Solution to Utilization of Smart Meter Data

● Koji Nomura ● Tetsuya Kashiwagi ● Taku Yamashita ● Tadashi Kawade

Since the Great East Japan Earthquake, when energy supply and balance issues began to attract public attention, various power saving approaches have taken root in our life. Besides human factor-related approaches such as turning off switches when electrical appliances are not in use and changing the temperature settings of air conditioners, solutions based on digital judgment are needed, such as a way to visualize the amount of power consumed by equipment and control such power consumption depending on demand. Power suppliers also now need to be able to make more sophisticated estimates of power demand so as to realize a more efficient and stable energy supply. The power suppliers can meet this requirement today through introducing smart meters. These devices can analyze power usage from diverse angles by collecting various pieces of data, including that on the power consumed, in small increments. Fujitsu will propose these kinds of solutions to support optimum data usage. We believe these solutions will be used by both the demand and supply sides of power and serve as a foundation for the Smart Grid to be introduced in future. In this paper, the structure and characteristics of the solution are described.

1. Introduction

Large-scale use of automated meter reading systems has started in smart grids, or power grids that make use of smart meters equipped with communications and control functions.

Such use has been considered up to now for the purpose of improving efficiency of operations. Recently, however, use in order to realize the concept of an advanced metering infrastructure (AMI) has been called for as an infrastructure for two-way data exchange between power suppliers and users (power consumers) by utilizing smart meters.

An AMI not only realizes the basic functions required by power suppliers such as the conventional power usage measurement but also allows support for a granulated power rate menu including remote control by two-way communications, time-of-use (TOU) rate, critical peak pricing (CPP) and peak time rebate (PTR). In this way, in addition to the effect of introduction that is produced for suppliers, functions available to consumers can be provided such as a consulting service based on power usage data and measures for reducing power usage made possible by visualizing power.

Furthermore, by quickly acquiring volume of power use of the individual consumers in 30-minute periods, it is becoming feasible to have investment control by optimizing power facilities and improving maintenance efficiency and rationalization in ways such as shifting power peak shift and controlling power generation.[1)]

Realization of these schemes is an important element in the realization of Smart Grid. Fujitsu considers it necessary to offer a new solution in the future and is making efforts to achieve Smart Grid.

This paper describes the functions of this solution.

2. Components for realizing Smart Grid

As shown in **Figure 1**, components for realizing Smart Grid can be roughly classified into four sections: metering, meter reading network (FAN: Field Area Network), data collection and data storage/analysis/utilization sections.

1) Metering section

This is represented by meters installed at the

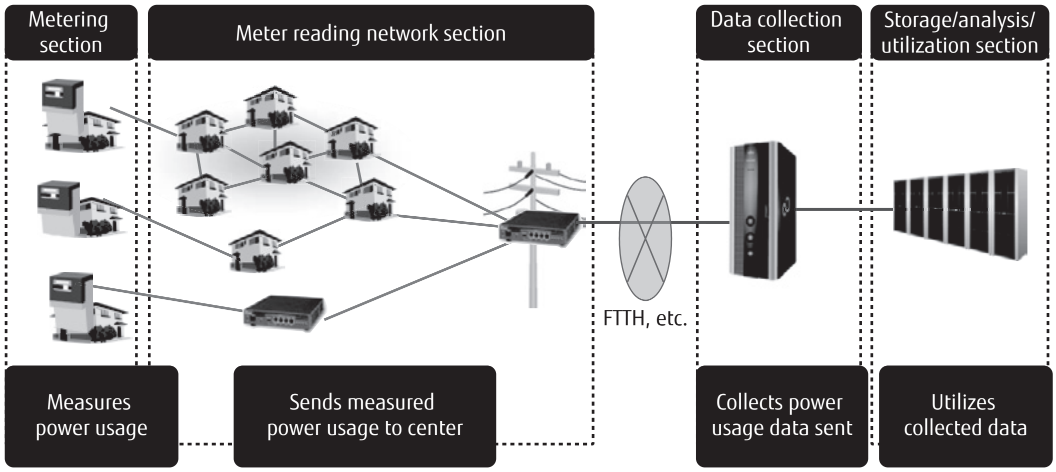


Figure 1
Overview of smart grid configuration.

individual consumers (homes) for measuring power usage. Most meters are currently analog meters, but they will be gradually replaced with digital smart meters. The introduction of these smart meters will allow power usage data to be stored in smaller increments.

