completed CRP upgrades at SSP7, the first site, in September 2023 as planned.

3.8 Delivery of TESS for Dhaka MRT Line 6



Dhaka MRT Line 6 Substations

TESS Installed at Line 6 substations

The Dhaka MRT Line 6 is Bangladesh's first electrified mass rapid transit (MRT) line, running on elevated tracks in a north-south direction in Dhaka City. It spans 16 stations and eight substations over approximately 20 kilometers.

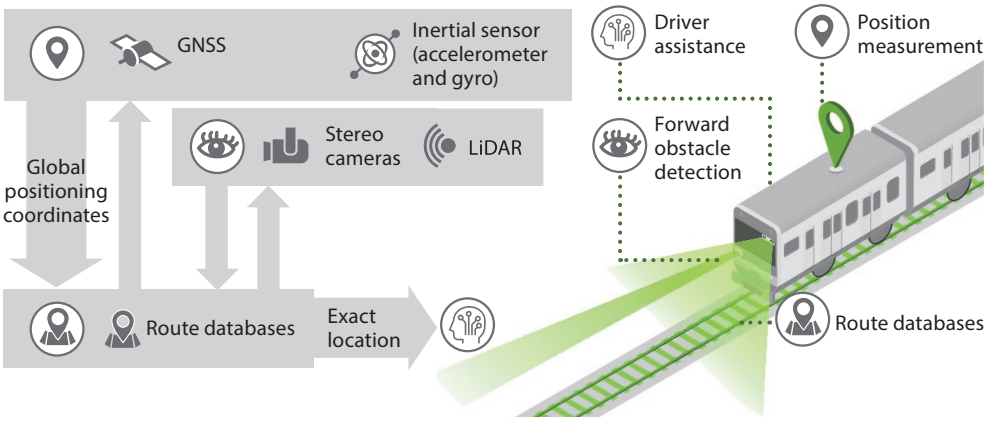
The MRT Line 6 project consisted of two phases. Toshiba Infrastructure Systems & Solutions Corporation delivered a total of eight sets of traction energy storage systems (TESS), one at each of the substations on the MRT Line 6 (2 MW–546 kWh×7 sets, 500 kW–137 kWh×1 set): five sets for the first phase of the line and three sets for the second phase. The entire line was inaugurated in November 2023.

TESS stores energy regenerated during braking and feeds it back into the traction power supply when a train accelerates. In addition to saving energy and preventing regenerative braking loss, TESS allows trains stranded between stations due to a power failure to travel to the nearest station. With eight sets of TESS, all trains along the entire line can now reach the nearest station in the event of a power failure.

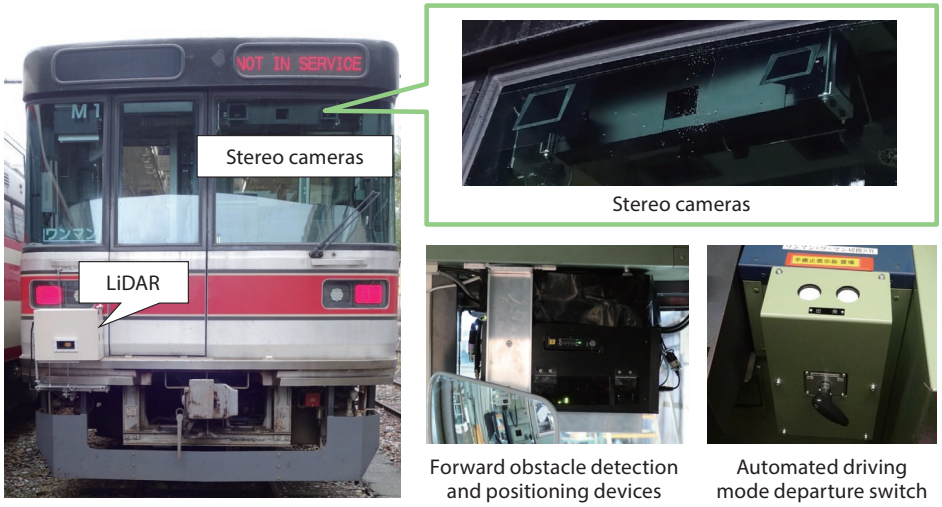
The deployment of TESS facilities on the MRT Line 6 is our first overseas TESS project to meet the requirements of relevant international standards, including the IEC 61850 communication protocol. We leveraged IoT devices to provide timely support remotely from Japan and train local field engineers to ensure effective maintenance of the TESS.

The MRT Line-6 accommodates the growing population and alleviates traffic congestion and air pollution in Dhaka City, contributing to socio-economic development.

3.9 Development of Key Devices for Advanced Autonomous Train Operation and Test Vehicle Trial Runs



Overview of advanced autonomous train operation system



Devices installed on test vehicle

The railway industry faces a shortage of train drivers and maintenance workers combined with a diminishing number of passengers, necessitating further improvements to operational efficiency. To address this issue, the Toshiba Infrastructure Systems & Solutions Corporation is developing railway technologies and equipment essential to autonomous train operation on ordinary rail lines, including forward obstacle detection, position measurement, and driver assistance devices.

