3.1 Reduction in Operating Cost of ZLD Wastewater Treatment System



Flow of processes in zero liquid discharge (ZLD) system incorporating BC membrane facility

Toshiba Infrastructure Systems & Solutions Corporation provides zero liquid discharge (ZLD) wastewater treatment systems for developing countries to address water scarcity and water pollution problems. However, the high operating cost of ZLD has been one of the obstacles hindering its widespread uptake.

A ZLD system consists of a reverse osmosis (RO) membrane system to separate and concentrate inorganic ions from wastewater and an RO concentrate evaporator to precipitate inorganic salts. Evaporation requires a large amount of energy and is costly. Although the evaporation cost can be reduced by increasing the RO water recovery rate, there is a limit to the maximum ion concentration achievable by the conventional RO membrane system.

To resolve this issue, we incorporated brine concentration (BC) membranes into a pilot ZLD system because BC membranes exhibit a higher ion concentration rate than RO membranes. As a result, the pilot ZLD system achieved an ion concentration of 18%, 2.2 times higher than that of the conventional RO membrane system. Since impurities (e.g., calcium) can cause membrane scaling, we conducted a pilot test to determine the maximum allowable impurity concentration.

We will continue to further reduce the operating cost of ZLD systems so as to contribute to preservation of the water environment in developing countries.

3.2 Commercialization of High-Rate Sand Filters with Reduced Footprint



Pilot test equipment for high-rate sand filters

There is increasing demand for reductions in the footprint and cost of industrial wastewater treatment equipment. Toshiba Infrastructure Systems & Solutions Corporation has developed high-rate sand filters featuring an approximately 40% smaller footprint than those of the conventional models.

Sand filters remove suspended solids (SS) from wastewater. The newly developed sand filters are pressurized downflow filtration units that provide a 1.6 times higher filtration rate than the conventional models with an equivalent filtrate quality. As a result, the new sand filters provide increased treatment capacity per unit area as well as a reduced footprint.

High-rate filtration requires more efficient backwashing because of faster clogging of the filter medium. To resolve this issue, we have established a unique backwashing procedure by analyzing the mechanism of removal of suspended solids captured by filter media using a high-speed camera.

Following verification of treatment performance through pilot tests, we have commercialized 14 models of high-rate sand filters with a treatment capacity of 5.5 to 160 m³/h per unit. Our next objective is to achieve wide deployment of these sand filters to meet the requirements of the wastewater treatment process.

3.3 Dual-Polarization Weather Radar with Wireless LAN Deconfliction Function



Indoor equipment of dual-polarization weather radar and outline of LAN deconfliction function

Accompanying a rapid increase in the number of wireless base stations, radio interference is becoming a serious concern in Japan because of tight frequency allocation. Therefore, urgent action is needed to solve or mitigate this problem. In response, the Ministry of Internal Affairs and Communications (MIC) is conducting R&D to improve the efficiency of spectrum utilization.

As part of MIC's project, Toshiba Infrastructure Systems & Solutions Corporation has delivered a dual-polarization weather radar with a wireless LAN deconfliction function to MIC. Upon detection of an interfering radio wave from a wireless LAN access point, this radar generates a pulse pattern to activate its dynamic frequency selection (DFS)^(*1) function. In response, the wireless LAN access point switches to another frequency channel to avoid interference.

The newly developed weather radar also provides features for advanced meteorological observation, including a moving target indication (MTI) function^(*2) that reconstructs the weather radar echo lost in the process of ground clutter removal and a novel selective MTI function^(*3) based on machine learning.

- (*1) A mechanism that allows wireless devices to detect radar signals and avoid interfering with them by changing the frequency channel
- (*2) A function to filter ground clutter echoes based on the difference in Doppler frequency between a weather radar echo and a ground clutter echo
- (*3) A function to determine whether to enable or disable the MTI function on a mesh-by-mesh basis

3.4 BISCADE[™] Fingerprint Authentication Dongle Enabling Multifactor Authentication



BISCADE[™] fingerprint authentication dongle



Scene of empirical research at Koganei Elementary School attached to Tokyo Gakugei University

There is a growing need for multifactor authentication to prevent unauthorized use of PCs and servers. Multifactor authentication requires two or more pieces of evidence or factors, generally from among the following types, to verify the identity of someone attempting to log in: knowledge (such as an ID or password), possession (such as a smart card or dongle), and biometrics (such as a facial image or fingerprint).

