Present Status and Future Outlook for Smart Communities

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ABSTRACT

The development of smart communities that provide low-carbon, highly convenient urban infrastructures are a global trend enabled by the adoption of smart power grids, efficient energy use, a stable supply of water and the like. Fuji Electric, which specializes in the core technology of power electronics, is working to broaden the range of available smart community products related to public infrastructure. These products have a uniform interface, and are all controlled by an integrated energy management system (EMS) that allows for the simultaneous realization of energy visualization and optimal operation of equipment. The promotion of overseas exports is also under consideration as a way to expand the smart community business further.

1. Introduction

In recent years, with the rapid industrialization and population growth in the emerging nations of China, India and elsewhere, demand has increased for primary energy, including crude oil and natural gas, and the resulting higher prices and supply instability have led to problems. On the other hand, in the developed nations of Japan, Europe and North America, in addition to the popularization of electric vehicles and the expanded usage of solar power and wind power, "smart grid" technology that combines electric power grids with information technology to dramatically increase the power supply capability and usage efficiency is becoming a strategic technology for enhancing international competitiveness.

With the widespread usage and interconnection to power grids of distributed power sources and electric power storage systems among end-users, the flow of power, rather than being unidirectional from the power plants of electric power companies to end-users, is becoming a bidirectional flow or is flowing back and forth among end-users. A smart grid is a power grid provided with a function for performing optimal supply/demand control of electric power.

Moreover, with a smart grid, since the grid is distributed at the regional level and is able to accommodate distributed power sources providing large amounts of regional power resources such as solar, wind and biomass power, the regional energy independence can be enhanced significantly. Thus, the benefits of a smart grid are that in the event of an earthquake or other regional disaster, the risk of damage to the energy infrastructure is distributed, and the supply of energy to important regional sites can be restored rapidly by using diversified local energy sources.

Furthermore, by incorporating the smart grid concept, expanding the utilization of various types of energy, and through utilizing buildings having a highly efficient energy savings function, highly efficient transportation systems and stable and safe water supply systems, urban development and urban regeneration projects are being planned and being carried out as "smart communities" for realizing a low-carbon and highly convenient urban infrastructure.

In projects related to such smart communities, IT companies are active participants. Moreover, because smart communities involve national energy policy and growth strategy, the advancement of smart communities has expanded into a global movement.

In Japan, since 1980, in initiatives led by the national government or electric utility companies, various technical measures have been developed for improving power supply reliability and expanding usage of renewable energy, and various efforts have been advanced for improving the sophistication of power grids. Furthermore, in response to recent global trends, various national projects are being advanced, including national smart community demonstration projects targeting energy infrastructure exports to foreign countries, and investigations of urban infrastructure construction in emerging countries.

Through previous efforts, primarily through collaborative development with domestic Japanese power companies to develop automation systems for distribution systems and remote meter reading systems for power meters, Fuji Electric has accumulated products, technology and know-how relating to the advanced operation of power grids. Moreover, Fuji Electric participated in the "Demonstrative Project of a Regional Power Grid with Various New Energies" conducted by the New Energy and Industrial Technology Devel-

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opment Organization (NEDO) for a period of 5 years beginning in 2003, and has amassed a proven track record for developing and evaluating “microgrid control technology” that balances the supply and demand of energy within a regional grid consisting primarily of renewable energy sources such as solar power, wind power and biomass power.

Combining its accumulated advanced power grid technology with end-user power savings technology and public system technologies such as transportation and water environment technologies, Fuji Electric is currently participating in national demonstration projects and research projects relating to smart communities, and by integrating its in-house resources for various fields, Fuji Electric is helping to advance the development and expand the lineup of smart community products and technologies.

This special issue reports on Fuji Electric’s support of these demonstration projects, product development for more advanced power grids and more highly sophisticated energy utilization by end-users in order to realize smart communities, and efforts to establish elemental technologies.

This paper describes the smart communities envisioned by Fuji Electric and their associated challenges, as well as the systems for technologies and products in Fuji Electric’s smart communities. For further details, please refer to the individual papers that follow this one.

2. Trends Toward Smart Communities

2.1 Smart grids and the mass adoption of solar power generation and wind power generation

With the aim of realizing a low carbon society, the increased adoption of solar power and wind power is being promoted worldwide.