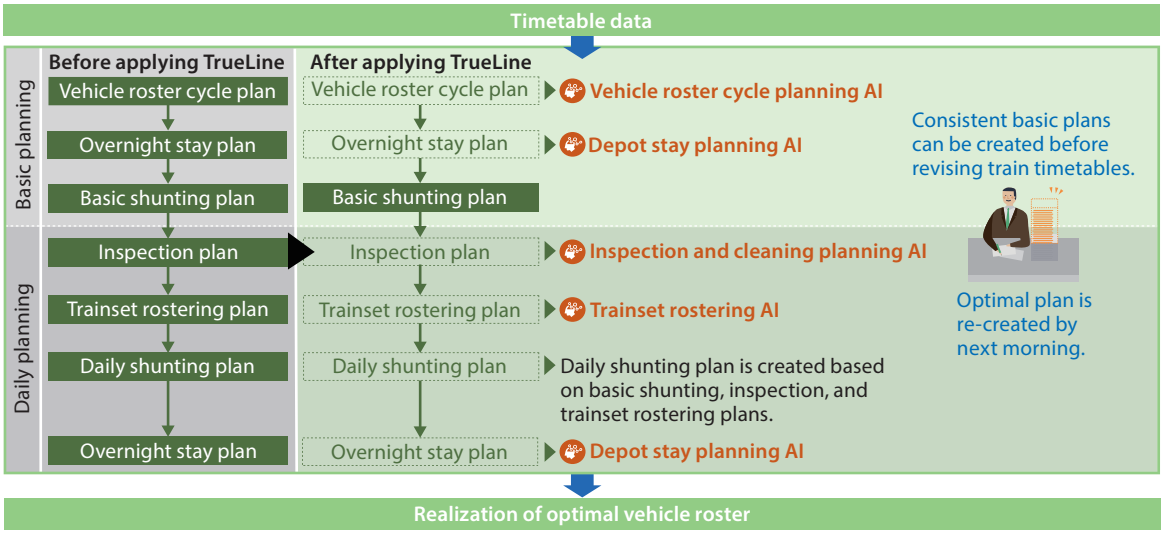
The forward obstacle detection device integrates stereo cameras and light detection and ranging (LiDAR) sensors to detect people on the track up to 300 meters away even at nighttime. The position measurement device provides positioning accuracy of ±0.5 meters or better using a global navigation satellite system (GNSS) and inertial sensors. The driver assistance device utilizes route databases, forward obstacle detection information, and position data for autonomous driving control.

We collaborated with Nagano Electric Railway Co., Ltd. to conduct field tests using commercial vehicles incorporating the above devices and carried out trial runs of autonomous vehicles to verify basic operations.

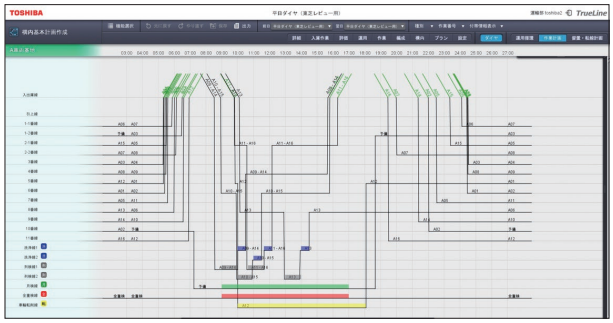
We will continue to improve railway operation efficiency and achieve practical application of the advanced autonomous train operation system.

This project is subsidized by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan.

3.10 AI-Based Vehicle Roster Planning Enhancement and Practical Application



Vehicle roster planning process employing AI-based TrueLine



Example of depot work scheduler display

In collaboration with Toshiba Infrastructure Systems & Solutions Corporation and Toshiba Digital Solutions Corporation, Toshiba Corporation developed the TrueLine vehicle roster planning solution consisting of three artificial intelligence (AI) components: vehicle roster planning AI, inspection planning AI, and trainset roster planning AI. We have now added depot stay planning AI to the latest release of TrueLine to facilitate depot operations. In addition, we have developed a shunting planning function that connects seamlessly with the depot stay planning AI, enabling automatic creation of daily depot timetables.

TrueLine allows railway operators to digitize timetable data and other assets to achieve optimal vehicle operation. It has been used by railway operators since April 2023, contributing to a significant improvement in vehicle operations, even in the event of accidents. The inspection, vehicle rostering, and depot stay plans proposed by TrueLine have proven effective for daily operations as well as for re-planning and rapid recovery following accidents.

3.11 FA2100TX and FR2100TX Industrial Computers

FA2100TX model 700

FR2100TX model 700

Item	FA2100TX model 700	FR2100TX model 700
CPU	Intel® Xeon® W-1270TE processor	
Main memory	8 GiB min. (8 GiB×1), 32 GiB max. (16 GiB×2) (DDR4-2933 SDRAM/PC4-23400)	
Storage	Single-disk model (Up to two units) HDD: 4 TB SSD: 128 GB, 512 GB	
	Mirroring disk model (two units with same type and capacity) HDD: 4 TB, 512 GB SSD: 160 GB, 400 GB	
Interface	LAN×4, USB (5 Gbits/s)×6, LINE OUT×1, VGA×1, DisplayPort×1, RS-232C (9-pin D-sub)×2, DI (Digital Input) / DO (Digital Output)×1	
Dimensions	100 (W)×310 (H)×340 (D) (mm)	430 (W)×87 (H)×450 (D) (mm) Mountable on JIS/EIA-standard racks
Expansion slot	PCI Express: 2 slots PCI (32-bit, 5 V): 1 slot	PCI Express: 2 slots PCI (32-bit, 5 V): 2 slots

Gi: gibi (2^{30}) DDR: double data rate SDRAM: synchronous dynamic random-access memory
HDD: hard disk drive SSD: solid-state drive T: tera (10^{12})
VGA: Video Graphics Array D-sub: D-subminiature JIS: Japanese Industrial Standards
EIA: Electronic Industries Alliance PCI: Peripheral Component Interconnect

FA2100TX/FR2100TX main specifications

Toshiba Infrastructure Systems & Solutions Corporation has developed two industrial computers for edge computing applications: the slim FA2100TX model 700 and 2U rack-mount FR2100TX model 700.

