Current Status and Prospects of Measurement and Control Technologies

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ABSTRACT

In order to realize a safe and reliable sustainable society, measurement and control technologies are essential. Fuji Electric has developed measurement and control technologies in many fields including power, industrial, water treatment, and commercial fields and achieved good results. In accordance with Japan's New Growth Strategy and Basic Energy Plan, as well as global market and technological developments, we are moving forward with technological development focused on energy and environment. The key for these technologies is to create them smarter, safer, and greener. We are pushing forward with approaches for solutions that achieve the optimal service and operation of energy supply, distribution, and up to the demand side, realize energy conservation, resource conservation, and decrease the environmental burden, and that ensure safety and peace-of-mind.

1. Introduction

Fuji Electric has previously developed measurement and control technology for realizing power savings, automation, higher efficiency and higher reliability in public infrastructure for power, transportation, water treatment, etc., in industrial fields such as for steel, chemical, automotive, electrical and electronic equipment, and in consumer fields for buildings, stores, vending machines, automotive devices, etc., and has realized many pioneering achievements. Aiming to realize measurement and control technology that will contribute to solutions to such social challenges as global warming, declining birthrates and aging populations, and the realization of safety and peace-of-mind, and such management challenges as globalization and increasing competitiveness, Fuji Electric is presently advancing technical development with a focus on the fields of energy and the environment. Additionally, in the wake of the Great East Japan Earthquake, Fuji Electric is attempting to initiate new efforts to realize a sustainable society.

This special issue introduces measurement and control technology for realizing energy conservation and societal safety and security, as well as solutions that use this technology. In this paper, Japanese strategic and global technical trends and issues relating to the manufacturing industry and concerning measurement and control technology, as well as the corresponding efforts by Fuji Electric are described.

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2. Trends and Issues for Measurement and Control Technology in The Global Market

2.1 Japan's New Growth Strategy

In June 2010, the Japanese Cabinet approved the "New Growth Strategy: A Scenario for Revitalizing a Strong Japan" consisting of the following seven strategies.

(a) National Environment and energy strategy based on green innovation
(b) National health strategy based on life innovation
(c) Asian economic strategy
(d) National tourism policy and regional revitalization strategy
(e) Science, technology and information communication strategy
(f) Employment and human resources strategy
(g) Financial strategy

Additionally, in order to promote these initiatives effectively, 21 national strategic projects having particularly strong potential to contribute to economic growth were selected. Of these projects, the following are noteworthy for their potential to contribute to measurement and control technology.

(1) Rapid increase in renewable energy due to adoption of "feed-in tariff"
(2) "Future Environmental City" concept

2.2 2011 Basic Energy Plan and Energy Conservation Technology Strategy

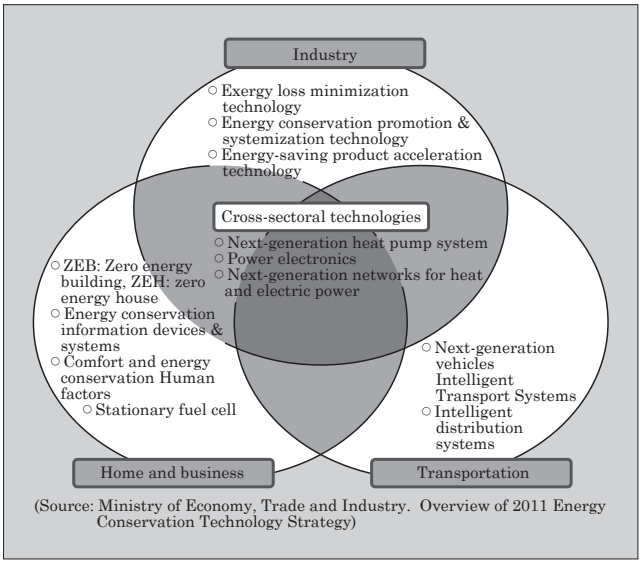
In June 2010, a comprehensive review of Japan's Basic Energy Plan was conducted. However, further review is necessary in light of the Great East Japan Earthquake and the accident that it caused at the Fukushima Daiichi Nuclear Power Station. In addition to the basic energy policy of the "3Es" (energy security,

environmental protection (global warming prevention), and efficient supply), policies for realizing economic growth centered on energy and for restructuring the energy industry have been newly added. Also, increasing the percentage of self-supplied energy and in the percentage of zero-emission power sources*1, maintaining and strengthening the world's highest level of energy utilization efficiency in the industrial sector, and the like have been set as targets for the year 2030.