These unstable sources of energy, with the exception of small power supply applications such as in remote areas, are directly connected to power grids. In general, if the mass adoption of solar and wind power exceeds about 10% of the power grid supply capacity, the frequency and voltage of the power grid will become unstable and power quality problems will arise. Additionally, depending on the load pattern of the power grid, it can be expected that surplus power will be generated and adversely affect the protection and control functions of the power grid in some cases.

In terms of the capacity utilization ratio of the system, the addition of large-scale equipment to the power grid-side is not always an effective way to compensate for the fluctuations in solar and wind power generation, however. For this reason, the end-user and the power grid must be organically linked by means of information technology, and the control of the user equipment (user’s grid) and of the large-scale power grid must be coordinated. A smart grid can realize such coordinated control, and is said to be a means for solving problems when adopting large amounts of solar and wind power.

Figure 1 shows the correlation between Fuji Electric’s assumption of the increase in solar and wind power generation and capital investment trends[1]. For the planned global spread of solar and wind power, the need for “user grids” will increase beginning in 2012, and smart grids are expected to come into widespread use as of 2017. Additionally, together with the associated capital investment, smart communities having high-level urban features are also expected to increase.

2.2 From smart grids to smart communities

The populations of Asia and Africa are to increase dramatically in the future. In these regions, industrialization is progressing rapidly, especially in nations with emerging economies such as India and China, and large investments are being made for the development of industrial parks and urban development, as well as the accompanying construction of public infrastructure

