Achieving Eco-power by Implementing Smart Power Controls

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OVERVIEW: With global population growth and rapid industrial expansion, global warming has become a worldwide concern. Given this situation, there is an increasing need for a smart grid system which will help reduce greenhouse gas emissions. Hitachi is developing technologies that will increase overall power supply safety and eco-friendliness. These include reducing CO_2 emissions from thermal power plants, a next generation of total monitoring and control systems to increase nuclear power plant operating stability, and power conditioning for wind turbine output voltage and frequency stabilization.

INTRODUCTION

IN other countries, especially those with developing economies, energy demand is increasing sharply. In Japan and other industrial nations, more prosperous and convenient lifestyles, an aging population, and increasing use of electronic and electric devices are expected to grow electricity needs steadily. At the 2009 UN Climate Change Conference in Copenhagen, a target to reduce GHG (greenhouse gas) emissions by at least 50% by 2050 was discussed in order to mitigate global warming. This would require developing improved power plants with lower emissions while maintaining a stable energy supply. Our current society relies heavily on fossil fuels such as coal, natural gas, and oil. However, if a "best mix of power" in which renewable energy and nuclear supply 70% of electricity needs is established by 2050, this target is achievable (see Fig. 1). To help achieve this target, Hitachi has developed ABWRs (advanced boiling water reactors), FBRs (fast-breeder reactors), and highly efficient coal-fired plants including IGCC (integrated coal gasification combined cycle). Hitachi has also been developing renewable energies such as solar and wind power generation, power storage systems, and CCS (carbon capture and storage). Power control systems are very important for monitoring and controlling this "best mix of power." In addition, achieving stable power operation must not compromise the aims of reducing costs, protecting the environment, and achieving efficient, safe and reliable operation.

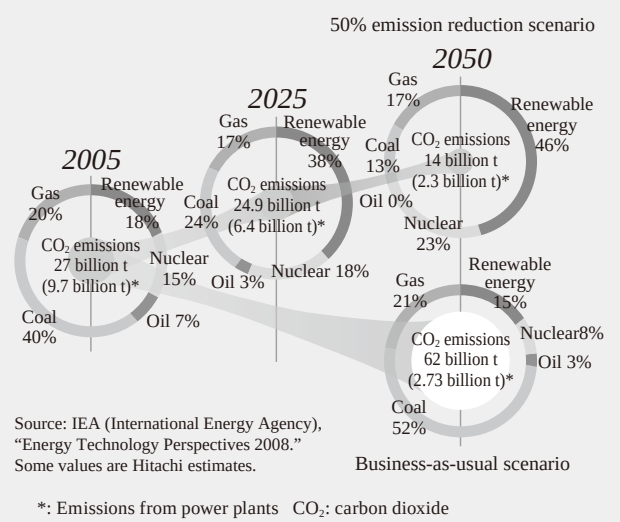

Fig. 1—Two Scenarios for Global Electricity Supply Mix and CO_2 Emissions.
One scenario shows the outlook for CO_2 emissions under the 50% emission reduction scenario (top) and the other is a business-as-usual scenario (bottom) together with the associated mix of energy sources.

This article describes Hitachi's latest environmentally conscious thermal power plant system, nuclear power plant control system, wind farm control system, plant diagnosis system, and RFID (radio-frequency identification) system.

RESPONDING TO ENVIRONMENTAL CONCERNS AND POWER DEMAND

Environmentally Conscious Thermal Power Plant Systems

Energy-efficient inverter system that reduces CO_2 emissions

Thermal power plants, particularly coal-fired plants, need to incorporate greater environmental protection measures. Hitachi is working on the use of inverter drives for electric motors to reduce CO_2

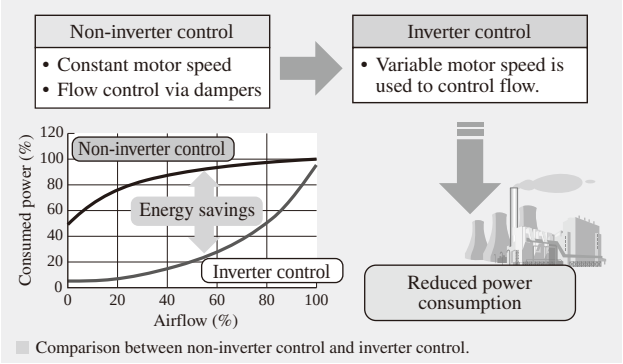

Fig. 2—Energy Savings Achieved by Inverter Control.
Using inverters for flow control in place of damper systems reduces power consumption.

