R&D Strategy for Smart Grids and Smart Cities in China

Jing Zhang
Tao Ye
Nariyasu Hamada

OVERVIEW: Drawing on its ability to deliver a fusion of social infrastructure and IT, and its extensive technology, experience, and know-how in the fields of energy efficiency and environmental protection, Hitachi is participating in a variety of environmentally conscious city projects in China, including smart grid and smart city projects. To ensure that its research and development remains closely tied to the region, Hitachi is also taking an increasingly globalized and localized approach. This involves the development in China of technologies that are designed for use with Chinese smart grids and in Chinese smart cities, specifically network simulator technology for the analysis of electric power distribution networks and technology for energy management systems.

INTRODUCTION

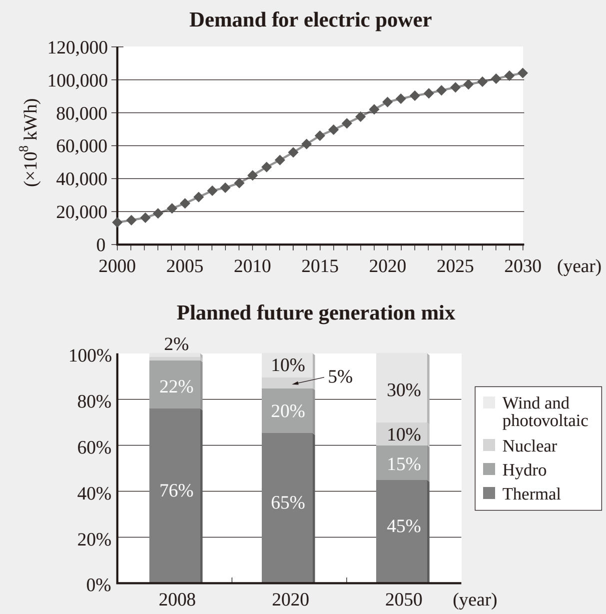
AGAINST a background that includes increasing energy demand driven by economic growth, and a population that is increasingly concentrated in cities (urbanization), China needs to strengthen its energy supply capacity while also protecting the environment. The realization of smart grids and smart cities are seen as offering ways of overcoming this challenge, where a "smart grid" is one that uses next-generation power infrastructure supported by information technology (IT), while a "smart city" is a next-generation city that uses IT to strike a balance between the environment, comfort, and economy.

Through its Social Innovation Business in China, Hitachi is seeking to contribute to regional development by supplying solutions that draw on its strengths in machinery, control systems, and information systems.

This article describes the current situation in China in the fields of smart grids and smart cities, together with the research and development strategy that Hitachi has formulated to keep pace with the nation's progress.

SMART GRIDS AND SMART CITIES IN CHINA, AND HOW HITACHI IS INVOLVED

Demand for electric power in China is forecast to continue growing (see Fig. 1). To satisfy this demand, China's 12th Five-Year Plan (2011 to 2015) has budgeted 6.1 trillion Yuan of investment in the electricity sector. The coal and hydro resources that fuel China's power generation are concentrated in the nation's southwest, while most renewable energy such as wind and photovoltaic power is generated in the northwest. The bulk of demand, in contrast, is located in eastern cities such as Beijing and Shanghai. Achieving a balance of supply and demand across the entire nation requires long-distance, very-high-voltage transmission networks with high capacity, and this is behind a proposed West-East Electricity Transmission



Source: Produced from data in China Statistical Yearbook 2008 and China Energy Efficiency Report 2009

Fig. 1—Change in Chinese Electric Power Demand and Planned Generation Mix Over Time.
Along with growth in the economy, demand for electric power in China is on a long-term rising trend. Meanwhile, greater installation of wind and photovoltaic power generation is planned to help protect the environment.

