International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

Y.2071

(09/2015)

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

Next Generation Networks – Frameworks and functional architecture models

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Framework of a micro energy grid

Recommendation ITU-T Y.2071

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Recommendation ITU-T Y.2071

Framework of a micro energy grid

Summary

Recommendation ITU-T Y.2071 provides the framework of a micro energy grid for interconnected local generation and distribution. After identifying key features and high-level requirements from the concepts of the micro energy grid, this Recommendation provides an architecture overview including the domain model, as well as the reference architecture, and describes control and management services for a micro energy grid. Finally, this Recommendation shows core systems and components for a micro energy grid.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.2071	2015-09-29	13	11.1002/1000/12581

Keywords

Advanced metering infrastructure, demand response, distributed energy resources, micro energy grid.

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FOREWORD

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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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1 Scope

This Recommendation provides the framework of a micro energy grid for interconnected local generation and distribution. After identifying key features and high-level requirements from the concepts of the micro energy grid, this Recommendation provides an architecture overview including the domain model as well as the reference architecture and describes control and management services for a micro energy grid. Finally this Recommendation shows core systems and components for a micro energy grid.

This Recommendation covers:

- Features and requirements of a micro energy grid;
- Architecture overview of a micro energy grid;
- Control and management services for a micro energy grid;
- Core systems and components of a micro energy grid.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T X.1111] Recommendation ITU-T X.1111 (2007), *Framework of security technologies for home network.*

[ITU-T Y.2701] Recommendation ITU-T Y.2701 (2007), *Security requirements for NGN release 1*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 aggregator [b-ITU-T FG-Smart]: A system in smart grid for collecting the energy generated by residences and micro grids.

3.1.2 building automation system (BAS) [b-ITU-T FG-Smart]: A system capable of computerized monitoring and control of a building's lighting and mechanical systems, and monitoring for performance and potential failure.

3.1.3 customer [b-ITU-T FG-Smart]: The end user of energy or services, who may also generate, store, and manage the energy. Traditionally, three customer types are discussed, each with its own domain: residential, commercial and industrial.

3.1.4 customer information system (CIS) [b-ITU-T FG-Smart]: A software application for handling customer calls, billing, and related operations.

3.1.5 data collector [b-ITU-T FG-Smart]: A distributed processing device that has supervisory control or coordinates information exchanges from devices within a substation from a headend system.

3.1.6 demand response (DR) [b-ITU-T FG-Smart]: A smart grid feature that allows consumers to reduce or change their electrical use patterns during peak demand, usually in exchange for a financial incentive. Mechanisms and incentives for utilities, business, industrial, and residential customers to cut energy use during times of peak demand or when power reliability is at risk. Demand response is necessary for optimizing the balance of power supply and demand.

3.1.7 distributed energy resources (DER) [b-ITU-T FG-Smart]: Energy generation and energy storage facilities located at the customer premises, or power transmission and distribution systems.

3.1.8 energy management system (EMS) [b-ITU-T FG-Smart]: A computer system comprising a software platform providing basic support services and a set of applications providing the functionality needed for the effective operation of electrical generation and transmission facilities so as to assure adequate security of energy supply at minimum cost.

3.1.9 energy services interface (ESI) [b-ITU-T FG-Smart]: A set of functions consisting of gateway functions and functions required for smart grid applications to control and manage the smart grid services in the customer premises.

3.1.10 energy storage [b-ITU-T FG-Smart]: Energy storage provides storage functions of electricity using various types of batteries.

NOTE – One example usage of energy storage is used to respond effectively to a dynamic price mechanism from a utility network. The electric energy is stored in the storage during a relatively lower price period, while the stored electric energy may replace the higher price of electric power from the utility network.

3.1.11 meter data management system (MDMS) [b-ITU-T FG-Smart]: Meter data management (MDM) refers to a key component in the smart grid infrastructure that is in the process of being evolved and adopted by utility companies. An MDM system (MDMS) performs long term data storage and management for the vast quantities of data that are now being delivered by smart metering systems. This data consists primarily of usage data and events that are imported from the head end servers that manage the data collection in advanced metering infrastructure (AMI) or automatic meter reading systems.

An MDMS will typically import the data, then validate, cleanse and process it before making it available for billing and analysis. The more flexible the MDM application, the better it is able to integrate to existing enterprise applications and help to streamline utility business processes. Benefits can be seen in billing, customer service, outage management and analysis of utility operations.