In March 2011, the Japanese Natural Resources and Energy Agency established the "2011 Energy Conservation Technology Strategy," which identifies key fields that contribute significantly to energy conservation, an important element of the Basic Energy Plan[4]. Based on a review of all aspects of the previous strategy, policies that exhibit a significant energy conservation effect as a result of the systematizing of various technologies, technologies that contribute to the manufacture and dissemination of products having an extremely high energy conserving effect when used, policies that pursue the development of energy conservation from entirely new perspectives etc. were identified to enable energy conservation from unconventional viewpoints.

Moreover, among the important technologies shown in Fig. 1, in addition to the technologies shown in the industrial sector, home and business sector and transportation sector, power electronics technology, such as high-efficient inverters, and next-generation network technology for thermal and electric power, such as a next-generation energy management system (EMS) for optimizing the regional usage of energy, are cited as technologies that span across sectors, and are expected to contribute with measurement and control technology.

*1: Zero-emission power source: A power source originating from nuclear power or renewable energy such as solar, wind, geothermal, or biomass power.



(Source: Ministry of Economy, Trade and Industry. Overview of 2011 Energy Conservation Technology Strategy)

Fig.1 Key technologies in the 2011: Energy Conservation Technology Strategy

2.3 Trends of measurement and control technologies

Recent trends of measurement and control technologies in the global market are discussed below.

(1) International standardization

Standardization of energy and industrial processes in the measurement and control field is actively being advanced mainly by International Electrotechnical Commission (IEC) standards such as TC8, TC59, T65 and TC95. International standardization is also actively being pursued from the perspectives of electronics, networking, wireless systems for industrial automation, and systems. Smart grid support is actively being advanced primarily by National Institute of Standards and Technology (NIST) in the US in conjunction with IEC. Standardization of wireless systems for industrial automation is being advanced through Wireless-HART from the HART Communication Foundation and SP100 from the International Society of Automation (ISA). As a method of local communication for the remote reading of gas meters, Japan has proposed a multistage radio relay method based on IEEE 802.15.4 g. For the safety of machinery and equipment, standardization in various fields and devices is being advanced with ISO 12100 (machinery safety) and IEC 61508 (functional safety of electrical systems) positioned as upper-level standards, and safety instrumented systems and the like are being introduced in Japan.

For EMS, standardization similar to that of ISO 9000 for quality management and ISO 14000 for environmental management was promoted, and went into effect as ISO 50001 in June 2011.

(2) Sensor technology

From the perspective of safety and security in response to a major earthquake or accident, radiation dosimeters, seismographs and gas detectors, and the like have attracted attention. Additionally, from the perspective of addressing global warming and environmental issues, electric power smart meters, and exhaust gas analyzers for plants and incinerators have also attracted attention. On the other hand, in order to simplify installation and maintenance, long-term and maintenance-free operation with wireless sensors and batteries or self-supplied power are required. To achieve these goals, micro electro mechanical systems (MEMS) (see "Supplemental explanation 1" on page 46) technology is used to achieve miniaturization and power savings.

(3) Control technology

Since the 1990s, model predictive control, neural networks, optimization technology and the like, together with information technology, have been applied to home appliances, automobiles and other such products in industry and society, and have contributed significantly to improved control performance and energy

conservation. On the other hand, due to sluggish demand stemming from the collapse of Lehman Brothers, production systems are desired to have the capability to respond to fluctuations in production volume at low cost. As a means for realizing this, the proper adjustment and use of PID controller parameters, together with methods for control performance monitoring, modeling in a closed loop and parameter adjustment are again attracting attention.