Against this background, Toshiba Infrastructure Systems & Solutions Corporation has developed the BISCADETM dongle, which provides both possession authentication in the form of physical possession of the dongle and biometric authentication via a fingerprint. The user's fingerprint is stored in a secure integrated circuit (IC) chip of the type also used in credit cards, etc., which is embedded in the dongle. The fingerprint data never leave the dongle during registration and authentication. The use of the BISCADETM dongle to log into a PC helps to improve both the security and convenience of user authentication because it eliminates the user's need to remember an ID and a password.

The BISCADE[™] dongle is expected to be used not only by enterprise users but also by elementary and junior high school students for the Global and Innovation Gateway for All (GIGA) School Program^(*). Chosen by Soliton Systems K.K. as a PC login system, the BISCADE[™] dongle has also been used as a key device for empirical research at Koganei Elementary School attached to Tokyo Gakugei University that was conducted in collaboration with Lenovo Japan, Ltd.

Mr. Shota Koike, the teacher at Koganei Elementary School in charge of the empirical research, commented, "It is very difficult for lower graders to distinguish between lowercase and uppercase letters. Since fingerprint authentication is commonly used in everyday life, even small children were able to use the dongle right away. The BISCADETM dongle was also useful for security education." Through this empirical research, we were able to verify the usefulness and convenience of the BISCADETM dongle.

In the future, we will commercialize the BISCADE[™] dongle to contribute to improvements in the login security and convenience of use of PCs and servers.

(*) The GIGA School Program is an initiative introduced by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan in 2019 to provide PCs for all students and connect them via a high-speed network, to realize an optimal and creative learning environment that can prepare them for life in the era of Society 5.0.

3.5 Pay-per-Use Secondary OCR to Enhance Address Recognition Accuracy of Existing Parcel Sorting Machines



VCD: video coding desk

Overview of pay-per-use secondary OCR service using manipulation technique

In the logistics business field, there is an urgent need for labor-saving and further automation of postal processes to handle the increasing volume of parcels being generated by e-commerce transactions as a consequence of the worldwide spread of COVID-19. On the other hand, parcel sorting machines equipped with conventional address optical character recognition (OCR) systems to read address information, including both address details and postal-code data, are showing an increasing tendency to generate errors accompanying the growth in the number of mail items of diverse types and shapes.

As a solution to these issues, Toshiba Infrastructure Systems & Solutions Corporation has developed a dedicated OCR function focusing on the recognition of address information that parcel sorting machines cannot conventionally recognize in address images, and is providing it as a pay-per-use secondary OCR service for users of existing parcel sorting machines. We have confirmed that this secondary service can successfully read about 70% of unrecognized address images under certain conditions. In addition, we have started offering a new secondary OCR service that can recognize the remaining 30% of unrecognized address images without changing the existing address OCR system through the use of a manipulation technique.

We will continue to provide a variety of services tailored to the needs of postal and logistics carriers to help them improve their operational efficiency and eliminate labor shortages.

3.6 Completion of Phase 1 Site Test of TESS for Dhaka MRT Line-6



Locations of traction energy storage systems (TESS) for Dhaka MRT Line-6, Bangladesh

TESS installed at substation on Dhaka MRT Line-6

Dhaka MRT Line-6 is Bangladesh's first mass rapid transit (MRT) system, connecting the northern and southern districts of Dhaka with a 1 500 VDC overhead catenary system spanning 16 stations and eight substations over a total length of about 20 km.

Toshiba Infrastructure Systems & Solutions Corporation has previously installed numerous traction energy storage systems (TESS) for Japanese railway operators, but the deployment of TESS facilities on Dhaka MRT Line-6 is our first overseas TESS project.

The main purposes of the TESS for this project are fourfold: (1) ensuring an emergency power supply to propel trains to the nearest station and safely evacuate passengers in the event of a power failure, (2) preventing regenerative braking failure due to an increase in feeding line voltage, (3) storing the regenerated energy that is otherwise dissipated as heat by wayside resistors so that it can be reused later, and (4) compensating for a voltage drop in the overhead line that could occur when multiple trains accelerate simultaneously.