3.1.12 sensor [b-ITU-T FG-Smart]: Sensors are a significant component of the electrical grid; sensors are used in several ways: temperature monitoring, security, providing data for peak demand adjustment. They are integral components of a smart grid.

3.1.13 service provider [b-ITU-T FG-Smart]: An organization providing smart grid related services to electrical customers and utilities.

3.1.14 smart grid [b-ITU-T FG-Smart]: The "Smart Grid" is a two way electric power delivery network connected to an information and control network through sensors and control devices. This supports the intelligent and efficient optimization of the power network.

3.1.15 smart meter [b-ITU-T FG-Smart]: Smart meter is a premise device to monitor and control electrical power usage of home devices based on "Demand Response (DR) information" from home devices. But, it is not recommended that the smart meter controls directly per each premise appliance because of the private security policy. To control and manage each premise appliance, it is required for a home management system such as a home gateway and a home server to support the control and management.

3.1.16 substation [b-ITU-T FG-Smart]: The site where equipment for switching or regulating electrical voltage is located.

3.1.17 supervisory control and data acquisition (SCADA) [b-ITU-T FG-Smart]: A computer system that monitors an industrial, infrastructure, or facility-based control process.

3.1.18 utility provider [b-ITU-T FG-Smart]: An organization that provides electric power, gas and water. In smart grid, a utility company supplies electric power.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 micro energy grid (MEG): A group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that act as a single controllable entity with respect to the utility grid. A micro energy grid can connect and disconnect from the utility grid to enable it to operate in utility grid-connected mode or island-mode.

NOTE – A utility grid is a commercial electric power distribution system that takes electricity from a generator, transmits it over a certain distance, then takes the electricity down to the consumer through a distribution system.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AMI	Advanced Metering Infrastructure
ATS	Automatic Transfer Switch
BAS	Building Automation System
BEMS	Building Energy Management System
CHP	Combined Heat and Power
CIS	Customer Information System
CTTS	Closed Transition Transfer Switch
DER	Distributed Energy Resources
DR	Demand Response
EMS	Energy Management System
ESI	Energy Services Interface
HAN	Home Area Network
HEMS	Home Energy Management System
ID	Identifier
LAN	Local Area Network
MDM	Meter Data Management
MDMS	Meter Data Management System
MEG	Micro Energy Grid
NAN	Neighbourhood Area Network
RER	Renewable Energy Resource
SCADA	Supervisory Control and Data Acquisition

WAN Wide Area Network

5 Conventions

In this Recommendation,

- The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this Recommendation is to be claimed.
- The keywords "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

6 Overview of a micro energy grid

The concept of a micro energy grid (MEG) is introduced so as to enhance the local reliability and flexibility of electric power systems, which may consist of multiple distributed energy resources (DER), customers and energy storage facilities. The MEG is considered as a small electric power system able to operate as a physical island or interconnected with the utility grids.

NOTE – Due to increasing shortages in fossil fuels and the impelling pressures from environmental protection, new high efficiency energy generation sources such as fuel cells and micro gas turbines, as well as renewable energy resources (RERs) such as wind and solar power, are becoming the most important DER.

In the MEG, there is an entity known as a prosumer that consumes and produces electricity, operates or owns a power system that contains sources, loads and energy storage, while optimizing the economic decisions regarding its energy utilization. The prosumer can be an owner of DERs and storage as well as a consumer as outlined below:

- DER owner: An owner who operates a DER which is connected to the MEG.
- Consumer: A consumer of electricity that may be a private individual, a business building, a large industrial / manufacturing industry or a transportation system. The consumer acts as a customer and may operate smart appliances which are flexible in demand.
- Storage owner: A provider of storage capacity for storing and delivering energy.

Therefore, the prosumer consumes, produces and stores energy and participates in a market externally. In addition, the prosumer operates a power system and economically optimizes its energy use internally. Stemming from the MEG concept and the roles of prosumers, the MEG can provide the following benefits:

- Power is generated where it is needed,
- Ease of renewable energy integration,
- Local control and ownership,
- Reduction in transmission losses and carbon footprint,
- Stand-alone grid and operation in isolation mode in case of blackout,
- Ease of finance and faster to build.

To support the MEG, the following features should be considered, [b-IEEE 1547.x] and [b-DOE MEG]:

- **Autonomy**: The MEG includes generation, storage and loads and can operate autonomously in utility grid-connected mode and islanded mode.
- **Stability**: Independent local control of generators, batteries and loads of the MEG is based on frequency droops and voltage levels at the terminal of each device.