2) Meter reading network section (FAN)

Power usage data from the individual consumers are sent through the meter reading network to be aggregated in the center server every 30 minutes. Generally, this route is called the A route. For communications through this A route, three systems are adopted: a wireless mesh network, power line communication (PLC) and mobile phone systems. The operator selects one of these three systems according to the use environment and meter installation location.

In addition, the B route, which allows the individual consumers to view power usage data via home energy management system (HEMS) devices, is available. By using this, consumers can check their power usage when necessary.[1)]

3) Data collection section

Utility companies in Japan are required to collect data from between 1 million and 27 million households. This means they need a functionality that allows them to reliably collect meter reading data sent simultaneously every 30 minutes from all households. In addition, they require a functionality to control instructions to meters of the individual consumers and control data acquisitions based on the instructions from the host system.

4) Data storage/analysis/utilization section

The aggregated data are used for calculating power rates of the individual consumers and gaining an understanding of their power usage. In the future, power usage data that is aggregated every 30 minutes will be used for various analyses and applications.

3. Solutions required

What will be required in the future is a solution that is capable of comprehensively realizing Smart Grid.

Functions to be provided as a comprehensive solution are shown in **Table 1** and the system of the solution in **Figure 2**.

The data collection section provides the "data collection solution," which reliably collects meter reading data and achieves linking with the host system, and the "network management solution" for visualizing the meter reading network to improve operational efficiency.

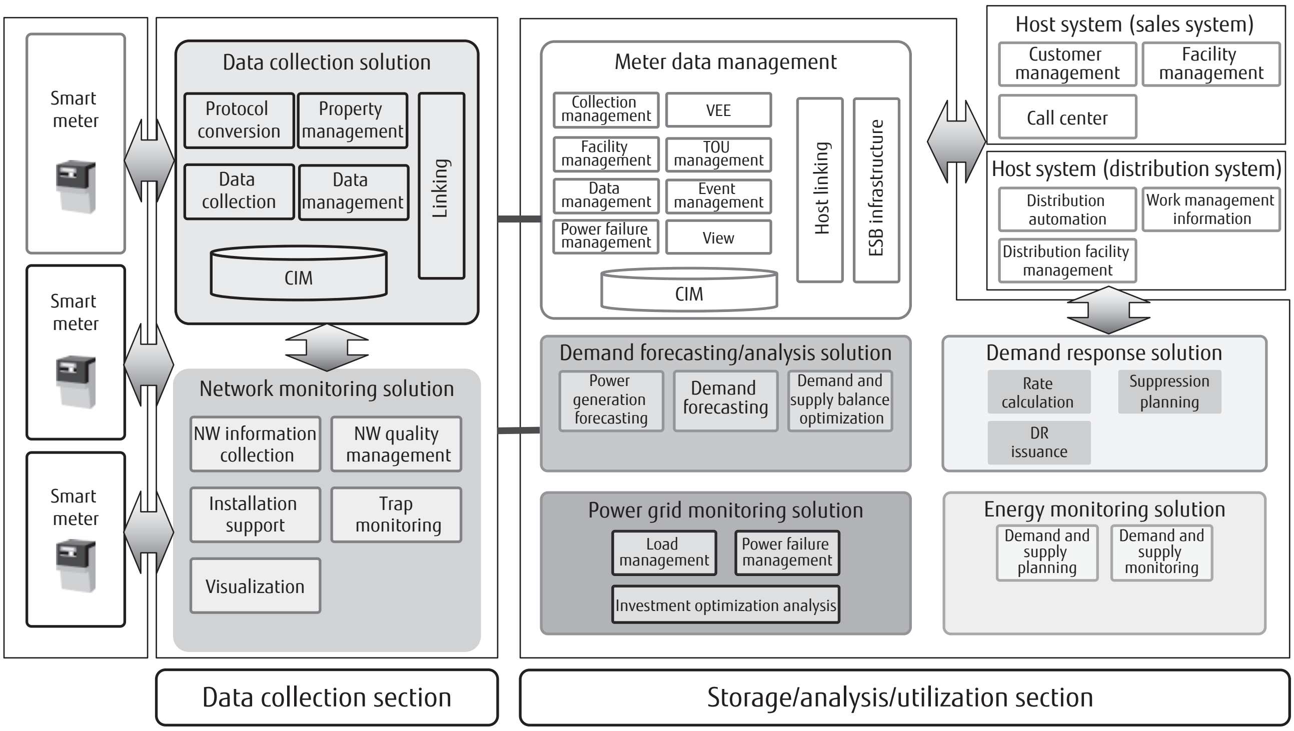
With the data storage/analysis/utilization section, it is important to provide a comprehensive set of solutions including the "demand forecasting/analysis solution" to realize demand forecasting based on the meter reading data, the "energy monitoring solution" for demand planning and monitoring, the "power grid monitoring solution" for power failure and load monitoring and the "demand response solution" to realize demand response.