Since the effects of a TESS facility depend on the train, route, and operating conditions, it is necessary to run a simulation to determine the optimal specifications for the TESS while taking the customer's requirements into consideration. As a result of such a simulation, it was decided to install eight sets of TESS ($2 \text{ MW}-546 \text{ kWh} \times 7 \text{ sets}$, $500 \text{ kW}-137 \text{ kWh} \times 1 \text{ set}$), one at each of the substations on Dhaka MRT Line-6. This turned out to be the largest project ever for us in terms of the number of installation sites per line and the total storage capacity.

The overall construction schedule is divided into two phases. Phase 1 for the installation and site test of the TESS for the first four substations ran from April to June 2021.

The COVID-19 pandemic brought unexpected challenges, including travel restrictions and logistics delays. Under these circumstances, we took unprecedented measures such as providing remote online support for the site test from Japan, and managed to complete the test without adversely affecting the construction schedule.

In October 2021, we performed a TESS charge-discharge test for Phase 1 while trains were running. Phase 2, involving the installation and testing of the TESS for the remaining substations, is scheduled for 2022. We will continue to cooperate with local engineers toward the successful completion of the project.

3.7 Emergency Power Supply Device for E235 1000 Series Trains of East Japan Railway Company



Accumulators of emergency power supply device for E235 1000 series trains of East Japan Railway Company

Although rail is more environmentally friendly than other forms of transportation, social demand exists for further decarbonization, higher energy efficiency, and greater energy saving as well as enhanced robustness of railway infrastructure in the event of a disaster.

Toshiba Infrastructure Systems & Solutions Corporation has delivered emergency power supply devices for the E235 1000 series trains of the Yokosuka-Sobu Line of East Japan Railway Company ("JR East"). In the event of a power failure of an overhead line, for example, these emergency power supply devices prevent trains from being stalled for a prolonged period between stations as they allow a train to run to the nearest station or other location where passengers can alight.

In normal times, the accumulators of the emergency power supply device are charged with overhead electricity. In times of emergency, the stored electricity is used to drive propulsion motors. The accumulators also supply electricity to an auxiliary power supply.

The emergency power supply device is installed separately to minimize interference with the existing propulsion and auxiliary power supply systems.

The accumulator uses the SCiBTM rechargeable lithium-ion battery from Toshiba Corporation because of its advantages of safety, durability, long life, rapid charging, and low-temperature performance in addition to high input-output characteristics.

We will continue our efforts to contribute to the further development of the railway industry.

3.8 Delivery of Propulsion System for DEC700 Series **Diesel-Electric Trains of West Japan Railway Company**





for engine startup

Main converter

Generator

Equipment of propulsion system for DEC700 series diesel-electric trains of West Japan Railway Company

Toshiba Infrastructure Systems & Solutions Corporation has delivered a compact, high-efficiency propulsion system to West Japan Railway Company ("JR West") for the DEC700 series of diesel-electric train cars.

The DEC700 is a new diesel-electric car developed by JR West to perform various technical verifications for migration to next-generation vehicles.

The DEC700 is propelled by an electric motor that is powered by a diesel-engine generator. Its propulsion system can also be used as a hybrid system by replacing the battery equipment for engine startup with larger-capacity equipment.

The DEC700 is equipped with a totally enclosed permanent magnet synchronous generator (rated efficiency: 97%) for more efficient use of the engine output. This makes it possible to reduce the engine output by about 4% compared with a conventional diesel-electric car equipped with an open type induction generator (rated efficiency: 93%), thereby improving fuel efficiency and reducing carbon dioxide (CO₂) emissions.

The main converter is compact and lightweight due to the use of a water-cooled power unit for the motor and generator controller, and SCiB™ rechargeable lithium-ion batteries supplied by Toshiba Corporation are employed for the battery equipment.

Completed in July 2021, the DEC700 is currently undergoing various performance and technical verification tests.

3.9 Delivery of Battery Energy Storage System and IoT Monitoring System for 8040 Type Trains of Hankyu Corporation







Configurations of battery energy storage system and IoT monitoring system for 8040 type trains of Hankyu Corporation

Toshiba Infrastructure Systems & Solutions Corporation has developed and delivered a battery energy storage system and an Internet-of-Things (IoT) monitoring system for 8040 type trains to Hankyu Corporation.

The battery energy storage system utilizes the SCiB[™] rechargeable lithium-ion battery. In the event of an overhead line outage, the stored electrical energy can be used to propel trains to a safe place where passengers can safely disembark. In addition, surplus regenerated energy can be stored in the battery energy storage system for use as an auxiliary power source for air conditioning and lighting.