NOTE – The MEG can operate in a stable manner during nominal operating conditions and during transient events, no matter whether the larger utility grid is up or down.

- **Compatibility**: The MEG is completely compatible with the existing utility grid. MEGs may be considered as functional units that support the growth of the existing system in an economically and environmentally friendly way.
- **Flexibility**: The expansion and growth rate of the MEG does not need to follow any precise forecasts. The lead times of corresponding components (e.g., fossil-fueled and renewable generators, storage systems and others) are short and the MEG can grow incrementally. The MEG is also technology-neutral and able to cope with a diverse mixture of renewable and fossil-fueled generators.
- **Scalability**: The MEG can simply grow through the additional installation of generators, storage facilities and loads. Such an extension usually requires an incremental new planning of the MEG and can be performed in a parallel and modular manner in order to scale up to higher power production and consumption levels.
- **Efficiency**: Centralized as well as distributed MEG supervisory controller structures can optimize the utilization of generators, manage charging and discharging energy storage units and manage consumption. In this way energy management goals can be profoundly optimized in economic as well as environmental respects.
- **Economics**: The economics of heat recovery and its application by combined heat and power (CHP) systems is very important to the evaluation of the MEG. In addition, the utilization of RERs helps to reduce fuel costs and CO2 emissions.
- **Peer-to-peer model**: The MEG can support a true peer-to-peer model for operation, control and energy trade. In addition, interactive energy transactions with the centralized utility grid are also possible with this model.

7 Requirements for a micro energy grid

The MEG must meet several requirements to enable seamless operation. The MEG has the following high-level requirements:

- It is required to provide open interfaces to easily support new applications and services to various stakeholders (e.g., service provider, consumer, etc.);
- It is required to support decentralized control for distributed generation and consumption;
- It is required to measure the demand, generation and status of each MEG component at various locations across the network;
- It is required to automatically configure and install new devices or systems for the MEG;
- It is required for a communication network to carry data across the various resources;
- It is required to interact with operators or any client or server to demonstrate and archive the MEG real-time data and receive the required commands and information;
- It is required to ensure interoperability between different information/communication models used in the MEG services, [b-NIST] and [b-IEEE 2030];
- It is required to self-organize systems and dynamically coordinate controllers for the recovery in the case of a problem (e.g., a blackout);
- It is required to support highly secure and safe communications for the MEG services;
- It can be optionally required to minimize the total operation costs subject to different constraints and apply them automatically to the MEG components.

MEG networks have the following high-level requirements. MEG networks are required to support:

- Fault tolerance for reliability;

- Seamless transfer between wired and wireless networks;
- Self-healing via topological reconfigurations;
- Communication security;
- Multi-point to multi-point data transfer in forming mesh network.

8 Architecture overview of a micro energy grid

The smart grid including the MEG may be considered as a conceptual model which has three top domains and nine specific domains as follows:

- **Smart power grid**: generation, transmission and distribution;
- **Smart service**: market, operation and service provider;
- **Smart prosumer**: DER, customer and transportation.

NOTE – DER and transportation are considered as separate domains from the NIST 7 domain model, [b-NIST].

For an MEG; generation, transmission and transportation are among nine specific domains that are not directly related to the MEG. In addition, the MEG provides the integrated operation and management of generation, consumption and customer services. Thus, the MEG service provider can include operation and the service provider. Figure 8-1 shows the simplified 6-domain model for an MEG drawn from the 9-domain model described above. This 6-domain model represents interactions and communication paths among domains.