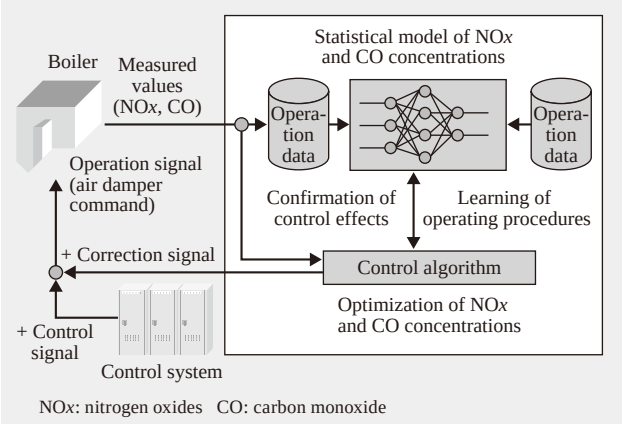

Fig. 3—Configuration of Control System for Reducing Environmental Impact.
Self-tuning control with reinforcement learning provides corrective values which optimize the concentrations of NOx and CO.

(carbon dioxide) emissions. Hitachi has already used inverters to drive FDFs (forced-draft fans) and IDFs (induced-draft fans) in boiler systems and condensate pumps and in turbine condensate booster pumps. In one 600-MW oil-gas thermal power plant, a 5,500-kW FDF inverter reduced CO_2 emissions by 30% when operating at rated load and by 90% at minimum load. Hitachi plans to increase the number of plants using inverters in order to make further reductions in CO_2 emissions (see Fig. 2).

Control system for reducing environmental impact (for NO*x* and CO)

The US Clean Air Act enacted in 2009 imposed strict regulations on the emissions of thermal power plants such as CO (carbon monoxide), NO*x* (nitrogen oxides), SO*x* (sulfur oxides), and Hg (mercury). Two types of control systems can be used to reduce environmental impacts. One type seeks to reduce the CO and NO*x* emissions of coal-fired plants and the other seeks to reduce the CO_2 emissions of all plants by improving their performance. Hitachi has developed a statistical model with an auto-switchover function as well as a reinforcement learning algorithm for self-tuning control, both of which are currently being tested at an operating coal-fired plant (see Fig. 3).

CCS control

Hitachi has been developing CCS technology. As a builder and turnkey EPC (engineering, procurement, and construction) supplier of thermal power plants, Hitachi is uniquely well-positioned to integrate CCS control with regular operations control. Leveraging this dual capability, Hitachi is currently studying the feasibility of combining control of the boiler, steam turbine, and gas turbine with CCS control while maintaining safe and efficient operation.

Stable Operation of Nuclear Power Plants

New nuclear power plant control systems

Hitachi is developing a new generation of total monitoring and control systems for NPPs (nuclear power plants) in order to compete globally and satisfy the global market. The main design philosophy is "convergence of information and control" (see Fig. 4) to realize highly efficient "smart NPPs." Hitachi has over 30 years of experience with these types of digital system. Because International Electrotechnical Commission (IEC) FS (functional safety) standards are being widely adopted, Hitachi is also developing and introducing FS-certified control platforms for

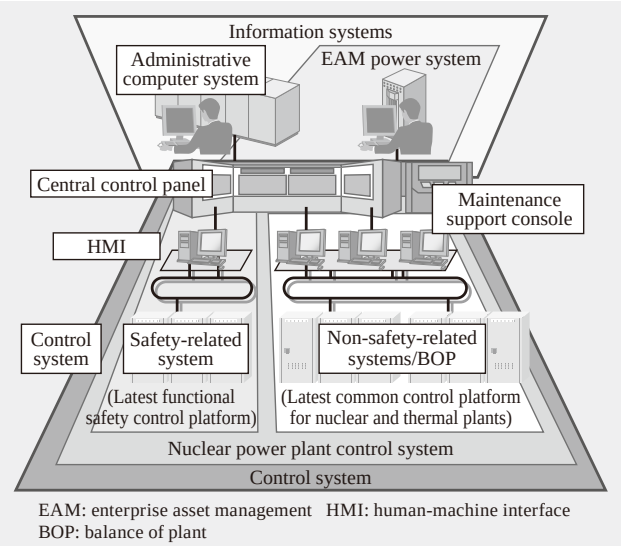

Fig. 4—Concept behind Control System for New Nuclear Power Plants.
This figure shows an overview of an information and control system for smart NPPs.