Edge computers collect and process a wide variety of data near factory equipment running in harsh environments. While delivering industrial-grade reliability, both models incorporate a new platform and large-capacity memory and storage to provide higher performance than previous models.

There are now four LAN ports compared to three on the previous models, and all six USB ports support 5 Gbps transmission speed. This configuration allows the new models to connect to various modern devices.

They also support legacy interfaces such as Peripheral Component Interconnect (PCI) and RS-232C, allowing continued use of legacy devices that have been in use for a long time. This means that all devices, new and old, can be connected to the same network through the new models. In today's factories, a variety of new and old devices operate together, and the new models are well suited to such factories to enable device connection and data utilization through edge computing. Compatible with the previous models in terms of size, the new models are also suitable as replacements to upgrade factory operations.

Intel and Xeon are trademarks of Intel Corporation in the United States and/or other countries.

3.12 Unified Controller Vm Series TypeL Combining Controller and Computing Functions

Unified Controller Vm series typeL

Toshiba Infrastructure Systems & Solutions Corporation has developed the Unified Controller Vm series typeL as a successor to the nv series type2, an industrial distributed control system (DCS) controller for petrochemical, steel, and other plants.

To reduce the amount of communication between control equipment and a host system on the cloud, we have been using edge computing, which brings plant equipment data to industrial computers for storage and analysis at the edge of a network.

To further reduce data traffic, the typeL is equipped with a computing function capable of running applications on a Linux® container or Windows, in addition to the controller function of conventional models. Therefore, the typeL provides both control and advanced data analysis capabilities. In addition, the typeL offers double the performance (i.e., reduced scan time) and tag points of conventional models, making it suitable for large plant systems.

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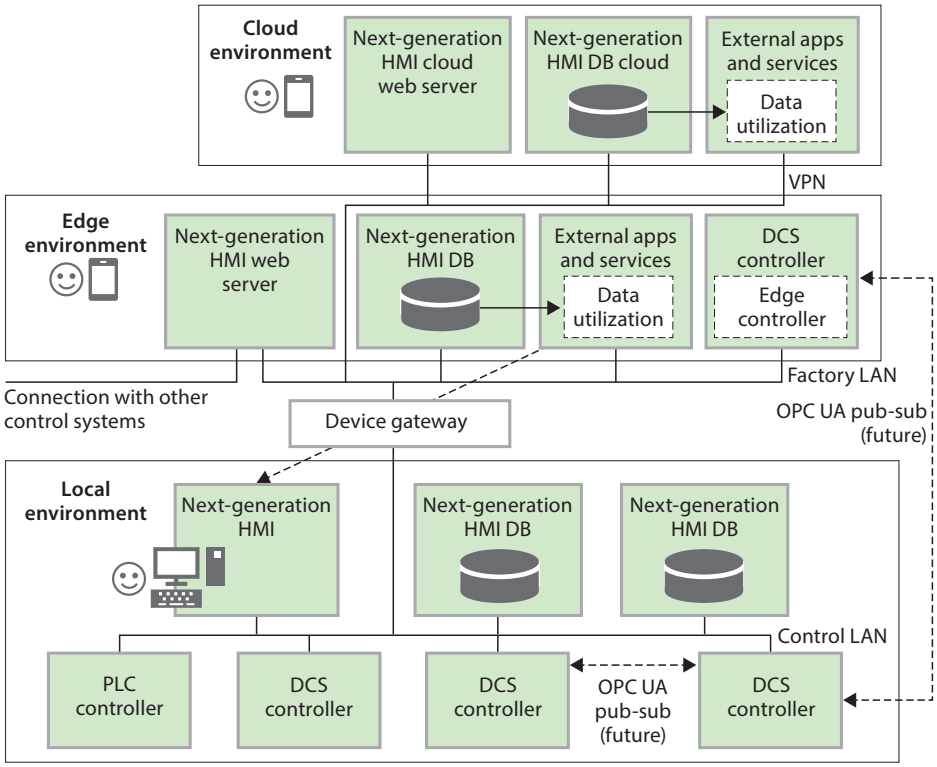
3.13 Next-Generation HMI Providing Enhanced Expandability Through Web Applications