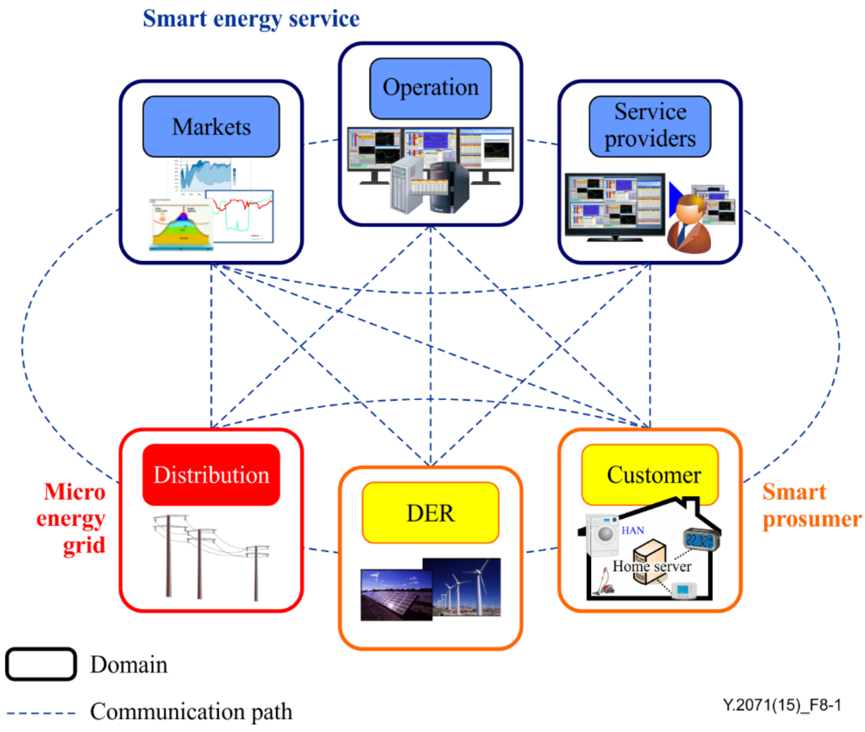

Figure 8-1 – 6-domain model for a micro energy grid

The reference architecture designed for an MEG takes into account this 6-domain model for an MEG.