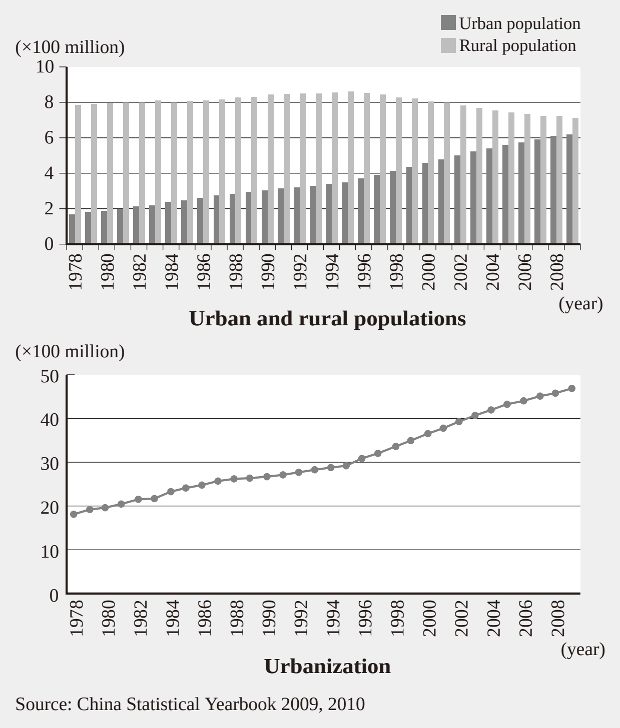


Fig. 2—Trend in China's Urban Population.
Each year, more than 10 million people migrate to the cities from rural areas.

Project. Based on the concept of a "strong smart grid," China is currently strengthening its transmission and distribution network, and also expanding use of renewable energy.

China's urban population continues to grow year on year, with more than 10 million people annually migrating to the cities from rural areas. This represents an annual movement of people comparable in size to the population of metropolitan Tokyo (see Fig. 2). A consequence has been a rise in concern about degradation of the natural environment caused by economic activity and the concentration of population.

Hitachi supplies electricity distribution management systems, grid stabilization systems, battery systems, community energy management systems, and other solutions for smart grids and smart cities, and is currently promoting proposals and participating in demonstration projects in cities around China, including Tianjin and Dalian[(1), (2)].

RESEARCH AND DEVELOPMENT STRATEGY IN CHINA

Hitachi (China) Research & Development Corporation has for some time being conducting locally based research and development in the field of power distribution and smart grids, as well as in information and telecommunications, digital equipment, and other similar fields. The following sections describe the scope of this research, looking in particular at its work on network simulator technology for the analysis of electric power distribution networks and technology for energy management systems.

Scope of Research

The systems covered by research at Hitachi (China) Research & Development Corporation can be broadly divided into distribution management systems used by power suppliers and community energy management systems used by consumers (see Fig. 3). In the future, it is anticipated that these two classes of systems will be coordinated using IT to optimize operation of the power distribution system. Data on infrastructural and consumer equipment is measured using IT, and this data is then used for analysis and control on various management systems. It is also anticipated that the future will see more widespread use of distributed generators such as wind or photovoltaic power, and energy storage devices such as batteries or electric vehicles (EVs).

Network Simulator Technology for Analysis of Electric Power Distribution Network

(1) Challenge

A challenge for management of the grid in China today is that losses of electric power in the distribution network make up approximately 70% of losses across the entire power system[(3)]. Work is also underway on strengthening the distribution network in response to issues with security of supply.

Meanwhile, greater use of wind, photovoltaic, and other forms of renewable energy is being encouraged to reduce carbon dioxide (CO_2) emissions and otherwise help protect the environment, and progress is being made on use of distributed generators (including small gas turbines as well as renewables) to foster "local production for local consumption" in the field of energy. However, greater use of distributed generators leads to reverse power flows in the distribution network. If the change in the power flow is large, it can influence the generation plans of power companies and complicate the task of maintaining power quality. Currently, the rules for power transmission and distribution in China do not permit reverse power flow. This has created a need to establish "local production for local consumption" of energy among power consumers by accurately forecasting and controlling the generation output of