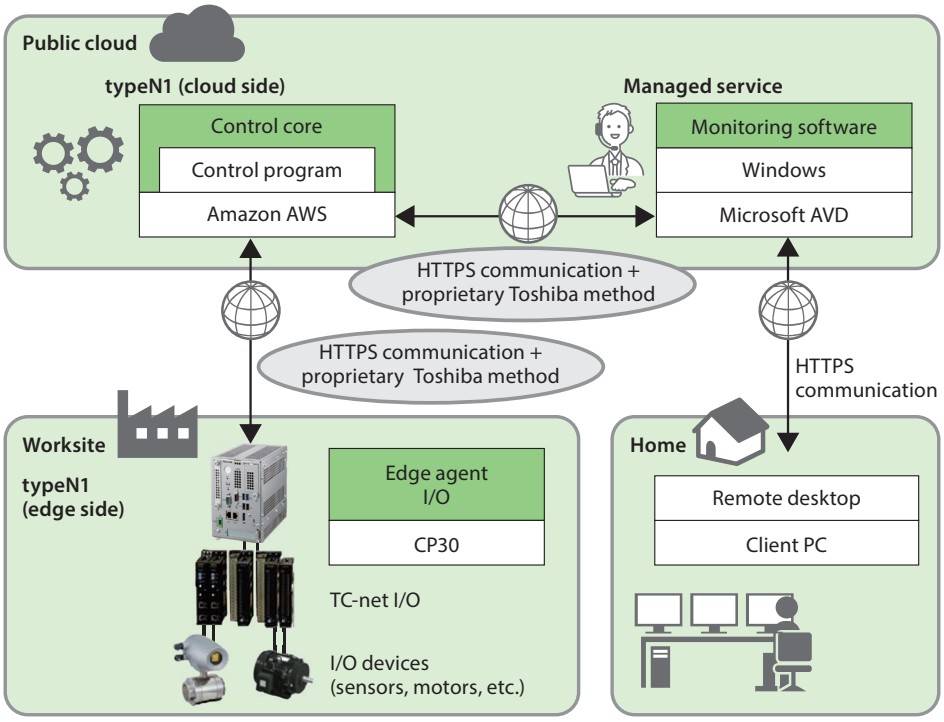
DB: database
VPN: virtual private network
OPC UA: Open Platform Communications Unified Architecture
pub-sub: publish-subscribe model
PLC: programmable logic controller
apps: applications
DB: database

Example of monitoring and control system configuration including next-generation HMI

DCS provide a human-machine interface (HMI) for monitoring and remote operation. To promote DCS DX, demand is growing for on-site and off-site monitoring and remote operation capabilities. It is therefore necessary to provide expandability to support digitalization while inheriting the functions of conventional HMIs.

To achieve this, Toshiba Infrastructure Systems & Solutions Corporation has developed TOSDIC VS (OI-VS10, OI-VS20, and VS-Developer), a next-generation HMI. To allow distributed deployment in various environments, TOSDIC VS incorporates Winter Cardinal, our original Web application framework. In addition, TOSDIC VS uses PostgreSQL, an open-source software (OSS) database management system, to enhance data management and failure recovery functions. Using the database log transfer function enables HMI redundancy. While inheriting the functions of the conventional HMI, TOSDIC VS is expandable to accommodate digitalization and thus will contribute to DCS DX.

3.14 Development of Instrumentation Component Virtualization Platform to Promote Operational Technology and Information Technology Integration



AVD: Azure Virtual Desktop
HTTP: Hypertext Transfer Protocol Secure

typeN1 configuration

Accompanying accelerating DX efforts in the manufacturing industry, demand continues to grow for a solution to consolidate data collected by control equipment into upper-layer applications for control functionality visualization and improvement. This has resulted in rapid advancements in integrating operational technology (OT) and information technology (IT).

In response to this demand and the shift to cloud computing, Toshiba Infrastructure Systems & Solutions Corporation has developed the typeN1 control core for the Meister Controller Cloud instrumentation component virtualization platform that provides OT-IT integration service using cloud computing technology. The typeN1 is a software-defined control core running on Amazon Web Services (AWS) which repeatedly executes a control program and is provided as software as a service (SaaS). The typeN1 allows input/output (I/O) at a worksite to be controlled from a cloud system, facilitating the use of cloud data for IT services. The typeN1 bridges OT and IT, contributing to promoting DX.

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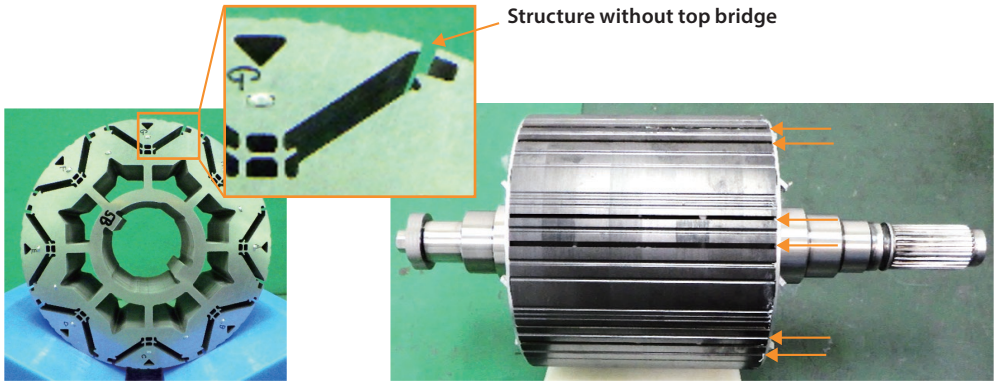
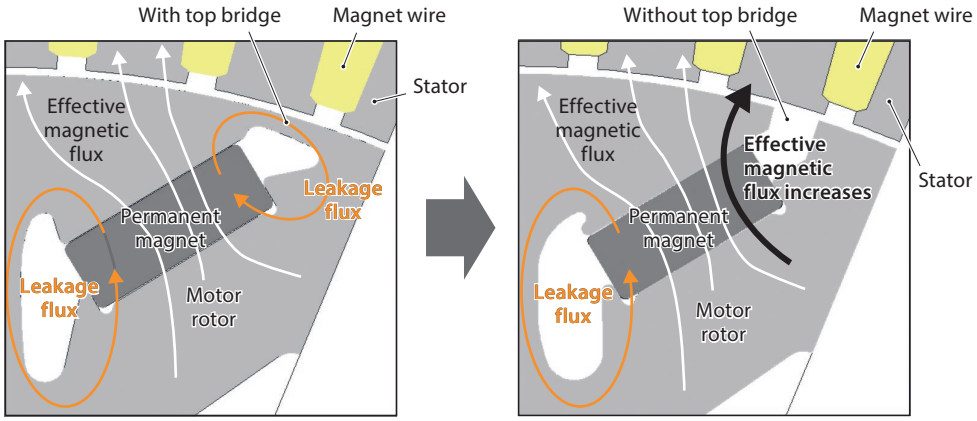
3.15 EV and HEV Motors Achieving Approximately 30% Reduction in Amount of Magnets Containing Rare-Earth Metals