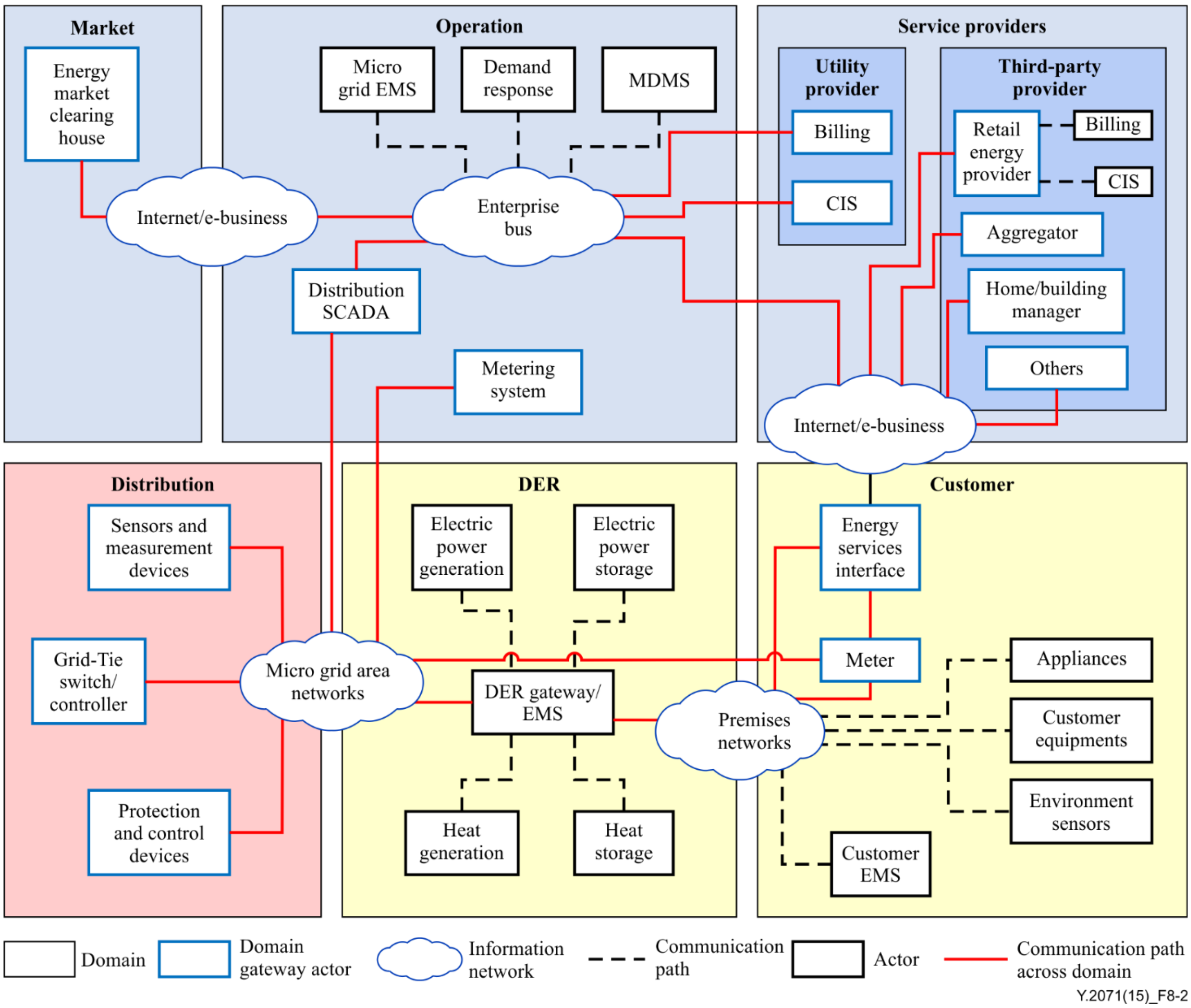

Figure 8-2 – Reference architecture for a micro energy grid

As shown in Figure 8-2, the reference architecture for an MEG consists of domains, information networks, actors and communication paths as follows:

- **Domain**: market, MEG service provider (operation and service provider), distribution, DER and customer;
- **Information network**: various types of networks for information delivery and resource sharing;
- **Actor**: devices, systems, or programs that make decisions and exchange information necessary for performing applications;
- **Communication path**: logical paths for data exchange between actors and/or between actors and information networks. It consists of communication paths within domains and communication paths across domains.

The following information networks exist:

- **Internet/e-business**: conventional public information networks such as Internet;
- **Enterprise bus**: each system for integrated operation and management services of the MEG is interconnected;
- **Micro grid area networks**: energy generation and distribution equipment within the MEG, related operating systems and meters in the customer side are interconnected.

- **Premises networks**: networks for prosumers having the roles of consumer, DER owner and storage owner, they can be made of both public networks and private networks.

Each domain has related actors as follows:

- **Market domain**: Energy market clearing house;
- **Operation domain**: Micro grid EMS, demand response management system, meter data management system (MDMS), asset management and distribution supervisory control and data acquisition (SCADA);
- **Service provider domain**: Billing, customer information system (CIS), energy provider, aggregator and home/building manager;
- **Distribution domain**: Substation, Grid-Tie interface, data collector and field device;
- **DER domain**: Electric power generation, electric power storage, heat generation, heat storage and heat sensor;
- **Customer domain**: Energy services interface (ESI), meter, sub-meter, customer energy management system, customer appliance and equipment, environment sensor and building automation system (BAS).

For an MEG, there are various systems and devices as follows:

- **Distributed energy resource (DER)**

  A DER includes distributed generation which is connected to the MEG.

  NOTE – Photovoltaic systems, small wind turbines, heat or electricity storage, combined heat and power (CHP) and controllable loads are examples of DER. These devices provide intelligence to be monitored and controlled to support DER applications which increase the efficiency of energy supply and reduce the electricity delivery cost and carbon footprint.

- **Storage**

  Storage provides an electricity reserve to the MEG.

  NOTE – Batteries, super capacitors and flywheels to match generation with demand are examples of storage in MEG. According to different energy sources, there can be electric power storage and heat storage, etc. Storage can supply generation deficiencies, reduce load surges, reduce network losses, etc.

- **MEG control system**

  An MEG control system consists of different subsystems of the MEG operator to ensure the control and management tasks of the MEG and the aggregation of supply and demand.

- **Home/building energy management system (HEMS/BEMS)**

  A HEMS/BEMS acts at the interface between the smart home/building and the MEG. Each customer is controlled by a HEMS/BEMS which communicates in-house with electronic appliances and to the outside with the MEG control system. The HEMS/BEMS aggregates the services of the electronic appliances in the household and provides them to the MEG.

- **Network device**

  An intelligent electrical device (e.g., so-called smart devices) in the MEG that can be supervised and controlled.

  NOTE – Sensors and circuit-breakers or switches are examples of network devices.

9 Control and management services of a micro energy grid

This clause describes typical application services for control and management of MEGs and shows the reference model for each application service.

As shown in Figure 9-1, there are four typical application services for control and management of an MEG: advance metering infrastructure (AMI), demand response (DR) management, customer energy management system and distributed energy grid management.