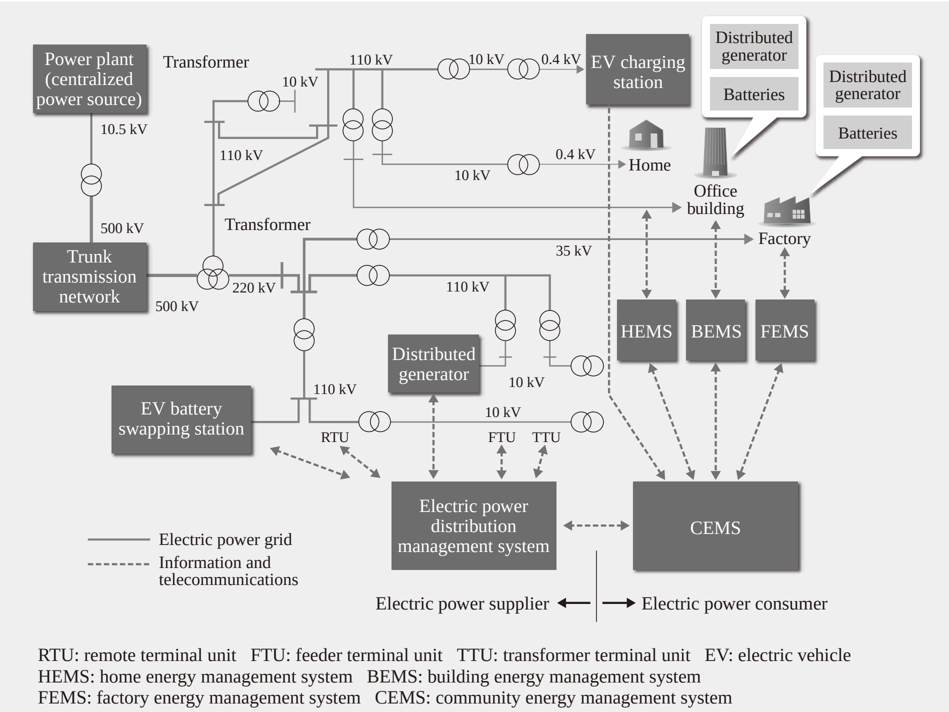


Fig. 3—Overview of Smart City Energy Infrastructure in China.
Future smart cities will make greater use of renewable energy and other distributed generators, and will coordinate the control of electric power distribution management systems and community energy management systems.

distributed generators (including renewable energy) to minimize the impact of reverse power flow on the distribution network.

(2) Research approach

Power grid companies like State Grid Corporation of China and China Southern Power Grid Co., Ltd. stipulate rules for the operation and design of electric power infrastructure on China's power distribution networks(4), and solutions are required for these technical issues that take account of actual conditions in China. For example, Hitachi believes it is necessary to assess the security of supply, safety, economics, and other aspects of the national grid stipulated by State Grid Corporation of China. This includes the reduction in power quality that results from the connection of distributed generators to the distribution network, how to minimize the duration of power outages through rapid fault detection and recovery, and the cost of equipment installed to strengthen the grid.

Hitachi (China) Research & Development Corporation is developing a simulator for analyzing electric power distribution networks that can analyze a variety of phenomena associated with the connection of distributed generators to a distribution network. The network simulator has data links to a distribution management system. It consists of a platform, with core functions such as performing (three-phase unbalanced) power flow calculations, and a set of applications for recreating a variety of distribution network phenomena (see Fig. 4).

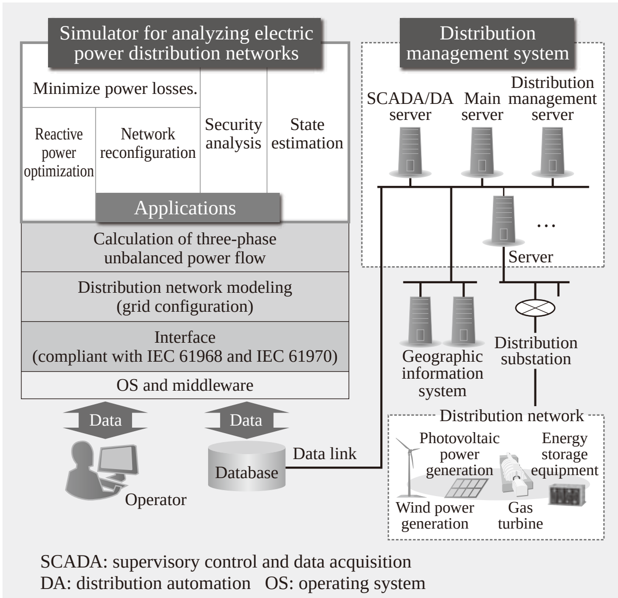


Fig. 4—Overview of Simulator for Analyzing Electric Power Distribution Networks in China.
The network simulator has a data link to a distribution management system and is used to recreate and analyze a variety of phenomena that occur in distribution networks (such as the impact of connecting distributed generators).

The first step involves modeling factors such as the configuration of China's distribution network, the features of its equipment, and its distributed generators (see Fig. 5). Modeling of distributed generators includes photovoltaic cells, synchronous generators, asynchronous generators, and doubly-fed induction

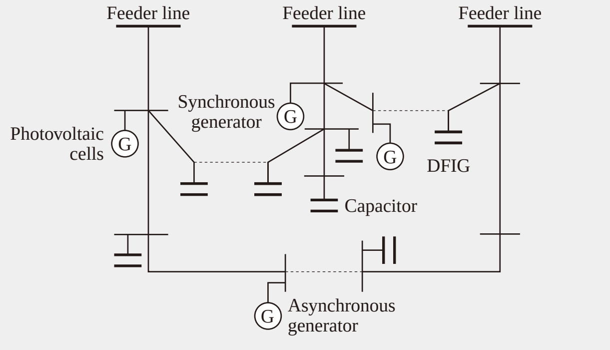


Fig. 5—Example Power Distribution Network in China.
The network simulator models the configuration of the power distribution network and equipment characteristics, and performs calculations such as minimization of power losses.