The IoT monitoring system collects information about the locations and speeds of trains as well as information about the operating status and power consumption of onboard equipment and transmits this information to a cloud server. In addition, the IoT monitoring system has a real-time remote monitoring function for visually displaying the IoT data and a function for downloading these data as a comma-separated values (CSV) file for analysis.

We will further enhance the reliability of batteries and other onboard equipment to help improve railway safety and save labor required for maintenance work.

Following a field test, the 8040 type trains commenced commercial operation in April 2021.

3.10 FS20000R Model 200 and Model 100 High-Speed, **Large-Capacity Industrial Servers**

FS20000R (with fro	ont panel)	Rear view
FS20000R with 2.5-inch SSD	FS20000R with 3.5-inch HDD	FS20000R with 2.5-inch SSD

and 3.5-inch HDD

FS20000R with 2.5-inch SSD

FS20000R model 200/100 industrial server

ltem		Specification		
		FS20000R model 200	FS20000R model 100	
CPU		Intel [®] Xeon [®] Gold 5218T	Intel [®] Xeon [®] Silver 4209T	-
Chipset		Intel® C621Chipset		-
	Speed	DDR4-2666	DDR4-2400	-
Main memory	Capacity	Single-CPU configuration: 8 Dual-CPU configuration: 16	-	
Storage	Configuration	3.5-inch nearline SAS HDD configuration: Up to four units 2.5-inch SATA SSD configuration: Up to eight units Mixed SSD-HDD configuration: 2.5-inch SATA SSD: Two units 3.5-inch nearline SAS HDD: Up to three units		-
Size		430.0 (W) × 86.6 (H) × 592.0 (D) mm		-
Temperature (op	erating/storage)	5 to 40°C/-10 to 50°C		-
Vibration (during operation) HDD configuration: 2.0 m/s² SSD configuration: 4.9 m/s² JIS C60068-2-6: 9 to 150 Hz, 1 cycle		- DDR: double data rate - JIS: Japanese Industrial Sta		

Main specifications of FS20000R model 200/100

Toshiba Infrastructure Systems & Solutions Corporation has developed the FS20000R model 200 and model 100 industrial servers (collectively "FS20000R"). While inheriting the industrial computer concepts of reliability, ease of maintenance, and long-term supply and maintenance, the FS20000R incorporates the latest central processing unit (CPU) and chipset to provide higher performance than the previous models. The FS20000R supports a highspeed 2.5-inch Serial Advanced Technology Attachment (SATA) solid-state drive (SSD) and a large-capacity 3.5-inch nearline Serial Attached SCSI (Small Computer System Interface) (SAS) hard disk drive (HDD) as well as a mixed SSD and HDD configuration to meet a wide range of user requirements. In addition, the FS20000R provides six LAN ports and allows high-speed graphics processing unit (GPU) cards to be used for deep-learning and other applications.

Because of these features, the FS20000R can be used for a wide range of industrial monitoring and control systems and other edge computing applications requiring high-speed, large-capacity processing.

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3.11 Converter Circuit Topology to Achieve Both High Efficiency and Noise Reduction



Newly developed MSS circuit with four serially connected devices



To increase the efficiency of power converters using power semiconductors, it is necessary to reduce their power loss. With the conventional approach, power loss can be reduced by increasing the voltage slew rate, but at the expense of an increase in electrical noise. Toshiba Infrastructure Systems & Solutions Corporation previously solved this trade-off by optimizing the efficiency-noise balance of each product.

We have now developed a converter circuit topology that provides both high efficiency and noise reduction. We named this topology multi-slice switching (MSS) because multiple power semiconductors (switching devices) connected in series switch on and off in a time-sliced manner. In an MSS circuit, a snubber circuit is connected to each switching device in parallel. The snubber circuit, which consists of a diode and a capacitor connected in series, suppresses surge voltage that occurs when the corresponding switching device is turned off. A regenerative diode is positioned so that one end is connected to the diode and capacitor of the snubber circuit, and the other end is connected to the central capacitor of the MSS circuit.

When the switching devices are turned on and off in a time-sliced manner, the snubber circuits store the electrical energy that was conventionally lost. Then, when all the switching devices in the same arm are turned on, the stored electrical energy is discharged from the snubber circuits to the central capacitor via the regenerative diodes. Subsequently, the energy stored in the central capacitor recirculates to a load or a power supply.