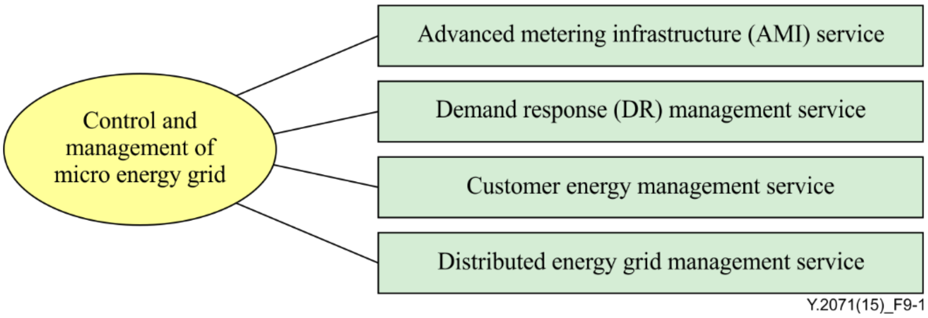

Figure 9-1 – Four typical application services for control and management of an MEG

A reference model for each MEG application service is designed to support interoperability among systems which are developed independently for application services. From the related applications and data information flows, the reference model represents the actors' configuration of each domain and the interfaces among actors.

9.1 Advanced metering infrastructure (AMI) service

AMI is an infrastructure for the collection and management of energy (e.g., electricity, gas, heat, etc.) consumption measurement data for each building within the MEG domain. Using bidirectional communications, it can provide real-time pricing information to customers for saving on energy consumption. AMI also provides an environment for the production and resale of renewable energy (e.g., solar, water, wind, etc.).

Figure 9-2 shows the configuration of actors in each domain (e.g., MEG service provider, distribution, DER and customer) and the relationships among actors as a reference model for AMI services based on the reference architecture for an MEG.