The following outlines the functions to be provided by the respective solutions.

Table 1
Functions provided by respective solutions.

Function name	Function description	Supporting solution
Basic function	• Data collection • Billing data confirmation • Visualization for consumers • Installation support • Network management (FAN/WAN)	Data collection solution Network monitoring solution
Operations function	• Power failure management • Load management (load profile)	Demand forecasting/analysis solution Power grid monitoring solution
Extended function	• Demand analysis and forecasting • Demand and supply balancing • Demand response	Energy monitoring solution Demand response solution

FAN: Field area network



VEE: Validates, edits and estimates
ESB: Enterprise service bus
CIM: Common information model
DR: Demand response

Figure 2
System of solution.

4. Data collection solution

This solution is responsible for collecting meter reading data and linking with the host system. The solution configuration can be classified into the adapter section and data processing section as shown in **Figure 3**.

4.1 Adapter section

The adapter section carries out data collection processing to support various communication systems. For reliable collection of large volumes of data from tens of millions of meters in a short period of every 30 minutes, an advanced distributed processing architecture is required.

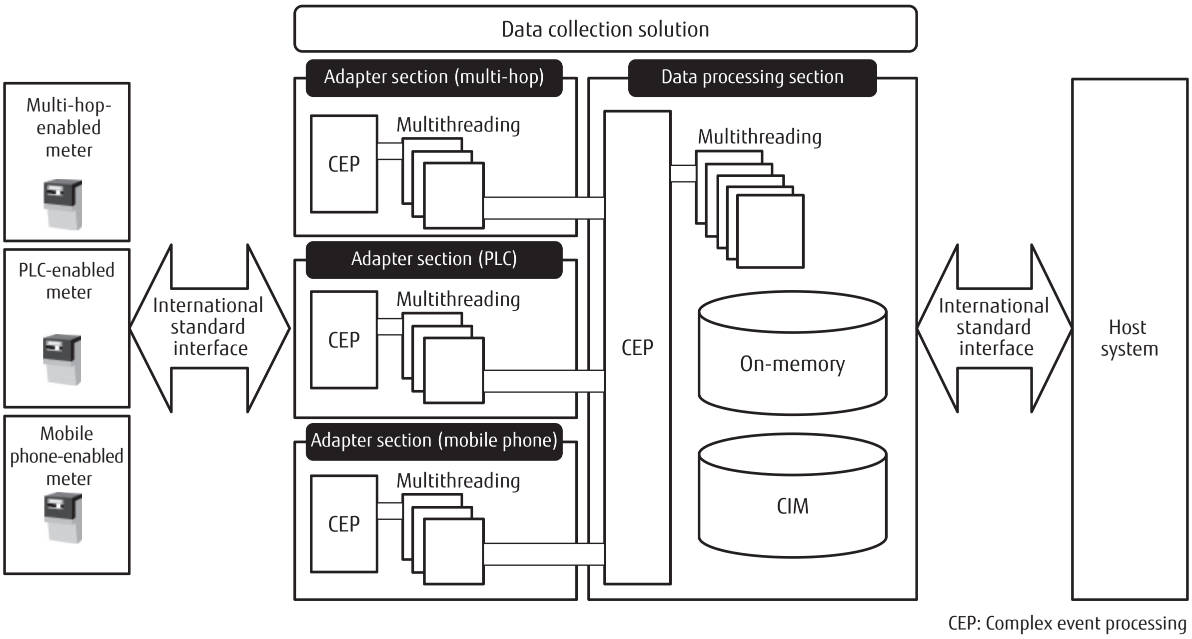


Figure 3
Data collection solution configuration and interfaces with devices and systems.

As technologies that allow power suppliers to classify large volumes of data and carry out high-speed processing, we find ones such as complex event processing (CEP) effective. Flexible distributed processing can be realized by building a scenario for each event. It is also essential to adopt an architecture capable of higher-speed processing by making use of technologies including multithreading of applications and on-memory database. In addition, to reduce the load on and prevent congestion of the meter reading network, control such as device accommodation management control (automatic construction of a network with the load equalized), control of the volume of data flow to the network and priority control will be necessary as well.

Regarding the interface with meters, compatibility with international standards such as those issued by the IEC and ANSI in view of the domestic electricity market can ensure high connectivity with meters that comply with standards, including overseas ones.

4.2 Data processing section

The data processing section aggregates data collected by the respective adapters and links such data with the host system. The linked data are used by power suppliers to calculate power rates and acquire power usage.