safety-related systems in a step-by-step way. For BOP (balance of plant) systems, Hitachi is following current global trends by developing a common control platform for thermal plants and nuclear plants. Hitachi also intends to enter the enterprise support services business (specifically plant information systems) by developing a power generation EAM (enterprise asset management) package for storing plant data and information as well as supporting equipment and facilities management.

Functional safety controller

In order to respond to market demand for functional safety systems, Hitachi has developed the R800FS/HSC800FS functional safety controller which has been certified compliant with IEC 61508:2010 (Ed. 2.0) SIL (Safety Integrity Level) 2 by TÜV Rheinland*[1]. Controllers are required to meet high functional safety standards to avoid unintended unsafe plant situations. To satisfy these requirements, the R800FS/HSC800FS incorporates advanced self-diagnostics and a fail-safe design that keeps plant outputs safe in the event of a fault. The R800FS controller uses dual Renesas Electronics Corporation SuperH*[2] CPUs (central processing units). These LSIs (large-scale integrated circuits) permit execution of high-speed parallel processing. The RIO (remote input/output) units of the HSC800FS also incorporate SuperH LSI cores and feature sophisticated self-diagnostics. To satisfy not only safety requirements but also general requirements, the R800FS/HSC800FS can execute both safety tasks and general tasks, control up to 4,000 RIOs, connect to information and control networks, and support system redundancy. The R800FS/HSC800FS is also certified compliant with CAN/CSA E61131-2 and UL508, and complies with the IEC 61131-2 EMC (electromagnetic compatibility) standard and IEC 61131-3 programming language standard (see Fig. 5).

Fig. 5—R800FS CPU (central processing unit) (left) and TÜV Rheinland SIL2 Certificate.

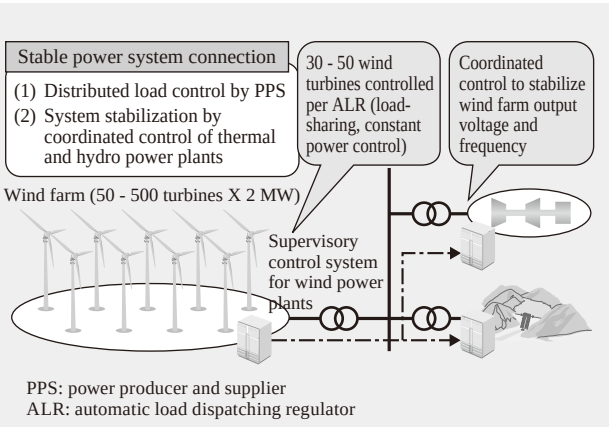

Fig. 6—Wind Farm Control System.
Hitachi has drawn on its expertise in conventional power systems to stabilize wind-generated power.

Wind Turbine Control System

Japan's plan to increase significantly the use of wind power in its national grid has created a need for technologies that can control output fluctuations and stabilize grid voltage and frequency. Due to the wind's inherent unpredictability and variability, wind farms do not output a constant level of power. To cope with this, some wind farm plants are now equipped with storage batteries. Outside Japan, especially in China, there are limited power transmission lines to sites suitable for wind farms, so controlling output fluctuations is important. Lead-acid storage batteries and NaS (sodium-sulfur) batteries have been developed to smooth wind farm output by controlling output fluctuations. Hitachi is developing and evaluating its own output fluctuation control system for wind farms that uses an overall wind farm output stabilization system to coordinate the individual wind turbine control systems (see Fig. 6).

SAFETY

In addition to stable and environmentally conscious operation, safety is also an essential concern for operating power plants. In response, Hitachi has developed and implemented the following systems.

Plant Diagnosis System

Power plants must understand their operating conditions hour-by-hour and schedule timely maintenance based on this understanding. Hitachi has developed a plant diagnosis system which uses plant

*1 TÜV Rheinland is a registered trademark of TÜV Rheinland.
*2 SuperH is a registered trademark or trademark of Renesas Electronics Corporation in Japan, the USA, and other countries.