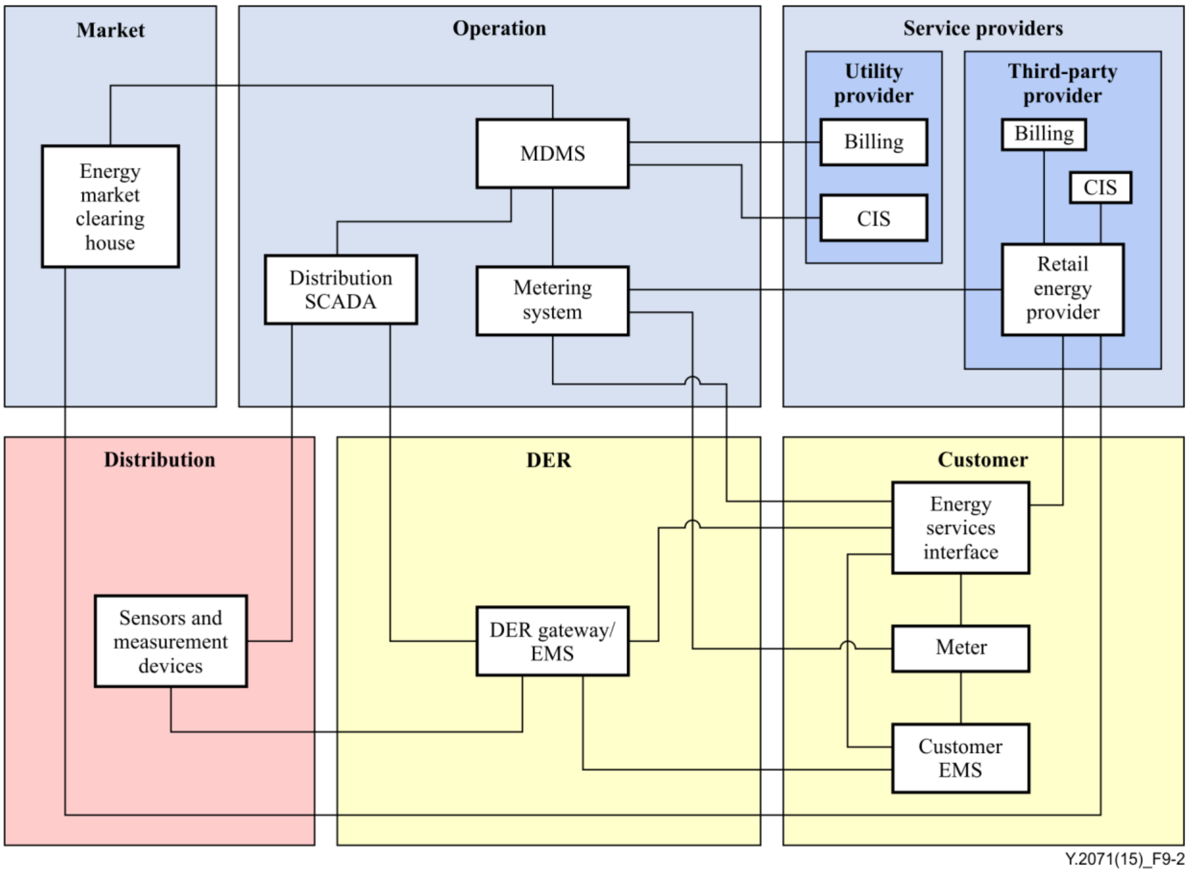

Figure 9-2 – A reference model for AMI services

9.2 Demand response (DR) management service

In the case where power reliability is at risk or where energy use within the MEG domain is at peak demand, DR management services provide mechanisms or incentives to reduce energy use. In this way DR management services optimize the balance of energy supply and demand within the MEG domain.

Figure 9-3 shows the configuration of actors in each domain and the relationships among actors as a reference model for a DR management service based on the reference architecture for an MEG.

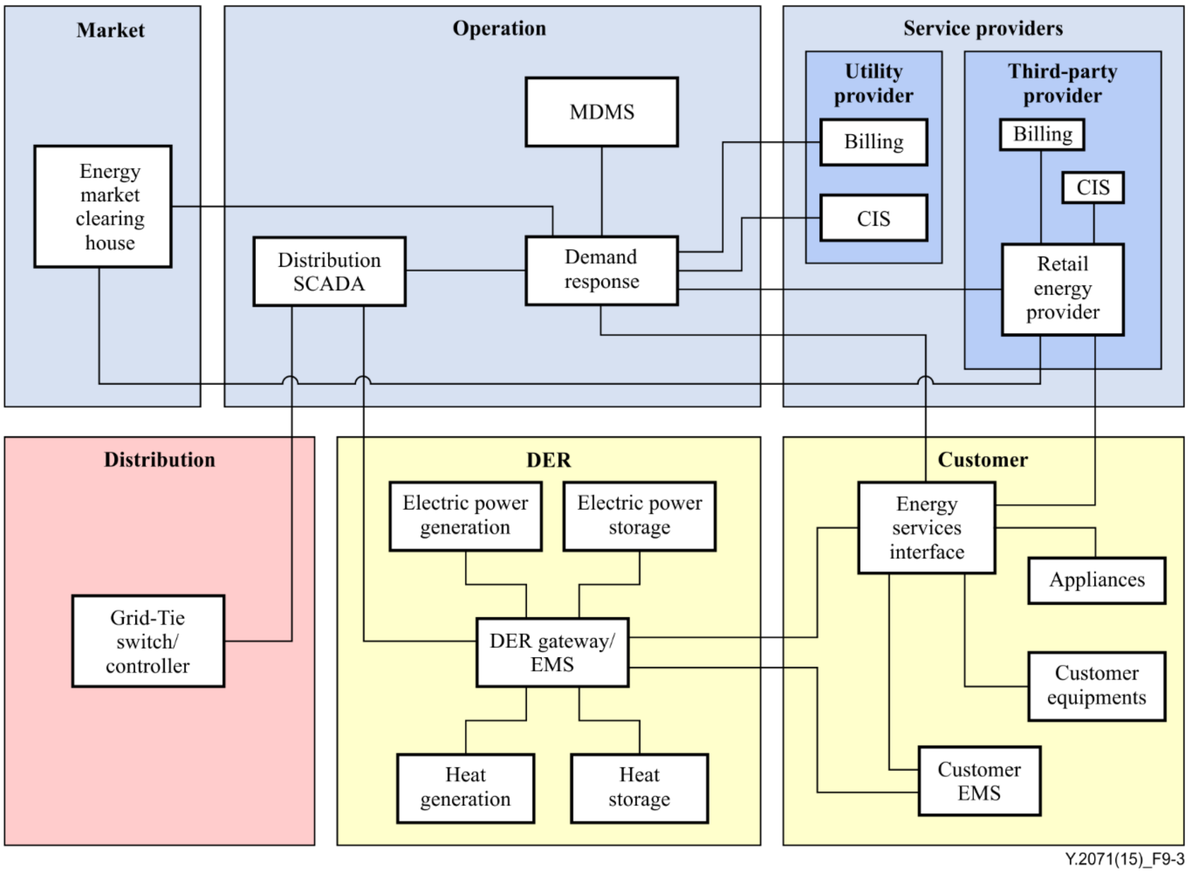

Figure 9-3 – A reference model for DR management services

9.3 Customer energy management service

A customer energy management service provides remote control and monitoring services of the building's mechanical and electrical equipment (e.g., ventilation, lighting, power systems, fire systems and security systems) in a particular area. These services include energy supply status monitoring, efficiency diagnosis of equipment, automatic data reporting of the building automation system (BAS) to save energy consumption of buildings with data from various kinds of energy sources (e.g., heating and cooling, electricity, renewable energy, etc.).