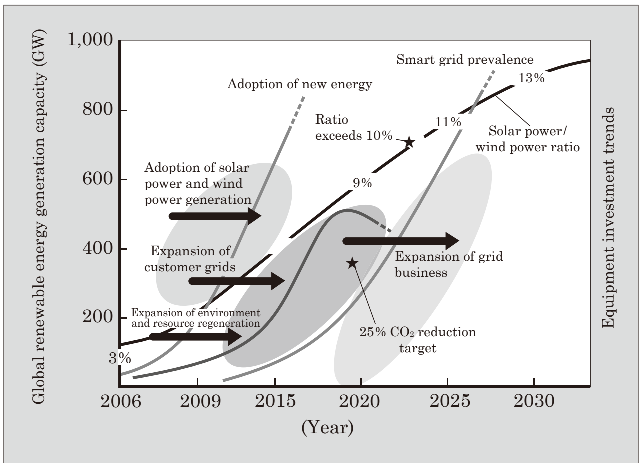

Fig.1 Smart grid equipment investment trends

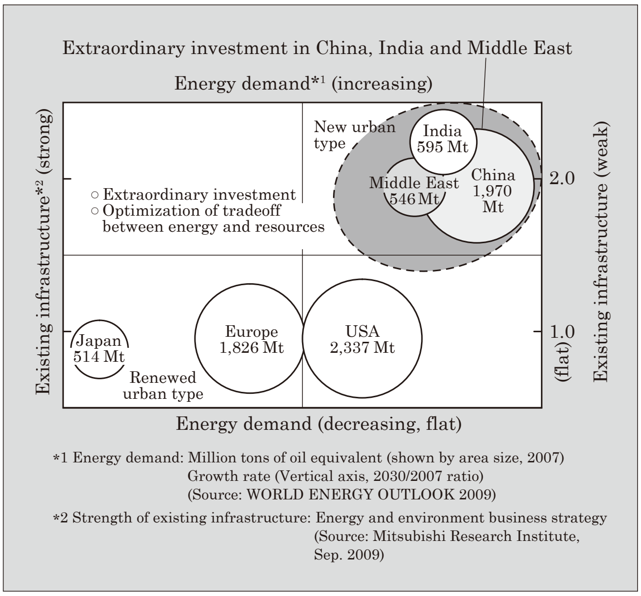

Fig.2 Energy infrastructure portfolio

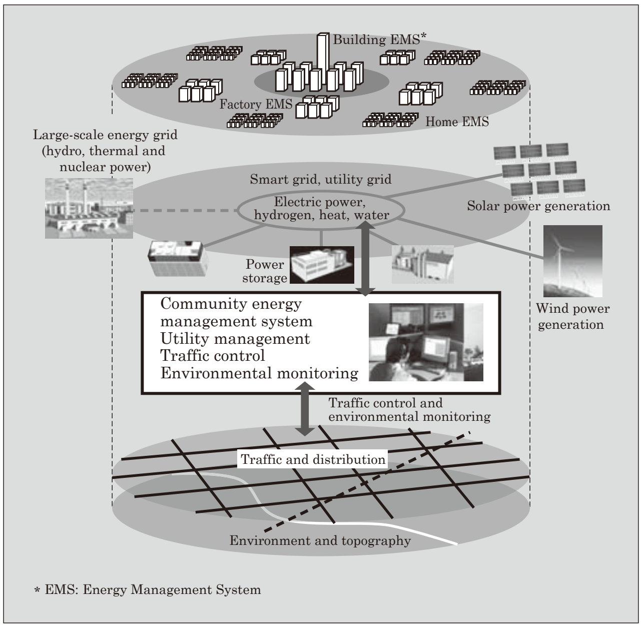

Fig.3 Overview of smart communities

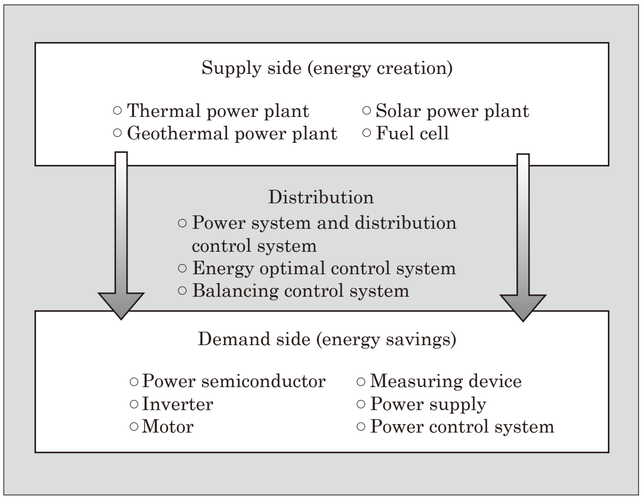

Fig.4 Fuji Electric's business areas

for supplying energy and water, and for transportation, distribution and the like.

In Japan, Europe, the United States and other developed nations, energy demand is flat and in some cases may decrease in the long-term due to a declining population and an overseas shift of production bases. In these countries, infrastructure investment is expected for renewal of the energy infrastructure developed during times of economic growth and to successively update that infrastructure into smart grids.

Figure 2 shows a portfolio of "new urban" and "urban renewal" type infrastructure.

Currently, more than 300 urban development and urban renewal projects are underway throughout the world. Not limited to providing power grids with smart functionality, these concepts have been expanded to the creation of eco-friendly urban spaces that combine water supply, transportation, distribution and energy infrastructure, i.e. smart communities (Eco-cities). (See Fig. 3.)

Smart communities can be defined in various ways according to various issues such as a particular country's energy policy, energy security and so on.

The Eco-city projects in the Middle East will be powered entirely by renewable energy, and aim to create the world's first carbon neutral and zero waste eco-friendly cities. Moreover, China is moving forward with 13 national eco-city projects, and has posted performance indicators for 32 items including a renewable energy usage of greater than 30%, a daily waste detoxification rate of greater than 70%, and a sewage water recycling rate of greater than 30%.

3. Fuji Electric's Activities for Smart Communities

3.1 Fuji Electric's business areas

The main markets for smart communities are new urban development in emerging nations and urban renewal in industrialized nations. Rather than provide individual elemental technologies, what is needed is a one-stop business scheme capable of constructing and operating a continuous energy supply chain, from an energy infrastructure consisting of energy supply and energy distribution functions to the effective utilization of energy on the user side (user's grid). Additionally, functions for water supply, waste disposal, transportation, distribution and the like are also requested of the developers of comprehensive social systems.

Figure 4 shows the business areas in which Fuji Electric is involved with smart community projects. Based upon high-performance power semiconductor technology, and with power electronics capable of "freely controlling energy" positioned as a core technology, Fuji Electric has established a product lineup that ranges from products for supplying energy to a smart community to products for the user's grid. These products aim to achieve integrated operation through the use of an integrated energy management system (EMS) platform, which is a mechanism that coordinates shared information.