(4) Smart grid and smart community technology

Smart grids got their start as next-generation transmission and distribution networks that utilize information and communication technologies. This concept has been extended to the creation of eco-friendly urban spaces (smart communities and smart cities) enabled by smarter electric power, as well as a smarter overall public infrastructure of heat, gas, water, etc. Field tests are being carried out in Japan in such cities as Kitakyushu and Yokohama. Funded by investments that are a magnitude of order larger, smart grid and smart community projects overseas in China, India and the Middle East are moving forward as part of new urban development.

In preparation for a rapid increase in the adoption of distributed power sources such as solar power and wind power in the future, measurement sensors for the fine-grained control of power distribution systems, control technology for control terminals and next-generation power distribution systems, as well as a cluster energy management system (CEMS) regional level energy management system are being developed.

(5) Energy management system (EMS)

Efforts aimed at introducing renewable energy such as solar power and realizing energy savings are progressing. To realize such goals, the overall energy supply and demand must be managed and operated integrally or in a concerted manner, and EMS fulfills that role. In addition to the conventional types of EMS for building and factories, i.e., building EMS (BEMS) and factory EMS (FEMS), development is being advanced for specific applications such as CEMS at the regional level, retail EMS (REMS) for retail distribution, home EMS (HEMS) for homes, etc.

2.4 Changes in the business environment and challenges

Recent changes in the business environment for Fuji Electric's customers, especially in the manufacturing industry, and the accompanying major challenges and needs are described below.

(1) Support of sustainable environment and society

In addition to the energy conservation initiatives traditionally promoted in order to mitigate global warming, even further power conservation is required in Japan. Specifically, in the summer of 2011, each customer within the Tokyo and Tohoku Electric Power service areas was requested to reduce their maximum power consumption by 15% compared to the year 2010. Equipment and device miniaturization and power conservation, which have be promoted previously, the continuous monitoring and improvement of operating efficiency, and the efficient operation of privately owned power generation facilities, including peak shifting and utilization of new energy sources, have become necessary. Moreover, in consideration of new reconstruction in the Tohoku region, efforts must be made to realize a sustainable society rather than merely implement temporary measures. As an effective means for popularizing electric vehicles and plug-in hybrid vehicles (PHVs), there is also a need to move ahead with safe and highly efficient vehicle-side drive control technology as well as establishment of infrastructure such as rapid charging stations. From the environmental perspective, measurement of low concentrations and trace components in gas emissions and waste water from businesses is needed in order to comply with hazardous substance regulations (air pollution, water quality pollution, RoHS*2, REACH*3, etc.).

(2) Ensuring high reliability and safety

Field equipment is becoming more and more complex and sophisticated. Meanwhile, in Japan and other developed countries, the experts who carry out field work are aging and retiring one after another, and there is concern about the ability to respond in the event of emergencies. Therefore, equipment is required to be highly reliable and safe, and operation support technology for the early detection of signs of abnormalities, estimation of the service life of facilities and equipment, and so on is anticipated so that preventative measures can be implemented before a failure occurs. Furthermore, in addition to traditional reliability, system availability must be improved, and design technology for enhanced fault-tolerance, earthquake resistance and the like is required. Moreover, tasks must be simplified so that new workers can engage in their work after receiving only short-term training, and facilities and equipment that are safe and can be operated easily even by non-experts are needed. To attain these goals, ensuring safety by providing intelligent functions such as self-diagnosis and functional safety on the equipment side for assisting workers and by monitoring their health and state of consciousness is required.

(3) Support of flexible manufacturing systems

Because of reduced demand and a supply shortage of raw materials and electrical power, the manufacturing industry is being forced to cut back on production or to transfer the production to other sites. Manufacturing facilities and operational control are often designed on the assumption of maximum production

*2: RoHS directive: EU (European Union) restriction on the use of certain hazardous substances in electrical and electronic equipment

*3: REACH: EU (European Union) regulation concerning the registration, evaluation, authorization and restriction of chemicals

volume, and if the production volume is limited, energy efficiency may decrease, and the control system stability and control accuracy may not be maintained. In situations with an uncertain outlook, a measurement and control system that supports a flexible production system and that is stable and has hassle-free maintenance is required. Furthermore, production sites and production lines must be able to be built, modified and moved quickly and at minimal cost. For this reason, equipment modularity, generalization and portability are advancing trends. For this purpose, field devices that use less wiring or that are provided with wireless capability, and devices having a plug-and-play function enabling operation simply by connecting equipment are required.

