

## Special Reports

### Energy and Environmental Technologies Contributing to Realization of Green Society – Joint Research with Tsinghua University

#### Joint Efforts between Industry and University to Achieve Low-Carbon Society

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#### Cooperation with Tsinghua University toward Realization of Green Society

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#### Tsinghua-Toshiba Energy & Environment Research Center Aiming at Improvement of Global Energy and Environmental Situation

CAI Ningsheng / ITO Yoshiyasu

There is a strong need for worldwide energy conservation and the reduction of emissions of greenhouse gases such as carbon dioxide (CO<sub>2</sub>) as countermeasures against global warming. In consideration of the energy and environmental situation of the world, Toshiba and Tsinghua University in China held an Energy & Environment Seminar based on their respective policies in July 2007. Going a step further, the Tsinghua (DTE) (DTE: Department of Thermal Engineering)-Toshiba Energy & Environment Research Center was established in April 2008 with the aim of accelerating research and development of energy and environmental technologies. Furthermore, on March 1, 2011, the Center was expanded to the Tsinghua-Toshiba Energy & Environment Research Center to enhance cooperative relationships with all departments of Tsinghua University. The Center has been actively engaged in joint research and development in the fields of energy and the environment, including high-performance energy devices, an exhaust gas treatment system, a water quality monitoring system, an environment-friendly power supply system, and technologies to counteract global warming such as a CO<sub>2</sub> capture technology and so on.

#### Flowpath Optimization for Steam Turbines Employing CFD Analysis and Application to Actual Blade Design

YUAN Xin / TEJIMA Tomohiro / NIIZEKI Yoshiaki

Toshiba and Tsinghua University have developed an advanced aerodynamic design optimization tool for steam turbine stages employing computational fluid dynamics (CFD) analysis. This tool consists of highly accurate and highly adaptive CFD programs for various parametric modeling tasks, not only for the design of simple blade shapes but also for the optimization of more complicated models such as those including the effect of a rotating blade with tip leakage, the configuration of nonaxisymmetric endwall contouring, and so on. This tool is expected to enhance the performance of steam turbines by providing completely three-dimensional optimized steam-path design that has not been attainable by human designers up to now.

#### Degradation Mechanism and Refinement of Amine Solvent for Post-Combustion Carbon Dioxide Capture Technology

WANG Shujuan / MIYAIKE Kiyoshi / OGAWA Takashi / KITAMURA Hideo

Carbon dioxide capture and storage (CCS) is expected to play a significant role in reducing carbon dioxide (CO<sub>2</sub>) emissions from coal-fired thermal power plants, which are one of the main causes of global warming due to their large volumes of CO<sub>2</sub> emissions.

With the aim of realizing CCS technology, Toshiba has been developing a post-combustion CO<sub>2</sub> capture technology using amines as a chemical solvent to separate CO<sub>2</sub> from boiler flue gas. As part of joint studies at the Tsinghua (DTE) -Toshiba Energy & Environment Research Center in China, Tsinghua University has clarified the mechanism of amine solvent degradation and reduction of CO<sub>2</sub> absorption performance by sulfur dioxide (SO<sub>2</sub>) in exhaust gases. Furthermore, the effectiveness of a method for the refinement of amine solvent using ion-exchange treatment has been confirmed.

#### Evaluation of Erosion of Hydraulic Turbine Materials by Chinese River Sand

PAN Wei / YAN Liang / KUROSAWA Sadao / SUZUKI Toshiaki

Performance degradation and damage of flowpath components due to sand erosion is a crucial issue in hydroelectric power generation equipment in China, because Chinese rivers contain large amounts of sand.

A study was conducted on the composition and concentration of sand in silt-laden water in a typical river in China and experiments on silt abrasion of hydraulic turbine materials, including a silt abrasion-resistant thermal coating developed by Toshiba, were performed using artificial sands as well as actual sand collected from the river. The results confirmed the effectiveness of the silt abrasion-resistant coating technology in protecting a hydraulic turbine from sand erosion. Furthermore, the results of the erosion tests demonstrated that artificial sands with similar compositions to the actual river sand can simulate the erosion behavior of the actual sand with high precision.

