

## Special Reports

### Core Technologies to Support Smart Grids

#### Smart Grid Technologies Supporting Electric Energy Infrastructure

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#### Core Technologies for Smart Grids

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Since the Great East Japan Earthquake, demand has arisen for more efficient and stable energy management in conjunction with the rapid introduction of renewable energy sources. Smart grid technologies have become increasingly important as a solution to this issue.

Toshiba is vigorously promoting the development of core technologies for smart grids, including system technologies for energy management systems, information and communication technologies (ICTs) for the provision of services to electricity users, and device technologies for distributed power supply systems, and is globally supplying products and solutions with high added value based on these technologies.

#### Monitoring and Control Technologies for Smart Grids

KATSUYAMA Minoru / KAKITA Chiharu

The rapid introduction of distributed power generation utilizing renewable energy sources in recent years has led to significant changes in the environment surrounding power grids. Furthermore, new elements such as electric vehicle (EV) charging stands and storage battery systems have gradually become part of the social infrastructure.

In keeping with this trend, Toshiba has developed new monitoring and control technologies for smart grids, including technologies for voltage regulation, frequency control, output power fluctuation control, EV charging control, demand response (DR), and battery aggregation control. We are making efforts to provide the  $\mu$ EMS (Micro Energy Management System) realizing the optimal solution to various issues using these technologies, either individually or in combinations of multiple technologies.

#### AMI System for Smart Grids

KOBAYASHI Takahiro / MAEDE Yukihiko / ITO Satoshi

Smart grids have been introduced worldwide to realize high reliability of electric power networks and high efficiency of electric power usage through coordination between information and communication technologies (ICTs) and the electric power network. The advanced metering infrastructure (AMI) system is planned to be installed in utilities in Japan as a key element of smart grids.

With Landis+Gyr AG, a leading company in the field of smart meters and now a member of the Toshiba Group, Toshiba has the capability to supply total AMI systems, consisting of smart meters, communication networks, a head-end system (HES), and a meter data management system (MDMS), as well as solutions using AMI technologies.

#### Stationary Battery Energy Storage Systems for Stable Electric Power Supply

TOYOSAKI Tomohiro / MIZUTANI Mami / TANNO Tsutomu

Stationary battery energy storage systems are expected to play an essential role in the stable operation of power grids with large-scale integration of renewable energy sources such as photovoltaic, wind power, and so on.

Toshiba has been expanding its lineup of stationary battery energy storage systems from small and medium- to large-size systems, based on technologies for its SCiB<sub>TM</sub> rechargeable batteries providing excellent input-output characteristics for their capacity as well as a long lifetime of more than 10,000 charge-discharge cycles. Applying these stationary battery energy storage systems, we have been offering a wide variety of battery solutions to realize stable electric power supply through related research and development activities and field experience.

#### Trends in International Standardization of Smart Grids and Toshiba's Approach

SAITO Takeshi / SHOBATAKE Yasuro / OHBA Yoshihiro

Smart grid systems, which support the wide dissemination of renewable energy and enhance the efficiency of both electric power transmission and distribution systems and systems on the consumer side, have been attracting considerable attention worldwide in recent years. In order to realize a smart grid system, the application of advanced information and communication technology (ICT) as well as the latest technologies in the electric power field, including distributed energy resources, is required. Interoperability of these technologies is also essential to provide new services including demand response (DR). International standardization of these technologies is therefore becoming increasingly important for the construction of smart grid systems.

With these trends as a background, Toshiba is vigorously promoting international standardization of smart grids including interfaces connecting users' systems with the electrical grid and cybersecurity.

#### Enhanced Integrated Smart Grid Evaluation System Contributing to Research and Development of Fundamental Technologies for Smart Grids

MIYAZAKI Yasuyuki / SAKATA Yasuji / OSAKI Yoshio

The development of technologies for smart grids requires close collaboration between power system technologies and information and communication technologies (ICTs). Preliminary verification applying a dedicated research and development facility to support these technologies can therefore shorten the development period for new systems.

Toshiba has developed an integrated smart grid evaluation system to verify cooperative functions between a Micro Energy Management System ( $\mu$ EMS) for the power grid and customer systems including home energy management systems (HEMS) and building energy management systems (BEMS), and is actively applying it to the research and development and product testing of fundamental technologies for smart grids. We have now enhanced this evaluation system with the incorporation of equipment such as a battery energy storage system, an advanced metering infrastructure (AMI) system, and so on, to facilitate the development of the latest technologies for smart grids.

## Feature Articles

#### Investigation of Trap Mechanisms Causing Random Telegraph Noise in Ultra-Scaled MOSFETs

CHEN Jiezhong / HIRANO Izumi / MITANI Yuichiro

Random telegraph noise (RTN), a physical phenomenon that causes variations in transistor operating current, has become one of the most important issues accompanying the shrinkage of transistors in recent years. In this context, attention is being increasingly focused on the effects of RTN on the properties of complementary metal-oxide semiconductor (CMOS) image sensors and NAND flash memories, particularly those related to reliability.

Toshiba is working to gain a further understanding of the physical mechanisms of RTN to improve the reliability of devices. We have now performed a systematic investigation of trap mechanisms causing RTN through experiments using ultra-scaled planar MOS field-effect transistors (MOSFETs). From the results obtained, we have confirmed that traps causing RTN are mainly classifiable into neutral and attractive traps, that the energy distributions of neutral traps are around 100 meV higher than those of attractive traps, and that neutral traps have a much greater impact on threshold voltage shifts. These results contribute to understanding of the trap forming process, and will assist in guiding optimization of fabrication processes to ensure high reliability.