(4) Support of a global business environment

In the manufacturing industry, products designed for key markets must to be supplied to those markets in a timely manner, and the locating of production sites, development sites and business sites near the desired markets is a progressing trend. On the other hand, there is an ongoing trend of production sites being consolidated in countries and regions having low costs, such as low labor cost. In response, technology for the integrated management of distributed sites, global supply chain management, security, the protection of intellectual property and the like has become important. Additionally, because of the intermixing of workers of different cultures, work standardization and work history management must be performed on the basis of a mutual understanding and respect of different cultures, and worksite equipment must be designed with greater levels of safety than in the past.

3. Fuji Electric's Efforts in Measurement and Control Technology

In response to the challenges described in section 2, future measurement and control technology is required to provide solutions that contribute to improving management competitiveness through "visualizing" processes and production, and realizing operation that is "more comfortable, conserves energy and is safe." The trend toward physically distributed and autonomous devices and components is progressing, and meanwhile, system standardization and a seamlessly integrated environment from the perspective of engineering services are required. In accord with these factors, as shown in Fig. 2, Fuji Electric is moving ahead with technical development and product commercialization by working to enhance smartness, safety, and greenness.

Enhanced smartness means to make devices that are smaller and that consume less power, as well as to increase the efficiency of advanced information processing functions for optimal plant operation and the like, and to increase the business and operating efficiency. Enhanced safety can be realized through efforts to ensure safety and security by supplying a functional safety system that supports high reliability design, fault tolerance, and international standards. Enhanced greenness is an eco-friendly initiative that involves the measurement of energy and environmental impact, and efforts to realize energy conservation, resource conservation, and so on. These development and commercialization efforts will be realized based