Motor rotor
(iron core)

Motor rotor
(assembled with iron core and other parts)

New motor rotor without top bridge



Conventional motor rotor

New motor rotor

Increase in effective magnetic flux resulting from top-bridgeless structure

Neodymium magnets containing rare-earth metals are used extensively in electrified vehicle(*) motors to reduce size and weight and achieve high torque performance. However, rare-earth metals are scarce, making them expensive.

With this in mind, Toshiba Infrastructure Systems & Solutions Corporation has developed a motor rotor with a new structure that requires approximately 30% less magnet volume than conventional motor rotors, helping reduce costs.

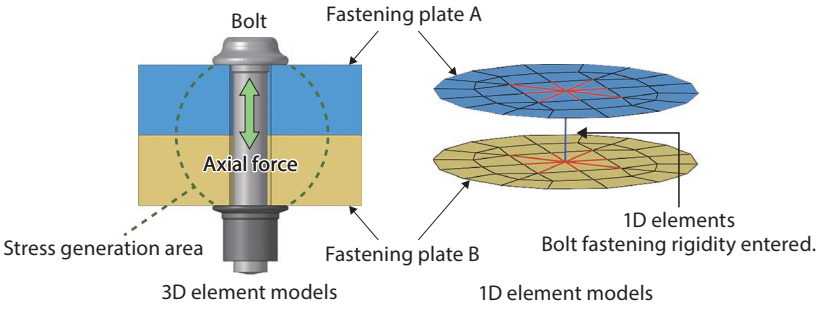
The rotor is designed to efficiently transmit magnetic flux from internal magnets to the stator. For a conventional rotor, a thin wall on the surface (called a top bridge) increases mechanical strength, however, the top bridge causes flux leakage.

To prevent this, the top bridge on the new rotor has been eliminated without compromising mechanical strength. This rotor structure reduces flux leakage, increasing the effective magnetic flux that contributes to torque generation. Combined with other techniques, the new structure helps reduce the magnet volume. We have established technology for mass-producing this rotor and delivered a prototype to an auto manufacturer in 2023.

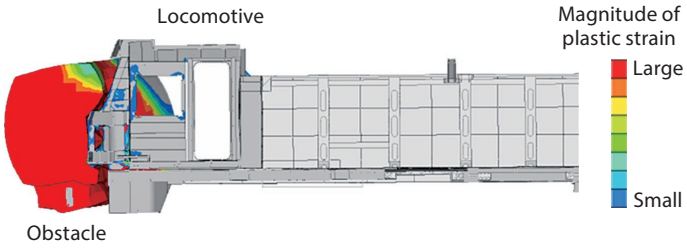
We will continue to provide low-cost motor products with enhanced environmental performance to contribute to the proliferation of xEVs.

(*) A generic term for vehicles powered by electric energy stored in batteries, including purely electric and hybrid vehicles.

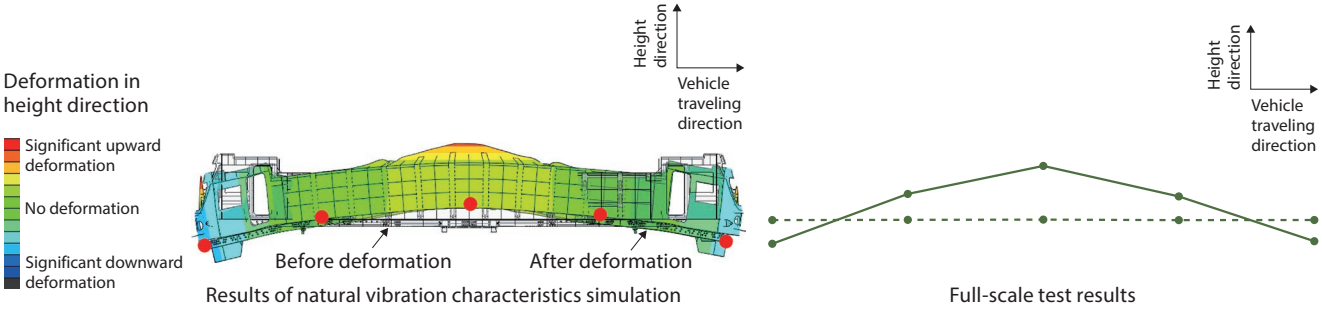
3.16 Static and Impact Simulations of Locomotives for Overseas Markets



Simple model representing bolted joints



Large obstacle collision simulation results (plastic strain distribution)



Comparison of natural vibration characteristics simulation results and full-scale structural test of locomotive

Railway vehicles for overseas markets must meet international standards and customer requirements, so simulations are used at the design stage to evaluate and improve the structure and determine whether performance satisfies industry standards and customer specifications. The simulator must produce results consistent with actual observations.