3.2 Energy supply-side products

Fuji Electric possesses plant technology relating to large-scale thermal power, hydropower, and geothermal (flash) power generation. Fuji Electric also supplies distinctive energy supply-side products such as binary generators that are able to utilize low temperature geothermal energy, lightweight and flexible amorphous solar cells, industrial-use phosphoric acid fuel cells and so on. Additionally, Fuji Electric also has a lineup of products for power substation and protection systems for safely connecting the above supply-side products to a power grid, power stabilizers that smooth solar and wind power fluctuations and supply stabilized power to power grids, and so on.

3.3 Distribution and demand-side products

Figure 5 shows Fuji Electric's envisioned structure of a smart community.

At Fuji Electric, "smart communities" are positioned as a type of public infrastructure that encompasses smart grids, transportation systems, water and sewage management, and the like. The smart grid structure is divided into five layers, with the core components of "power devices" forming the first layer, followed by "power electronics equipment" and "user's grids" for performing power conversion and power control, "microgrids" used as regional grids, and "smart grids" as the energy infrastructure. Energy and information flow in both directions between each of these layers to realize optimal energy operation in smart grids and smart communities.

(1) Power devices and power electronics equipment

Fuji Electric supplies power electronics equipment such as uninterruptible power supplies (UPS) and high-current DC power supplies for which Fuji Electric has a high market share worldwide, powertrains for electric vehicles, transport and conveyance systems, etc. Additionally, a new 3-level conversion circuit that uses Fuji Electric's proprietary reverse blocking IGBT (RB-IGBT) has been developed, and achieves 30 to 40% lower loss than a conventional circuit.

Power electronics in smart communities is applied over a wide range of fields including, for example, power conditioners for solar power generation systems, power storage systems for the effective utilization of surplus renewable energy, reactive power compensators and voltage regulators for maintaining the power grid voltage at a proper level, etc.

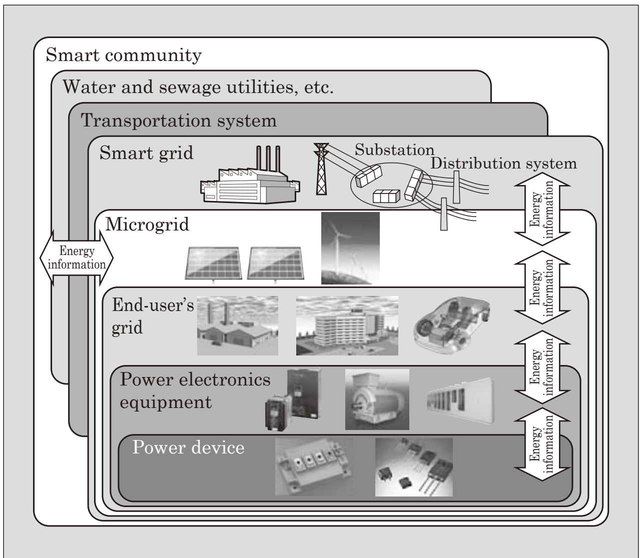

Fig.5 Structure of a smart community

(2) User's grids

The key role of a smart community is considered to be the achievement of energy savings in the household, industry and transportation fields and the like.

Targeting the end-users of plants and buildings, Fuji Electric installs and deploys EMSs for energy visualization, analysis and evaluation, and the overall optimized operation of equipment. Fuji Electric also applies power electronics to develop "green navigation" and provide a total solution for energy savings.

In addition, for Internet data centers (IDC) where the energy demand density has increased as servers have become more highly integrated, green IDC solutions centering on ultra-efficient uninterruptible power supplies and local air conditioning systems are being proposed. Moreover, targeting convenience stores and distribution businesses, one-stop integrated solutions are also provided for the construction of energy-saving stores.

With a smart grid, these EMSs and an upper-layer community EMS are hierarchically linked on the same information platform.

A two-way interconnection with an upper level EMS or power company is realized via "smart meters" installed in homes and at other small-scale end-users. A smart meter, in addition to having a conventional real-time metering function of the cumulative power consumption, also has an information display terminal that continuously exchanges information with an upper level EMS, and implements a demand response function, which according to the supply and demand status of power companies, varies the selling price of electricity and induces load control for the end-user.

(3) Microgrids

For the introduction and evaluation of microgrids on remote islands, many projects are planned or are underway, both in Japan and overseas.

At present, a large number of diesel generators are used for supplying power to remote islands, and mitigating the high generation cost resulting from fuel transportation costs and reducing the environmental load are challenges. The remote island demonstration projects aim to resolve, through the coordinated operation of existing diesel generators and power storage systems, the problem of supply/demand imbalance and to maintain the power quality of the power grid when solar power, wind power, or other type of renewable energy is adopted in large quantities.