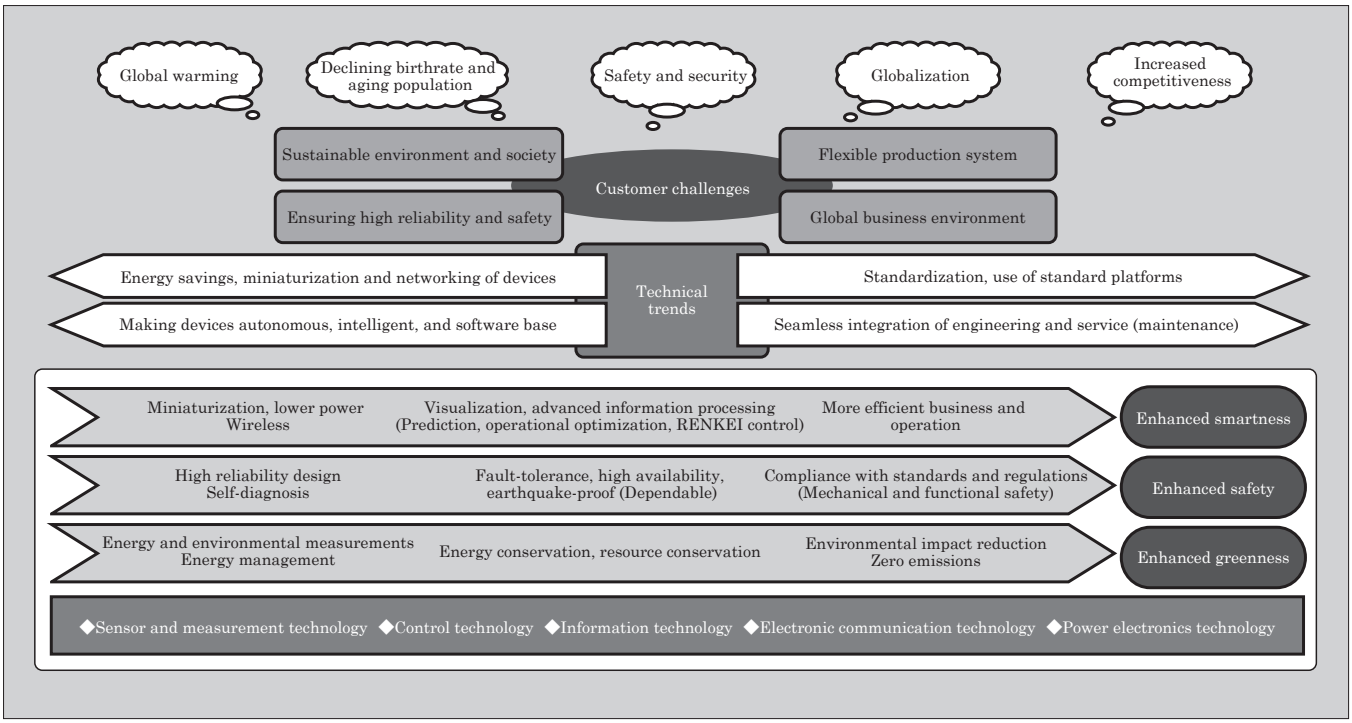


Fig.2 Fuji Electric's targeted measurement and control technology

not only upon sensor and measurement technology and control technology, but also on core technologies such as information technology, electronic communication technology and power electronics technology.

As shown in Fig. 3, Fuji Electric's business areas can be divided into the following three regions: an energy supply (energy creation) side for geothermal power plants, fuel cells and the like; a demand (energy conservation) side for steel, electronic device, machine, food, and chemical industrial fields, retail distribution, internet data centers (IDCs) and the like, and; a distribution side (connection) for linking the supply and demand sides. Product development for optimal and safe operation, extending from the energy supply side to the distribution and demand sides, and for realizing solutions focused on energy conservation, resource conservation and reduced environmental impact is being advanced at each hierarchical level, from devices and modules to component productions, system products and solution products. Additionally, efforts for achieving a "global Fuji Electric" are being advanced more than ever before. In pursuit of "glocal" development that meets the needs of local regions worldwide (globally), Fuji Electric has established development sites in China, the US and Europe to enhance local development.

Specific examples of these efforts are described below.

3.1 Sensor technology

MEMS devices are an effective means for realizing power savings and resource savings in the sensors and actuators used to constitute control systems. Fuji Electric has long been committed to MEMS technology, and has developed and commercialized such products as measurement devices, radiation dosimeters, gas analyzers and the like that incorporate MEMS technology. Recently, Fuji Electric has been working on the development of high-speed and high-sensitivity multi-component gas analyzers, battery-operated methane sensors that can be incorporated into gas alarm unit, high performance vibration sensors for detecting abnormalities or signs thereof in buildings and for diagnosing the integrity of those structures, and vehicle-mounted pressure sensors for use in various types of control applications, and has achieved significant success in realizing miniaturization and power savings.

In the field of radiation measurement, based on case studies at nuclear power plants, an earthquake-proof body surface contamination monitor that will continue to operate even in the case of a magnitude 7 earthquake has been developed in order to ensure greater safety. This device has been installed at the boundaries of radiation controlled areas in nuclear power plants, and measures the surface contamination of radioactive material on the body of a worker exiting the controlled area. Furthermore, for the environmental radiation monitoring equipment, various emergency measures are being implemented so as to allow monitoring and measuring operations to continue even when an earthquake occurs. Also, in recent years, management of pipe wall thickness has become necessary in order to ensure stable operation at power plants, and Fuji Electric has developed a new radiation transmitting-type pipe thickness measurement system. This pipe thickness measurement system utilizes a 3-beam calculation method to improve the measurement performance, and is able to measure a thickness profile through heat insulating material.