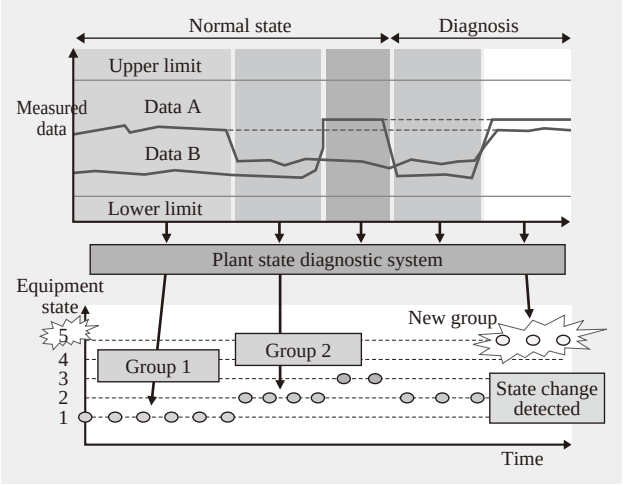

Fig. 7—Plant Diagnosis System.
ART (adaptive resonance theory) allows user-friendly plant diagnosis.

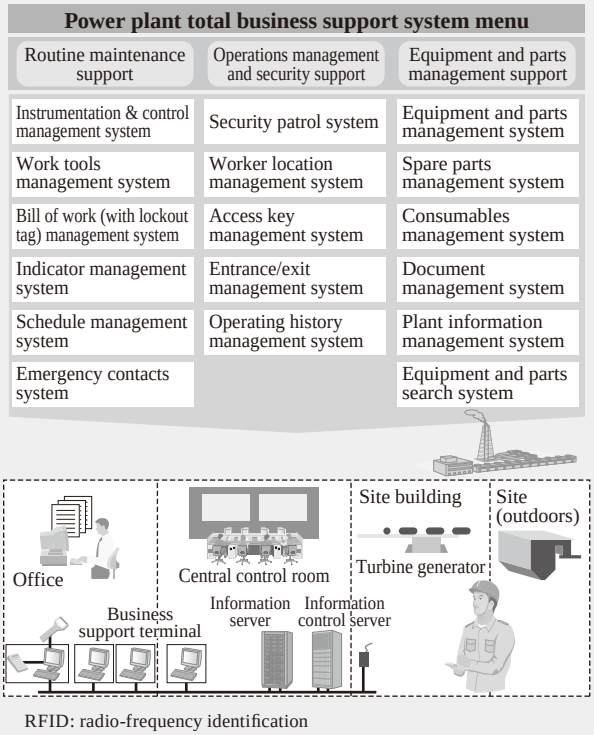

Fig. 8—Periodic Inspections Assistant System Using RFID. This integrated business support system for daily plant operation uses RFID technology.

operating data to diagnose the plant operating status automatically. The system was developed based on Hitachi's extensive experience with handling thousands of plant data points in many operating plants. Using ART (adaptive resonance theory), the plant diagnosis system gathers plant data and automatically diagnoses the plant's condition online. ART uses collected online plant data to classify (define) the condition of the plant by saving each unique set of data as a group. A new group is created whenever the gathered online data does not match an existing group. The creation of a new group is interpreted as a change from the normal (historical) behavior. The system is easy to use and does not require complex operating practices (see Fig. 7).

RFID System

To ensure reliable operation, periodic inspections in which the plant is shut down, disassembled, checked, repaired, and rebuilt are an essential part of the total plant life cycle. These periodic inspections require people with a high level of knowledge about the plant's instrumentation, equipment, systems, and processes. Also, in order to ensure the quality and efficiency of field work, personnel training must be a high priority. To cope with the challenges posed by these periodic inspections, Hitachi has developed the periodic inspections assistant system by combining RFID and IT (information technology) systems (see Fig. 8).

CONCLUSIONS

This article has described Hitachi's solutions for environmentally conscious thermal power plants, stable operation of nuclear power plants, systems for stabilizing the output of wind farms, an ART-based plant diagnosis system, and the periodic inspections assistant system which uses RFIDs and IT. Hitachi will further develop and enhance new and existing technologies in order to continue contributing to the global supply of reliable electric power.

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