generators (DFIG). Next, the system calculates the impact of connecting a distributed generator to the grid, and countermeasures for dealing with this. Examples include the voltage fluctuations in the distribution network and the amount of reactive power that needs to be injected to minimize power losses. Other analyses include the impact of and recovery from grid faults, and the benefits of consumers using batteries for peak shifting (smoothing of power demand). In addition to existing analysis techniques developed and used in Japan, work is also in progress on developing the simulator using actual data from China. Hitachi is also working on joint research with Tsinghua University to keep up with the technical issues, technology developments, and other trends in China's electric power infrastructure.

Technology for Energy Management Systems

(1) Challenges

Protection of the environment is becoming a higher priority as China becomes increasingly urbanized, bringing a growing need for energy management and control by consumers. One example can be found at the Sino-Singapore Tianjin Eco-city, where development work is targeting 22 key performance indicators (KPIs) (see Table 1). Controlling for a particular objective requires the collection of relevant data so that it can be used for analysis and prediction to elucidate the causal relationships with the control objective. If the control objective changes, ongoing data collection and the modification of the control method to suit the objective are required.

(2) Research approach

Hitachi develops and supplies IT platforms (smart city platforms) that support social infrastructure(5). Hitachi (China) Research & Development Corporation is developing energy management applications that are built on IT platforms developed in Japan, but which also take account of the requirements and other circumstances specific to China. Energy management is a cycle that involves measuring and visualizing data from equipment and other sources; conducting analysis, prediction, and evaluation of energy supply and demand; formulating plans for the operation, equipment, and other aspects of energy supply and demand; and performing actual control, maintenance, and repair work (see Fig. 6). The main aims of control are to save energy; reduce energy costs; cut or shift peaks in energy demand; make efficient use of photovoltaic power generation and batteries; and reduce CO_2 emissions. Specifically, this includes using meteorological information to predict the generation output of photovoltaic and other distributed generators, and also adjusting supply and demand in accordance with electricity tariffs that vary depending on the time of the day, and in accordance with other considerations such as which areas are used (including homes, offices, and commercial buildings) and how consumers behave (including information on people's movements, and when they arrive at, leave, or use a facility). Other considerations are the need for standardization and factors that are difficult to measure or evaluate, such as ensuring consumer comfort (including temperature, humidity, illumination, and restrictions on when a facility can be used) and whether the KPIs referred to above have been achieved.

TABLE 1. Examples of Key Indicators for Eco-cities (from Sino-Singapore Tianjin Eco-city Key Performance Indicators)
With the aim of building an environmentally conscious city, the development of the Sino-Singapore Tianjin Eco-city is targeting a set of key performance indicators (KPIs).

Eco-city KPI	Target	Target date
Usage of renewable energy	≥ 20%	2020
Usage of water from non-traditional sources*1	≥ 50%	2020
Proportion of green trips*2	≥ 30%	2013
	≥ 90%	2020
Proportion of green buildings*3	100%	from 2011

Source: Sino-Singapore Tianjin Eco-city Key Performance Indicators
*1 Non-traditional sources such as recycled water, rainwater, and seawater desalination.
*2 Use of forms of transportation that conserve energy, produce little pollution, and are good for health, such as cycling or walking, and bus, subway, or other modes of public transportation.
*3 Buildings that are environmentally conscious throughout their life cycle, from construction to use and demolition, including by making maximum use of renewable energy, conserving resources, reducing pollution, and providing comfortable spaces.