3.2 Control technology

Control technologies that perform optimization and

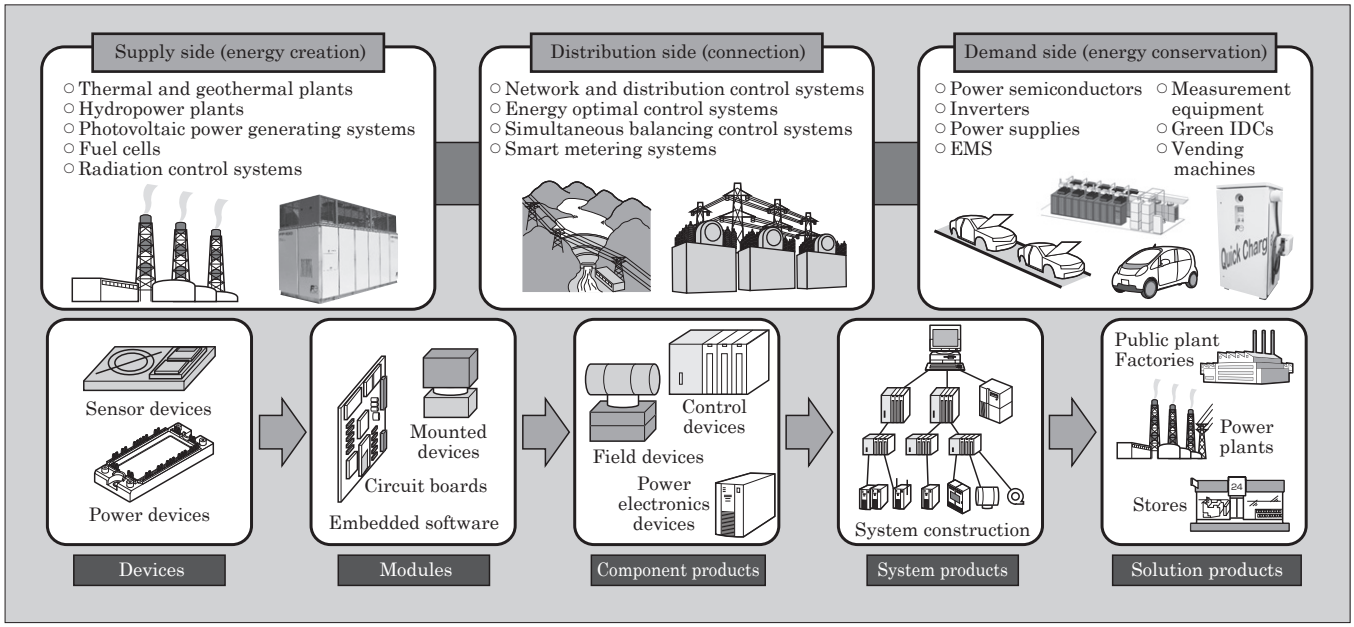


Fig.3 Energy and environment business areas and product hierarchy

that make predictions and diagnoses are core technologies for realizing energy savings and enhanced safety in equipment and plants. Fuji Electric has been engaged in the development of such control technologies for many years as core technologies. Among these, Fuji Electric has focused on PID control technology for single-input, single-output systems, model predictive control technology for multivariable systems, neural network technology for predictive and diagnostic applications, multivariate statistical process control technology, and nonlinear optimization technology for optimizing large-scale complex problems such as power networks. For model predictive control, even further improvement in control performance was realized by implementing the control in a programmable logic controller (PLC) so that the control can be used in applications requiring long-term stable operation, and by employing an external disturbance rejection method using an observer. Moreover, many control systems are said to exhibit control performance degradation and a lack of adjustment due to changes in the characteristics of the controlled object, and in response Fuji Electric has also developed a control performance monitoring function.

3.3 Monitoring and control system

Fuji Electric has delivered its "MICREX-NX" distributed monitoring and control system for medium and large-scale applications to many plants, including steel mills, water treatment plants, chemical plants, etc. With the MICREX-NX, safety instrumented functions and general instrumented functions can be mixed on the same controller and engineering tools. Using this feature, a safety instrumented system for a gas production plant has been built and delivered.