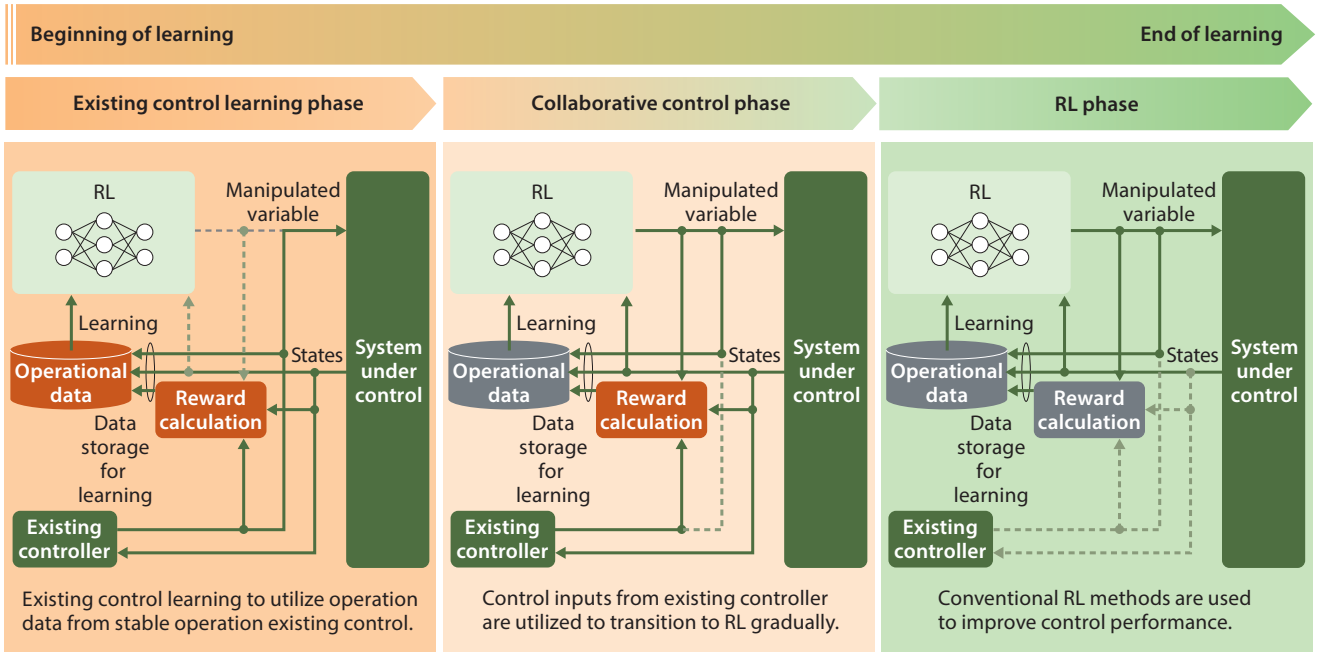
To improve vehicle assembly efficiency, bolts are used to fasten major portions of the vehicle structure together. For bolted joints, Toshiba Infrastructure Systems & Solutions Corporation calculated the stiffness and entered it into a one-dimensional (1D) model instead of using a three-dimensional (3D) element model to reproduce fastening conditions.

We used the 1D element model to construct the structural model of the entire locomotive and employed a static simulation to create a structural design that meets customer requirements. Full-scale testing confirmed structural soundness with a simulation error of less than 2% for the first natural frequency of the locomotive.

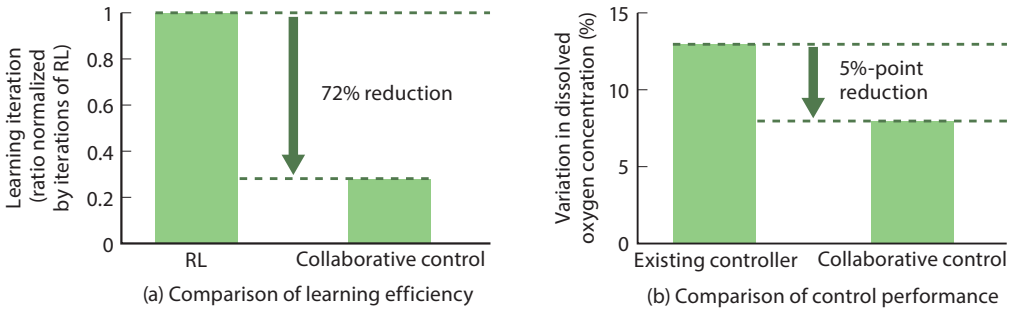
For locomotive collision safety performance, we performed full-scale element tests to evaluate energy absorption capacity and other aspects, verifying consistency between the results of an impact analysis and full-scale element tests. We conducted an impact simulation using the characteristic values obtained from the full-scale element tests. For the bolted structure, we applied the characteristic values obtained from a bolt impact test to a 1D element model and developed a method to evaluate the crash resistance performance of the entire locomotive structure via simulation.

Through repeated feedback of static and impact simulation results, we were able to create a structural design that met all the requirements. In the future, we will employ these simulation technologies to evaluate the strength of our transportation and infrastructure products.

3.17 Control Technology Applying Reinforcement Learning to Reduce Learning Time and Improve Control Performance



Block diagram of collaborative control based on reinforcement learning using information on existing controller



Evaluation of RL for dissolved oxygen concentration control

Reinforcement learning (RL) is an AI technique used to train machine learning models to find better states for a system under control. Unlike supervised learning in which correct answers are provided during training, RL focuses on learning appropriate actions based on rewards. For social infrastructure systems requiring long-term operation, RL is expected to help recover, maintain, and improve system performance in the event of control performance degradation due to environmental changes. On the other hand, RL uses a process of trial and error to derive control logic, which can require numerous time-consuming attempts to achieve the desired performance.