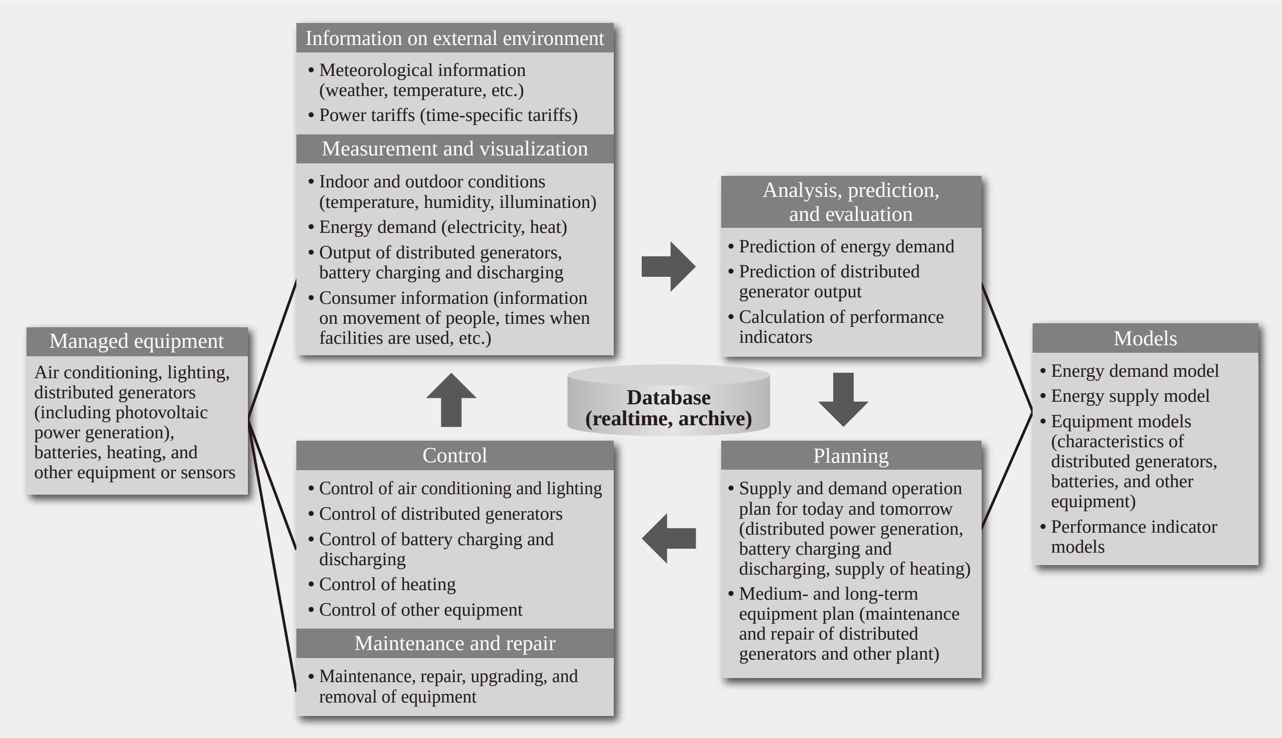


Fig. 6—Building Energy Management Flowchart.
Energy management involves a cycle that includes measuring and visualizing data from equipment and other sources; conducting analysis, prediction, and evaluation of energy supply and demand; formulating plans for the operation, equipment, and other aspects of energy supply and demand; and performing actual control, maintenance, and repair work.

Hitachi is currently involved in the international standardization of smart city infrastructure measurement indicators(6). This work aims to collate the different requirements for urban infrastructure, which include improving the quality of life for residents, delivering sustainable growth and efficient operation for city managers, and taking account of the environment to satisfy world opinion, and to standardize the evaluation and measurement methods for determining the extent to which these are achieved. Through its research and development in China, Hitachi's plan is to develop performance indicators and technology for energy management systems by using activities such as the smart city and eco-city projects in Tianjin and Dalian to evaluate and verify actual operational data.

CONCLUSIONS

This article has described the current situation in China in the fields of smart grids and smart cities, together with the research and development strategy that Hitachi has formulated to keep pace with the nation's progress.

Being characterized by differences in the pace of progress and the development policies pursued in different parts of the nation (urban versus rural, costal versus interior), customer needs in China are very diverse. Hitachi is taking an increasingly globalized and localized approach to research and development, the most upstream of all corporate activities, seeking to build a value chain that is closer to its customers and extends from research and development through to sales and marketing and the supply of products, solutions, and services. Hitachi aims to contribute to the progress of social infrastructure in China by taking the system technologies it has built up through its experience with social infrastructure in Japan and enhancing them based on an understanding of Chinese culture.

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ABOUT THE AUTHORS

Jing Zhang
Joined Hitachi (China) Research & Development Corporation in 2010, and now works at the Social Infrastructure System Laboratory. She is currently engaged in the research and development of analysis technology for power distribution networks. Ms. Zhang is a member of the IEEE.

Tao Ye
Joined Hitachi (China) Research & Development Corporation in 2005, and now works at the Social Infrastructure System Laboratory. He is currently engaged in the research and development of technology for energy management systems.

Nariyasu Hamada
Joined Hitachi, Ltd. in 1989, and now works at the Social Infrastructure System Laboratory, Hitachi (China) Research & Development Corporation. He is currently engaged in the research and development of Chinese social infrastructure. Mr. Hamada is a member of The Institute of Electrical Engineers of Japan (IEEJ).