To reduce the load on the host system and achieve flexible connectivity with other systems, the section retains the minimum required data. Ensuring that the connection interface with the host system and the self-retained data model conform to international standards will be an effective way to improve compatibility with other systems when Japanese utility companies, which have been vertically integrated up to now, adopt a horizontally specialized model of electricity such as separation of power generation from power transmission and distribution.

5. Network management solution

This solution supports operation in smart meter deployment. Devices are not replaced with smart meters simultaneously at a particular timing. Rather, users install smart meters when replacement becomes necessary due to the end of support by utility companies or when new houses are built and it will take about 10 years before they are installed in all households. The solution visualizes a meter reading network that expands in proportion to the gradual deployment of smart meters, and provides operational support including monitoring and failure response.

5.1 Network data registration function

Storing quality information and route information of the meter reading network, supporting a network configuration that allows for high-quality meter reading and constructing and analyzing the route information allow power suppliers to periodically analyze the stability of the meter reading network.

5.2 Alert monitoring

This function is capable of quickly identifying and responding to any error status generated. However, rather than monitoring all alerts, it is important to automatically determine the degree of urgency based on the importance of alert information or on past responses taken to appropriately provide the operator with helpful information.

5.3 Visualization of meter reading network

A geographic information system (GIS) is used to display the network configuration information, such as smart meter and communication device layout and communication routes, on a map (**Figure 4**) by means of a Web browser. By overlaying these with other information for display such as the meter reading network quality information collected with the data collection solution, the system can help power suppliers to identify the cause of failure or monitor for signs of failure.

5.4 Simulation function

We think that functions to support further improvement of operational efficiency and optimum facility layout can be offered by providing functions of smart meter installation simulation and routing simulation.

6. Demand forecasting/analysis solution

The role of this solution is to allow advance operation planning that optimizes the balance between power demand and supply. To maintain a relationship between power demand and supply with the latter properly exceeding the former, one of the following measures can be taken: increasing the supply according to the demand, reducing the demand, or combining both measures. Regardless of the measure taken, the following functions are required and demand result data collected from smart meters are used as the input.