#### Control Technologies for Regionally Independent and Environmentally Conscious Electricity Supply Systems in Chinese Smart Grid Market

MIN Yong / LU Zongxiang / HAYASHI Hideki / KOBAYASHI Takenori

The effective introduction and utilization of renewable energy has become a serious issue for the reduction of greenhouse gas emissions. In the field of power transmission and distribution systems, smart grid technologies based on bidirectional information and communication technology (ICT) are a promising solution for the promotion of renewable energy utilization in power grids. In particular, regionally independent and environmentally conscious electricity supply systems, or so-called microgrid systems, will be a key technology for the smart grid in China.

Tsinghua University and Toshiba have developed control schemes and algorithms for two typical and marketable microgrid models in China: (1) photovoltaic (PV) microgrid systems in urban distribution systems, and (2) large-scale wind power integration into power grids. The effectiveness of these systems is now being evaluated in field demonstration tests.

#### Application of Water Quality Monitoring Unit Equipped with Biosensor to Large Bodies of Open Water in China

SHI Hanchang / QIU Yong / SATO Takeshi / HARAGUCHI Satoshi

Water pollution in rivers and lakes is a serious issue accompanying the expansion of industry in China. A water quality monitoring unit developed by Toshiba for water supply and sewerage systems, which is equipped with a biosensor to detect harmful material spill accidents, can also be used for monitoring water quality in large bodies of water by expanding the areas of application up to the scale of rivers and lakes.

However, the results of a water survey in China suggest the possibility that water in polluted areas contains materials that impede the stable operation of the biosensor. Tsinghua University and Toshiba have therefore developed a pretreatment technology to remove inhibitors of stable operation, in order to expand the areas of application of the biosensor.

## FEATURE ARTICLES

#### Site-Specific 2D Carrier Profiling Technology and Application to Failure Analysis

ZHANG Li / KOIKE Mitsuo / HARA Keiryō

With the increasing difficulty of process control accompanying the miniaturization of large-scale integrations (LSIs), demand has been growing in recent years for a measuring technology with nanoscale resolution for two-dimensional (2D) carrier profiling, which is related to the performance of scaled silicon devices.

Toshiba has been developing a scanning spreading resistance microscopy (SSRM) technology for 2D carrier profiling with a wide dynamic range of carrier concentration and a high spatial resolution of about 1 nm. We have now developed a site-specific SSRM technology and applied it to the failure analysis of real static random access memory (SRAM) devices. As a result, we have succeeded in directly observing carrier concentration in an ultra-thin device of less than 60 nm in thickness and clarifying a failure mode caused by the manufacturing process as well as its mechanism. We have also achieved significant improvements in the yield rate by optimizing the process parameters such as the impurity doping conditions.

This high-spatial-resolution and site-specific SSRM technology is expected to accelerate the development of advanced LSI devices through the application of failure analysis, improvement of reliability, and clarification of failure mechanisms.

#### Diagnosis Method Supporting Extraction of Issues and Estimation of Measures for Supply Chain Management

YOSHIDA Satoshi / OHSHIMA Hiroko

With the development of emerging markets and the diversification of existing market needs in recent years, reconstruction of global supply chain management (SCM) is required to supply products to each market in a timely manner and at lower cost. In particular, accompanying the increase in the number of sales, manufacturing, and procurement sites and the complexity of their relationships, there is a strong necessity for improvements in the extraction of issues and the estimation of measures for SCM in order to determine policies more efficiently.

As a solution to this issue, Toshiba has developed a diagnosis method for SCM consisting of two main tools: a SCM Function Level List that makes it possible to clarify the gap between the goal (TO-BE) and actual status (AS-IS) of SCM and identify improvements more easily, and a Simple Inventory Simulator that allows users to quantitatively compare the effects of proposed solutions.