In 2009, Fuji Electric delivered a total of nine microgrid demonstration systems to remote islands in the Kyushu and Okinawa regions.

(4) Smart grids

As a participant since 2010 in the "Next-Generation Energy and Social Systems Demonstration Project" of the Japanese Ministry of Economy, Trade and Industry, Fuji Electric is working on the development and demonstration of a cluster energy management system (CEMS).

Figure 6 shows the characteristics of the CEMS that Fuji Electric is working on. Targeting the exporting of new urban energy infrastructure to emerging nations, this demonstration project evaluates the utilization of renewable energy and local industrial resources, the potential contribution to large-scale interconnected power grids, as well as the usefulness and profitability thereof. Additionally, for local end-users to contribute to supply/demand operational management for energy, leading research of demand response, various incentives, and the like is also planned.

Furthermore, since 2009, in NEDO's "Smart Power Network Research," Fuji Electric has also been involved in the development and demonstration of component devices and distribution control systems for next-generation distribution systems.

(5) International standardization strategy

In international standardization activities concerning smart grids and smart communities, Europe and North America have a slight lead at present. The global deployment of distinguished domestic technologies is an important part of the international standardization strategy. Focusing on power electronics, smart meters, and the EMS field, Fuji Electric is increasing its participation in various standardization activities, including the Japan Smart Community Alliance established by the Japanese Ministry of Economy, Trade and Industry and NEDO.

4. Future Challenges

The main markets for smart community public infrastructure projects exist in urban development and urban regeneration projects overseas. As a supplier of component and system products, Fuji Electric is expected to face the following challenges in expanding its business.

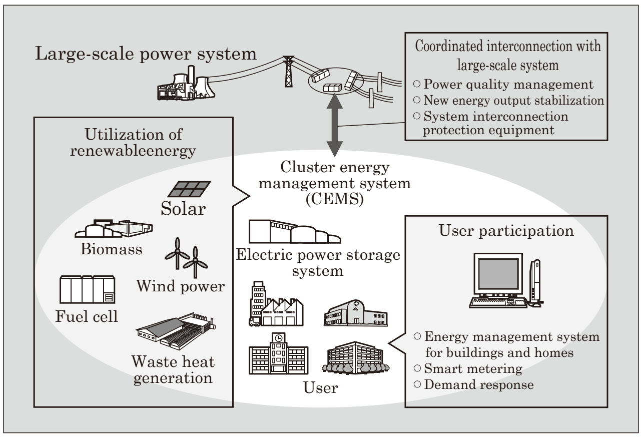

Fig.6 Characteristics of cluster energy management

4.1 Engineering, procurement, construction (EPC) skill

A smart community project, especially when exporting infrastructure, requires a business scheme for providing total solutions, from planning to construction and operation. Accordingly, as the project structure, collectives consisting of suppliers, developers, engineering firms, constructors, operators and maintenance workers, finance companies and the like are expected to be increasingly formed and advanced by domestic Japanese companies and regional overseas companies.

In order for Fuji Electric to play a major role in these collectives, the "EPC skill" level must be enhanced so as to provide a one-stop solution capable of aggregating the resources of the group companies and performing the engineering, procurement and construction work for the energy infrastructure.

4.2 Safety and security in the construction of public infrastructure

A smart community oversees the efficient operation of not only the energy infrastructure but also the public infrastructure, which includes water, sewage and waste treatment systems, transportation systems and so on, for an entire city and requires robustness as a lifeline for city functions in the case of a disaster, and also requires know-how for incorporating substantial safety and security features.

Possessing technology and know-how relating to the protection and control of power distribution equipment and large-scale plants, Fuji Electric positions these safety and security technologies as important distinguished items in its lineup of smart community products.

5. Postscript

Smart communities are mostly still in the planning and demonstration stages. As solar cells and electric vehicles come into widespread use in the future, the construction and operating costs for smart grids will become comparable to those of large-scale power grids, and the full-scale launching of the smart grid market is expected.

Aiming to provide a safe and secure low-carbon energy infrastructure, Fuji Electric intends to strive for further technical innovation and thanks all concerned parties for their guidance and cooperation.

References

(1) World Energy Outlook 2008, International Energy Agency.