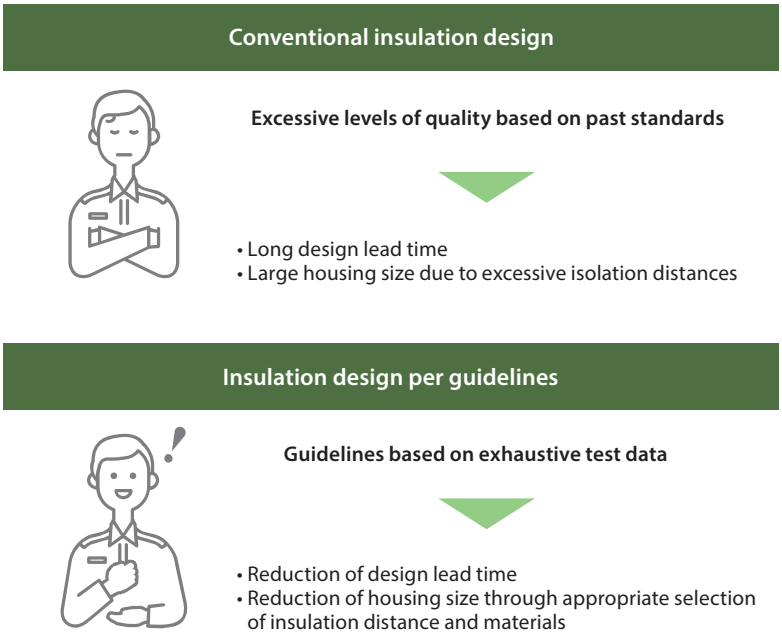
To solve this issue, Toshiba Infrastructure Systems & Solutions Corporation has developed a collaborative control method that efficiently derives control logic and improves control performance by leveraging the control inputs of existing controllers for RL. The collaborative control process consists of the following three phases:

- Existing control learning phase, which utilizes data from existing stable control operations for RL
- Collaborative control phase, which leverages existing control inputs for reward calculation and coordination with existing control
- RL phase, which improves control performance

Each of the above phases is executed based on learning progress to achieve a balance between learning efficiency and performance. We have verified the effectiveness of this collaborative control approach via a simulation of dissolved oxygen concentration control for a sewerage treatment system. The results showed that the new collaborative control approach required 72% fewer learning iterations than conventional collaborative control and achieved a 5%-point reduction in oscillation amplitude during dissolved oxygen concentration control compared with the existing control method. This confirms that the collaborative control approach combining the existing control method and RL provides better learning efficiency and control performance than conventional RL.

As a next step, we will apply the new collaborative control method to various control systems to verify its effectiveness to develop practical RL-based control techniques for controller products.

3.18 Insulation Design Standards Reducing High-Voltage Electrical Products Design Lead Time and Housing Size



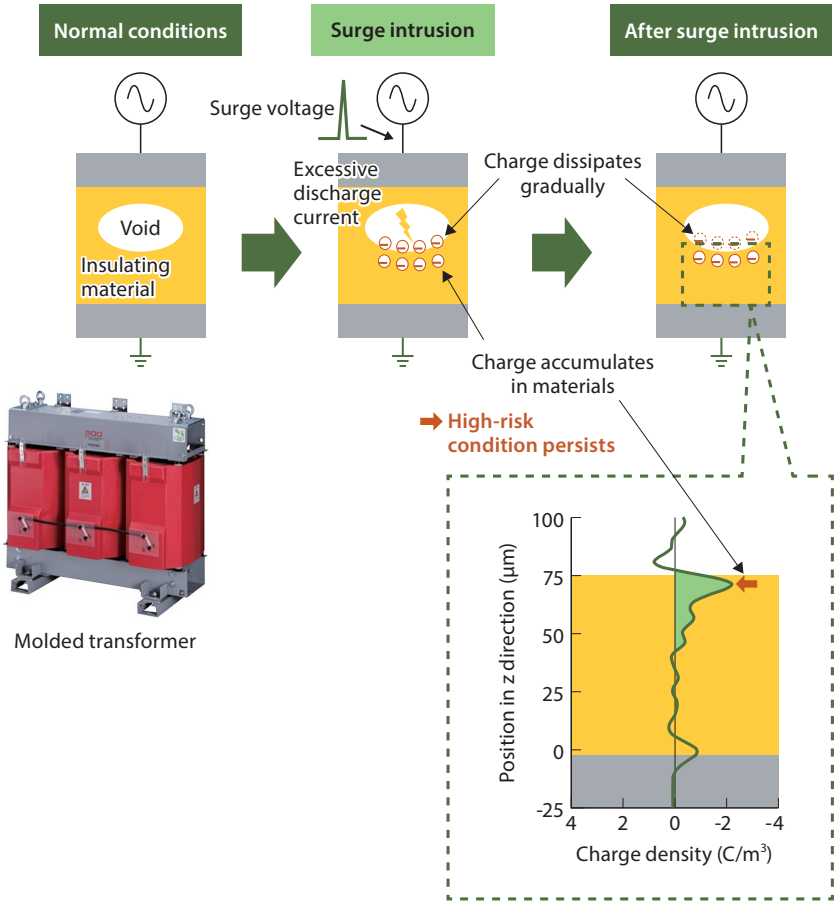
Air insulation design guidelines and effects

Toshiba Infrastructure Systems & Solutions Corporation offers many electrical products with different voltage classes and uses. Although they have specific insulation design standards, excessive levels of quality are sometimes required based on past standards. High-voltage systems with increasingly higher rated voltage pose some issues, including lengthy design lead times and large housing sizes due to suboptimal insulation design.