At the same voltage slew rate (same level of electrical noise), the new MSS circuit has lower switching loss and hence higher efficiency than a conventional circuit. On the other hand, at the same efficiency, the MSS circuit generates less electrical noise than a conventional circuit because of the reduced voltage slew rate. Therefore, the MSS circuit solves the trade-off between efficiency and electrical noise. A power converter with a prototype MSS circuit achieved an efficiency of 99.21% under the following test conditions: input DC voltage of 340 V, output AC current of 25 A, switching frequency of 20 kHz, and instantaneous slew rate of $2.5 \text{ kV/}\mu s$.

3.12 Building Air-Conditioning Simulator to Achieve Balance between Comfortable Environment and Energy Saving



Air-conditioning control technology using building air-conditioning simulator to achieve balance between comfortable environment and energy saving

At present, air conditioners account for about 40% of the total power consumed by a building. It is therefore important to save the power consumption of air conditioners. On the other hand, building operators receive many complaints about room temperature from tenants. Building operators consequently need to pay attention to the issue of room comfort.

With this as a background, Toshiba Infrastructure Systems & Solutions Corporation has developed a new air-conditioning control technology to optimize both room comfort and energy saving.

Conventional air-conditioning control technology cannot always respond to future fluctuations in usage environments, including the outside temperature, room temperature, and number of occupants on a floor, because it is based only on current information on usage environments. In contrast, the newly developed technology uses a building air-conditioning simulator that performs high-speed calculations of the relationships among air-conditioning settings, room temperature, and power consumption for a full day, taking the predicted outdoor temperature and flow of people into consideration. The computed relationships between the air-conditioning settings for a full day and the resulting room temperatures can be used to determine optimal temperature settings, taking future fluctuations into consideration.

We simulated an air-conditioned building on a certain winter day using the newly developed simulator. The results obtained confirmed that this technology helps to avoid excessive heating and provides a 25% reduction in power consumption.

We will further improve this technology by increasing the accuracy of prediction of the flow of people in a building.

3.13 Detection and Discrimination of Cyanobacteria Using Spectral Imaging and Deep Learning



Flowchart for detecting, discriminating, and counting cyanobacteria



Examples of detection and discrimination of cyanobacteria

Flowchart of discrimination of algae and examples of detection and discrimination of cyanobacteria

Algae are biological contaminants of water purification systems that produce a musty odor.

Toshiba Infrastructure Systems & Solutions Corporation is developing image recognition technology to automatically discriminate and count cyanobacteria (blue-green algae) in raw water. This technology uses spectral images containing color information for each pixel at high resolution to distinguish features of algae such as their pigments and shapes.

We created a deep-learning-based discriminative model from 327 spectral images of algae culture strains (supplied by the Microbial Culture Collection facility of the National Institute for Environmental Studies of Japan) and raw water. We then attempted to detect cyanobacteria in 75 spectral images of raw water and identify the genera of the cyanobacteria detected (*Anabaena, Oscillatoria, Phormidium*, and *Microcystis*).

As a result, we succeeded in detecting 95% of the cyanobacteria, with a false detection rate of 0.09 per image. This translates to 98% discrimination of the genera of cyanobacteria.

Our next step is the detection and discrimination of algae other than cyanobacteria.

3.14 Application of Materials Informatics to Power Receiving and Distribution Equipment



Microstructure to increase mechanical strength

Overview of development of casting materials for power receiving and distribution equipment applying materials informatics (MI) method

Materials informatics (MI) is a field of study that applies the principles of information science and technology to the development of materials. MI can be used to predict material properties or factors based on a machine learning model generated from experimental results.

A casting material provides high-voltage insulation and supports a mechanical load in power receiving and distribution equipment. It is a composite of epoxy resin and an inorganic filler containing particles of various sizes.

Toshiba Infrastructure Systems & Solutions Corporation applied the MI method to the development of casting materials for power receiving and distribution equipment. We used persistent homology (PH), a type of topological data analysis, to extract the topological features of the microstructures of casting materials using image data. The relationship between mechanical properties and the extracted features was explored using machine learning methods to clarify that the mechanical strength of the casting material could be increased by controlling its microstructure. As a result of reverse mapping, we found that the mechanical strength is greatly affected by the spherical inorganic filler with fine particle size.

In the future, we will develop a method for predicting mechanical properties with high accuracy.