#### Single-Nanometer-Scale Patterning Technologies Applying Self-Assembling Materials

SASAO Norikatsu / YAMAMOTO Ryosuke / SUGAWARA Katsuya

A self-organizing phenomenon in diblock copolymers, which can spontaneously form regular single-nanometer-scale patterns, has been a focus of attention as a next-generation lithography technology. However, as this pattern formation is the result of a naturally occurring process, it is necessary to control the uniformity and positioning accuracy of such self-organized patterns in order to apply them to the semiconductor device fabrication process.

Toshiba has developed the following technologies for next-generation lithography and beyond: (1) a solvent-annealing method to uniformly arrange self-assembling materials with a dot diameter of less than 10 nm, and (2) a self-organizing technology guided by prepatterns formed on the substrate to control both the uniformity and position of patterns. We have confirmed that precisely oriented patterns can be successfully transferred onto a substrate by utilizing these technologies.

#### Specification Mining Technology for Automatically Inferring Software Specifications from Source Code

IMAI Takeo / SAKAI Masahiro / IWAMASA Mikito

Correspondence between a program and its specification is essential for efficient redesign and reuse of software.

Toshiba has been developing a technology for mining latent specifications from a given program and reflecting them in the original specification documents. This technology enables developers not only to acquire latent information that is useful for future development and reuse, but also to keep specifications up to date. As part of this work, we have developed a new technology for automatically inferring preconditions from programs; that is, conditions that a program assumes in order to perform its intended function. We have conducted experiments on a prototype tool for C language, and confirmed its ability to obtain generic specifications similarly to or more effectively than by human effort.

#### Understanding of Redistribution of Inlet Temperature Distortion in Gas Turbines Based on High-Order LES

Debasish BISWAS

Gas turbines, which serve as combined-cycle power generation equipment along with steam turbines, must operate at high temperatures to achieve high efficiency. In particular, the demand for increased cycle performance of gas turbines creates a severe heat load in the first turbine stage, and the mean flow temperature is usually well above the limit supported by the surrounding materials.

To design efficient cooling of high-temperature gas turbine blades, Toshiba has been developing a numerical simulation technology, based on a high-order large eddy simulation (LES) turbulence model, to understand the physical phenomena associated with the temperature redistribution behavior of the highly unsteady and distorted temperature field from the combustor to the turbine inlet. We have confirmed the effectiveness of our newly developed simulation technology through experiments and simulations, especially in the area of the rotor. This numerical simulation technology is expected to contribute to the development of next-generation gas turbine generators with increased efficiency.

#### Combiner for Head-Up Display Systems Using Translucent Fresnel Reflector

HORIUCHI Kazuo / SHIMAKAWA Shigeru / OKADA Naotada

The introduction of head-up display (HUD) systems, which project images on the windshield of an automobile, is expected to contribute to a reduction of traffic accidents as drivers can see the images with minimal eye movement, allowing them to keep their eyes on the road and background. However, the large size of the projection unit has made it difficult to install HUD systems in a wide variety of automobiles.

Toshiba has developed a combiner for HUD systems equipped with a translucent Fresnel reflector, which reduces the size of the projection unit to about half. The combiner makes it possible to magnify projected images without disturbing the background while maintaining the image quality, though the use of a newly developed technology to decrease ghost images.

#### Rationalization of Global Supply and Demand Planning Utilizing Combinatorial Auction Method

MURAO Ryo / KOGA Yasutaka / SAKURAI Yuki

With expanding scale and complexity of supply chains in recent years together with the globalization of manufacturing and sales sites, totally optimized planning of supply and demand has been becoming increasingly difficult. Even if planning can be optimized, it is also difficult to realize it on a practical level without building win-win relationships among a number of internal and external partners. Accordingly, not only methods for optimization and but also those for the coordination of opposing interests are essential for future supply-chain management.

Focusing on a combinatorial auction (CA) method inspired by sociology, which is one of the optimization methods based on the multi-agent system, Toshiba, in cooperation with Kobe University, has developed a supply and demand adjustment method that can visualize adversarial relationships among manufacturing and sales sites and provide information to improve the quality of decision-making.

#### Degradation Diagnosis Technologies for Power Distribution Facilities

MURAYAMA Kiyoko / TAMURA Tamami / MIZUIDE Takashi

The degradation of power distribution facilities depends on various conditions including the installation environment, usage status, implementation of maintenance and inspection, and so on, in addition to the duration of operation. Quantitative degradation diagnosis technologies have recently become a focus of rising expectations because gaining a correct understanding of the condition of deterioration of each piece of equipment of a power distribution facility is essential for the planning and implementation of facility maintenance and preventive measures.

Toshiba has developed two new degradation diagnosis technologies for power distribution facilities: a remaining-life assessment technology that estimates insulation resistance from the physical properties of materials used in power distribution equipment, and a grease degradation diagnosis technology that monitors the degradation index of the viscous resistance of grease used in switching devices. These technologies are contributing to the planning and implementation of maintenance and preventive measures for power distribution facilities.

## Frontiers of Research & Development

Color Filter Design Technology for CMOS Image Sensors Employing Photonic Crystal Structure