To solve these issues, we developed insulation design guidelines that can be widely used for various high-voltage products, focusing on air insulation. We organized insulation design considerations into comprehensive guidelines based on short-term and long-term breakdown tests. The guidelines allow even inexperienced insulation designers to easily create a design with an appropriate insulation distance, helping reduce design lead time and housing size significantly thanks to the reduced insulation distance.

We will share the guidelines with internal product developers and collect feedback to expand the range of application.

3.19 Elucidation of Partial Discharge Phenomenon in Molded Devices Due to Surge Intrusion



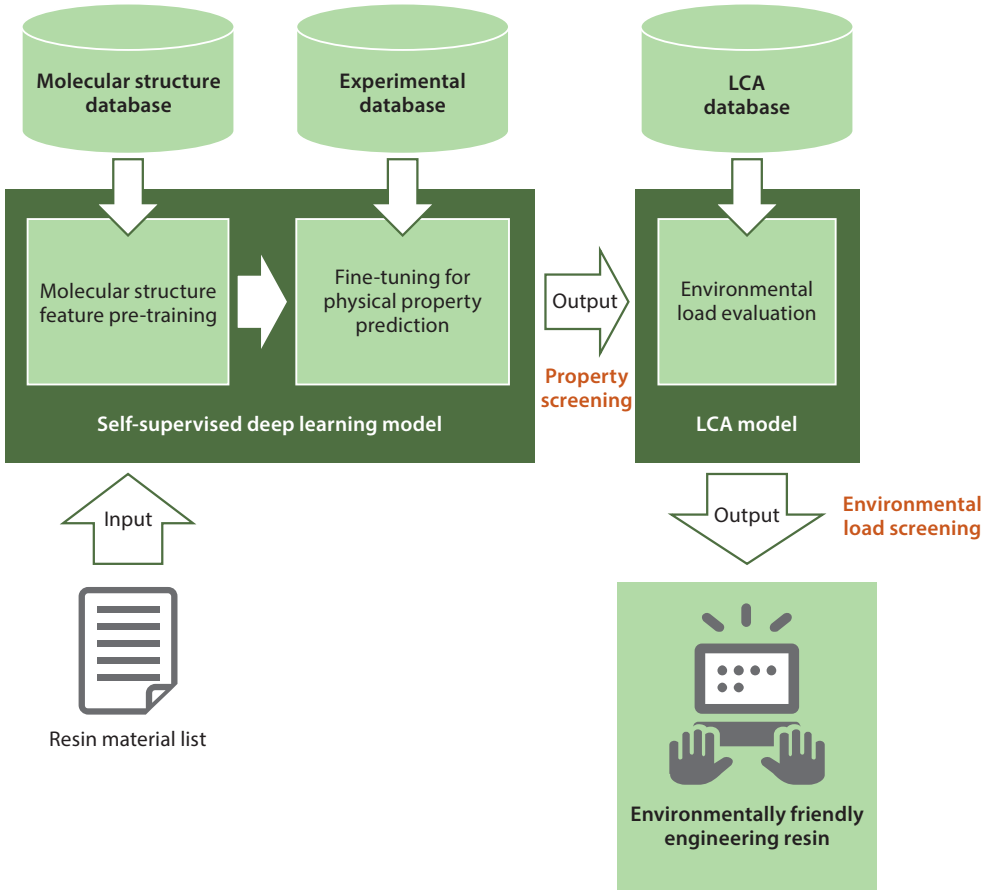
Changes to insulating material due to surge voltage application

Molded transformers and other electric power equipment have been used for several decades. Transient voltage surges such as lightning and switching surges can enter and damage these devices during operation, however, the phenomenon occurring inside remained unclear. In this study, Toshiba Infrastructure Systems & Solutions Corporation experimentally elucidated the phenomenon that occurs in insulating materials during surge events.

When surge voltage enters the voids in a molded device that remain after the manufacturing process, excessive discharge current flows momentarily, causing the surface of these voids to become heavily charged. At this point, partial discharge occurs at voltages lower than the operating voltage, leading to material degradation. The charge dissipates gradually, but, in practice, partial discharge is observed continuously. Detailed investigations of charge behavior in insulating materials revealed that charges accumulate not only on the material surface but also inside the materials, and a high risk persists because of slow charge dissipation.

We will incorporate this insight into the design of molded devices to increase surge resistance and prevent sudden failure.

3.20 Technology to Explore Environmentally Friendly Insulating Resin Materials Using Deep Learning Models



Technology for polymer material exploration combining deep learning model and life LCA

Many electric power devices use resin materials to insulate and support high-voltage conductors. Given the increasing need to reduce their environmental impact, it would be better to replace current insulating resins with more environmentally friendly ones. However, there are currently no known insulating resin materials that can improve environmental compatibility without compromising current product performance. There is a need for technology that can quickly search for resins from a wide variety of choices.

With this in mind, Toshiba Infrastructure Systems & Solutions Corporation has developed a self-supervised deep learning model that uses molecular structure and other databases to predict resins' physical properties without the need for experiments. By combining this deep learning model with life cycle assessment (LCA) methods, we have established a data-driven search and proposal method which helps significantly reduce the lead time required to select environmentally friendly resin materials.

We plan to further enhance the new deep learning model and modularize this technology so that it can be deployed for developing various products.