- Power generation forecasting

Figure 4
Visualization of meter reading network.

- Demand forecasting
- Daily operation plan optimization

The following subsections outline these functions.

6.1 Power generation forecasting

Power generation forecasting relates to photovoltaic (PV) power generation and predicts how much insolation can generate how much power by solar cells. Based on weather information provided every three hours, the output of the solar cells installed at different points is forecast for the respective periods of time.

To improve the accuracy of this PV power generation forecasting, accurate weather information for smaller areas is required. In addition to the weather information currently available, various sensors can be installed at points closer to the solar cells to collect weather information and power generation data, and this improves the accuracy of PV power generation forecasting.

As the forecasting basis, a regression model with the insolation and output used respectively as the explanatory and explained variables is used. Accordingly, by using the wind velocity as the explanatory variable and the output as the explained variable, this solution can be applied to wind power generation forecasting. In the same way, combining this solution with various types of natural energy as explanatory variables allows it to be applied to renewable energy in general.

6.2 Demand forecasting

Demand forecasting relates to power demand and predicts how much temperature rise will cause how much increase in demand. By collecting the data of changing weather conditions and demand data during a certain period of time as time-series data via smart meters, power suppliers can determine the past trend of power demand and applying future weather condition forecasting to the trend allows them to predict future power demand.

For this power demand forecasting, forecasting for a wider area increases the accuracy by the "smoothing effect." However, power supply destinations are expected to become more geographically dispersed and distributed than now. On the premise of this, provision of demand forecasting wanted by power suppliers requires power demand to be determined based on forecasts for smaller areas and forecasts and plans for respective consumers.

As the forecasting basis, a regression model with the temperature as the explanatory variable and power demand as the explained variable is used. However, the regression will not be linear and other factors such as periodic variation must be taken into consideration.

6.3 Daily operation plan optimization

As described in 6., in order to optimize the balance between power demand and supply, there should be enough power reserve which can be calculated based on the power demand forecast. A daily operation plan must be formulated in advance in which power demand and output from renewable energy, which are originally not managed, are more accurately predicted so that the resulting shortage of power supply can be covered by power obtained by running controllable power generation facilities such as thermal and other power generation systems.

In order to formulate a daily operation plan, in addition to maintaining the demand and supply balance, power suppliers must plan the output of the respective power generation facilities to maintain the balance while the CO_2 emissions and cost are further reduced. As the planning basis, a multi-objective optimization model with the maintenance of the demand and supply balance as the constraint equation and minimization of CO_2 emissions and minimization of cost as the objective functions is used.

7. Energy monitoring solution

The role of this solution includes monitoring to see if the power demand and supply balance is appropriately maintained according to the daily operation plan formulated in advance and, if it is not, or is estimated not to be, appropriately maintained, correcting the operation plan formulated in advance to maintain an appropriate demand and supply balance.

For appropriate maintenance of the power demand and supply balance, the following functions are required and demand result data collected from smart meters are used as the input.

- Demand and supply monitoring
- Demand and supply planning

The following subsections outline these functions.

7.1 Demand and supply monitoring

Demand and supply monitoring is intended for collecting data relating to power generation and demand result data from various facilities, sensors and smart meters and monitoring to see if the power demand and supply balance is maintained for every 30-minute period according to the daily operation plan formulated in advance. In order to see if the demand and supply balance is maintained in a given 30-minute period, data for shorter periods such as two and five minutes are collected.

In addition, this function gives a warning of any error detected in the facilities.

7.2 Demand and supply planning

If demand has been found to be more than or far below the supply as a result of monitoring the demand and supply balance for 30-minute periods, the daily operation plan made in advance must be revised/changed. To that end, two measures can be taken: re-optimization in the same way as the advance operation plan formulation and manual provision of correction values.

In addition, weather information differs between the time when the daily operation plan is formulated in advance and after the day's operation has started. And so, the power demand and generation must be forecast again based on the latest weather information to correct the day's operation plan accordingly.