To lower the cost for small and medium-scale applications, Fuji Electric has developed the "MICREX-VieW," a common platform for monitoring and control. With an emphasis on ensuring compatibility with preexisting monitoring and control systems made by Fuji Electric, the MICREX-VieW has been designed as a system that inherits the various assets of existing systems. Moreover, redundancy of the operator stations, databases, control LANs, controllers, I/O units and other various devices that constitute the system is also possible individually. Thus, not only can a highly reliable system be newly constructed, but a system can also be updated gradually in stages with a flexible configuration. For small-scale applications, Fuji Electric has also developed the "MICREX-VieW Compact" system that combines a general-purpose PLC and a programmable display. By generating programs from control function specifications such as instrumentation flow diagrams and logic diagrams created with Visio*4 office automation software, these monitoring and control systems can realize an integrated environment that facilitates engineering work.

In the field of machinery control, which includes control for steel rolling mills, metal processing, printing, packing and the like, high-speed, high-accuracy multi-axis synchronous control systems are required. To realize such drive solutions with a general-purpose PLC, Fuji Electric has developed the "E-SX bus," a proprietary network that enables high-speed, high-accuracy multi-axis synchronous control and large capacity I/O control, and also the "SPH3000MM," a new high-speed CPU module equipped with the E-SX bus.

3.4 Wireless communication technology

For wireless technology, Fuji Electric established a platform that facilitates the development and construction of wireless systems that conform to the ISA 100.11a wireless standard for process automation. ISA 100.11a is a wireless networking standard that combines the highly reliable performance and real-time performance essential in industrial environments. A wireless network system conforming to this standard can be installed at locations in factories or plants where a wired network would be difficult to construct, and may be used for temporary installations during construction or for testing, thereby enabling systems to be constructed with an increased degree of freedom.

Smart metering technology is an important factor for realizing smart communities. Based on technology developed for electric energy meters and remote metering system, smart metering technology capable of bidirectional communication between electric utilities or gas companies and individual consumers is being developed by Fuji Electric. As wireless communication technology for smart metering, a method for multi-stage relay wireless operation with ultra-low power consumption for long-term battery-powered operation has been developed. This method is being advanced for international standardization as IEEE 802.15.4 g.

3.5 EMS platform

Fuji Electric has previously developed EMSs for various uses in the fields of electric power, steel mills, water treatment, retail distribution and so on. A platform that integrates these EMSs of different fields so that CEMS, FEMS, BEMS and REMS can be used with a common mechanism to construct systems efficiently has recently been developed. Through handling various energy models for electric power, heat, gas and the like, this platform enables visualization, energy management and energy conservation RENKEI control. The Web screen supports multiple languages, and systems ranging in size from small-scale systems of a single server to large-scale systems of several tens of servers can be constructed with the same engineering tools.

*4: Visio is a trademark or registered trademark of Microsoft Corporation and its affiliates.

4. Future Outlook

Needless to say, the importance of using renewable energy and of conserving energy will continue to increase in the future, and measurement and control technology will play a large role in the effective and safe implementation thereof.

In present-day measurement and control systems, the integration of engineering is progressing but the engineering work as well as operation and maintenance work still impose a large burden. Development is underway to realize the following types of functions in next-generation systems.

(a) Functionality that, in addition to measuring an object or system to be controlled, also performs data consolidation, and provides easy-to-understand directions without a difficult operation (improved visualization and operating ease in next-generation equipment)
(b) Ability to add, modify and automatically setup devices and functions while the system is running (plug-and-play functionality)
(c) Wireless and self-powered sensors and measurement devices
(d) Control scheme that does not require re-adjustment (maintenance-free control)
(e) Intellectual property protection of software assets, including embedded software

5. Postscript

Fuji Electric's efforts and outlook for measurement and control technology have been described herein based on Japan's strategies for growth and technology relating to energy and the environment, and on global market and technological trends.

To mitigate global warming, a reduction in CO_2 equivalent greenhouse gas emissions worldwide to at least 50% of 1990 levels is needed by 2050. In response to the accident at the Fukushima Daiichi Nuclear Power Plant, each nation is changing their approach to nuclear power and cannot continue with an extension of their current efforts. New measures and policies, including a review of our current lifestyles, must be carried out in order to realize these aims.

With measurement and control technology positioned as a supporting pillar of our energy and environmental business, Fuji Electric intends to contribute to the realization of a safe and secure sustainable society.