#### Redundant I/O Module for nv Series Unified Controller

KURIMOTO Takeshi / KODERA Shigehito / YAMAGUCHI Yasuharu

Toshiba has developed a new input/output (I/O) module with a redundant configuration for the nv series unified controller, which is used in various fields including general industrial infrastructure, social infrastructure, and electric power plants. Long-term continuous operation of the new I/O module is ensured by its enhanced reliability, robustness, and maintainability. Furthermore, it offers easy configuration and renewal engineering for migration from the existing CIEMAC<sub>TM</sub> series to the nv series unified controller and system updating to the latest controller.

#### Commercial Operation of Nam Ngum 2 Hydroelectric Power Station in Laos

TOMITA Yoshitaka / TEZUKA Kotaro / OKUBO Masashi

The Nam Ngum 2 Hydroelectric Power Station of the Nam Ngum 2 Power Company Ltd., located about 100 km north of Vientiane, the capital of the Lao People's Democratic Republic, successfully started commercial operation in December 2010. The CH. Karnchang Public Company Ltd., the prime contractor for this project providing engineering, procurement, and construction (EPC) services, awarded Toshiba a contract for the main generating equipment in August 2006.

We have carried out the design, manufacturing, installation, and testing of the main equipment for the power station including turbines, generators, and a supervisory control and data acquisition (SCADA) system, as well as the electrical equipment. The Nam Ngum 2 Hydroelectric Power Station is expected to serve as a power supply base for the Kingdom of Thailand.

#### D4-S Series Protection Relay Realizing High Cost Performance

HANZAWA Koji / SUGIURA Hideaki / FUKUSHIMA Kazuto

Protection relays are key devices that maintain the stable operation of an electric power system by detecting faults such as lightning faults that occur in the system, including transmission lines and substation facilities, within several tens of milliseconds and issuing a trip command to a circuit breaker in order to isolate the faulty part.

Toshiba has been continuously developing protection relays since launching the D1 series as the world's first microprocessor-based digital protection relay in 1980, and recently released the D4 series fourth-generation protection relay in 2007. Based on the design concept and technologies acquired through the development of the D4 series, we have now developed the D4-S series protection relay for high-voltage (HV) and low-voltage (LV) power networks. The D4-S series offers long-term supply and operation as well as high reliability and high cost performance due to its simple configuration with limited expandability.

#### Advanced Auxiliary Power Unit and Application to MUE-Train

KIKKAWA Kenichi / OTANI Hiroaki

The recent increase in awareness of global environmental issues has led to growing demand for high reliability, energy saving, and ease of maintenance in the railway transportation field. Improved environmental performance of auxiliary power units (APUs) for rolling stock is also required, such as further reduction of the environmental load.

Toshiba has developed an advanced APU in response to this situation. This APU achieves a higher efficiency of 96% compared with the 94% efficiency of conventional APUs, through the adoption of a three-level inverter system instead of the conventional two-level type and the application of low-loss insulated gate bipolar transistors (IGBTs). It also achieves a 23% reduction in weight compared with conventional models of the same capacity, through the use of leakage transformers as isolation transformers to eliminate the need for AC reactors. We provided the advanced APU with the rated output capacity of 260 kVA for the multipurpose experimental train (MUE-Train) for conventional railway lines of East Japan Railway Company.

#### Laser Welding Technologies for Realization of Long Lifetime and High Reliability of SCiB<sub>TM</sub> Infrastructure Battery

OKADA Naotada

Through the application of laser welding technology to shield the aluminum-alloy bodies of the battery cells, the SCiB<sub>TM</sub> infrastructure battery developed by Toshiba achieves light weight, long lifetime, and high reliability. However, the welding of aluminum alloy using conventional pulsed lasers generally tends to be unstable and a cause of welding defects including cracks.

As a solution to this issue, we have developed a laser welding technology applying a pulse laser with a shaped-pulse waveform to obtain stable welding without defects. We are now developing a welding technology for larger batteries using a high-power continuous-wave (CW) laser to increase the welding speed.

## Frontiers of Research & Development

New-Generation Headup Display Achieving Augmented Reality