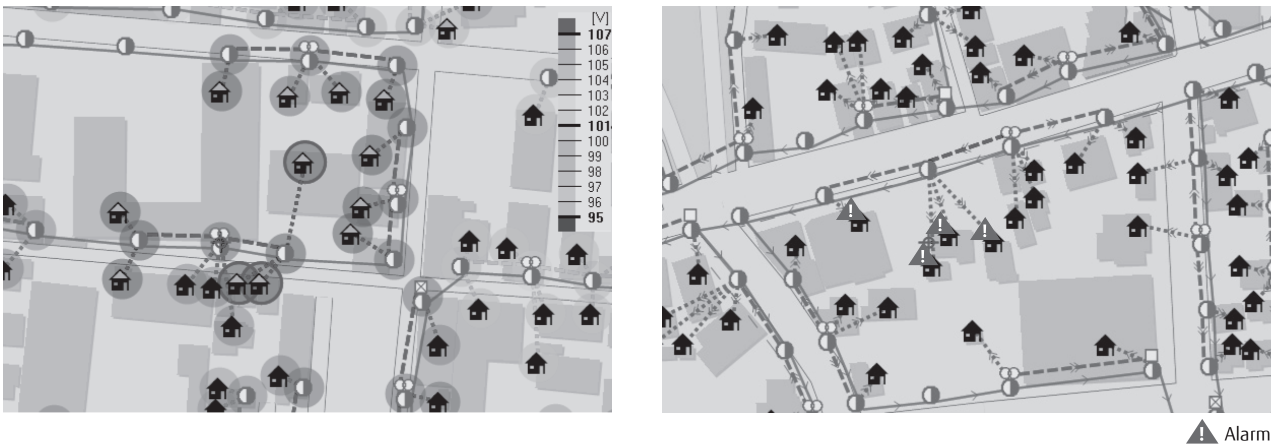
8. Power grid monitoring solution

The wide use of smart meters allows power suppliers to sophisticatedly operate systems and design distribution systems, although the actual conditions of such systems were difficult to acquire in the past. For system operation, meter readings collected every 30 minutes from smart meters can be used for acquiring the state of an entire distribution system including the low-voltage system in a timely manner. For system formation, the load state can be acquired in time series, and this allows power suppliers to streamline distribution systems including transformers and low-voltage lines. Provision of functions that assist with these operations can support sophistication of distribution operations.

8.1 System operation support function

The system operation support function includes the power flow monitoring and power outage monitoring functions. The former makes visible and displays the states of power flow at the timing of collection of smart meter reading data and the latter provides alarm display of the failure facilities by identifying faulty facilities and power outage location. These functions are realized by providing a superimposed display of various types of information on a GIS, and this has often been used for management and design of distribution system (**Figure 5**).

The power flow monitoring function offers a color-coded view of voltage classes to allow power suppliers



(a) Voltage monitoring screen (b) Power failure monitoring/faulty facility identification screen

Figure 5
Facility operation support function.

to intuitively acquire the state of the distribution system and, for reverse power flow occurring increasingly frequently as distributed low-voltage power supply systems become widespread, a view that indicates the direction for high and low voltages respectively. This encompasses all perspectives to see the state of the entire distribution system: plane perspective based on the difference of load density and land category classification, line perspective for each feeder from the distributing substation and a point perspective for each arbitrary facility such as a pole and meter.

The power outage monitoring function displays the state of power outage of the meter. In addition, when there is more than one meter experiencing a power outage, the function identifies faulty facilities based on the power supply route of the distribution system to give alarm display for facilities where there is a high possibility of an accident. This not only allows power suppliers to acquire the presence and location of a power outage but also assume faulty facilities, making it possible for them to take prompt recovery measures.

8.2 System formation support function

While it is important for power suppliers to be able to acquire the state in a timely manner for system operation, system formation requires them to streamline facilities based on the year-round load state. Time-series processing of the meter readings for 30-minute periods by means of a high-speed power flow calculation engine used for the system operation support function is considered to be capable of providing power suppliers with an actual power flow management technique that allows them to determine voltages and currents that are closer to the actual conditions. The actual power flow management technique uses specifications, such as the power usage based on the meter readings for 30-minute periods and connections and impedances of the distribution system facilities, to provide time-series management of the voltage and current for the respective facilities including transformers, low-voltage lines and service lines. It allows power suppliers to manage the state of use and tolerance with a focus on the respective facilities. With this technique, the function makes it possible for power suppliers to accurately manage peak and off-peak voltage and current values, time periods of occurrence and even seasonal variation, activities that are impossible with assumptions of peak current based on monthly meter readings, a method often adopted for the conventional load management technique. It leads to streamlining of the sizes of facilities such as transformers, low-voltage lines and service lines.

9. Demand response solution

This solution supports a system where a margin of supply capacity is created by reducing demand from the perspective of information and communications technology (ICT) and realizes stable supply of electricity in the age of renewable energy. Generally, creating a supply capacity margin by reducing demand is referred to as demand response (DR). It encourages consumers to reduce power usage by setting up a system of raising the peak power rates, paying consumers an incentive for reducing demand, etc. to adjust the power demand and supply.

The demand response solution is intended for DR aggregators (DRAs) and is equipped with functions for reducing power usage under tight energy conditions, which is a role of DRAs. There are three major functions to realize DR: demand forecasting, DR program management and consumer information management. They contribute to the realization of accurate demand control.

9.1 Demand forecasting

As demand forecasting by DRAs, that based on weather information and past demand results as well as that with the reduction effect of implementation of DR programs taken into account are required. Demand forecasting on the assumption that DR programs are implemented takes into consideration the reduction effect (performance) for the respective DR programs, contract details (service menus) of consumers covered by the implementation of DR programs, sensitivity of temperature, incentive and electricity price and other factors.

9.2 DR program management

A DR menu is a specific set of agreements for realizing DR and includes TOU, CPP and direct load control (DLC). DRAs, which implement DR in response to demand reduction requests from power suppliers, are required to reduce demand accurately and flexibly according to the requests. This function manages DR programs in various methods from different viewpoints such as reduction effect, conditions of implementation and target of implementation to allow DRAs to select consumers to whom DR is to be requested and accurately measure reduction quantities (demand forecasting function). In addition, a function of managing and visualizing the state of implementation of various DR programs is also provided.

9.3 Consumer information management

In various scenes of DR, it is essential to have consumer information. For example, for DRAs to select consumers to whom DR is to be requested they need to use the contract information and the past demand and reduction results of consumers and demand forecasting needs to take the past reduction results of consumers into consideration. Consumer information management is intended for managing consumer information from various viewpoints including the contract, demand results and reduction results for the respective consumers in order for DRAs to accurately and flexibly respond to demand reduction requests from power suppliers.

10. Conclusion

This paper has outlined solutions that are expected to be necessary in the future for utilization of smart meters.

While the roles of the individual solutions are important, they must be provided as a total solution that creates a multiplier effect. It may be 10 more years, when deployment of smart meters is estimated to be complete, before the individual solutions can organically function. In 10 years, the energy supply balance issues will be different from those of the present and approaches to power conservation are expected to be different as well. We believe that offering solutions that keep up with the needs of the times is Fujitsu's mission and a role it is expected to play.

References

1) Ministry of Economy, Trade and Industry: Report of the Study Group on the Smart Meter Scheme. February 2011 (in Japanese).
http://www.meti.go.jp/committee/summary/0004668/report_001_01_00.pdf

Koji Nomura
Fujitsu Ltd.
Mr. Nomura is currently engaged in overall smart network solution operations.

Taku Yamashita
Fujitsu Ltd.
Mr. Yamashita is currently engaged in development of energy management systems.

Tetsuya Kashiwagi
Fujitsu Ltd.
Mr. Kashiwagi is currently engaged in planning and development of energy management systems.

Tadashi Kawade
Fujitsu Ltd.
Mr. Kawade is currently engaged in field testing of energy management systems.