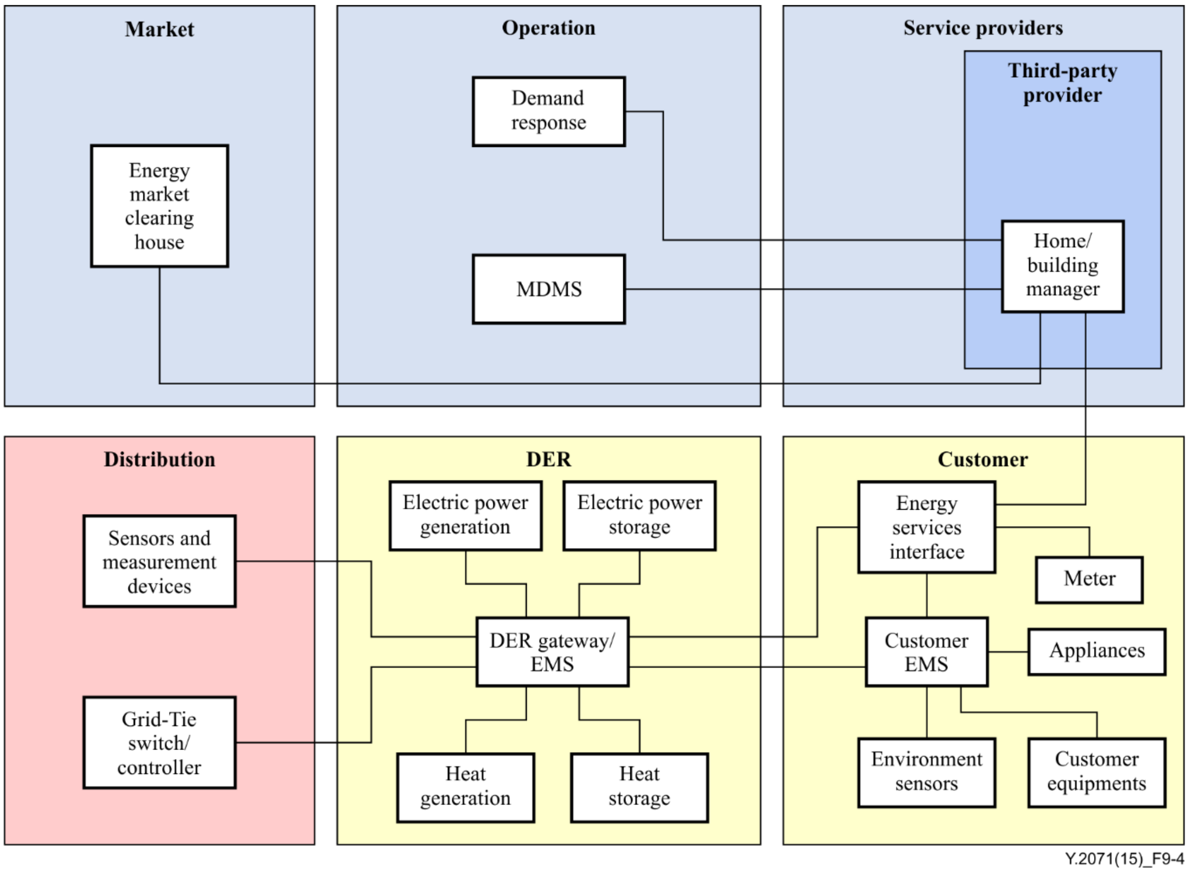

Figure 9-4 – A reference model for a customer energy management service

Figure 9-4 shows the configuration of actors in each domain and the relationships among actors as a reference model for a customer energy management service based on the reference architecture for an MEG.

9.4 Distributed energy grid management service

A distributed energy grid management service provides the environment to support optimized supply management and grid operations through integrated surveillance control for energy resource management, energy grid operation and internal network information within the MEG domain.

Figure 9-5 shows the configuration of actors in each domain and the relationships among actors as a reference model for a distributed energy grid management service based on the reference architecture for an MEG.

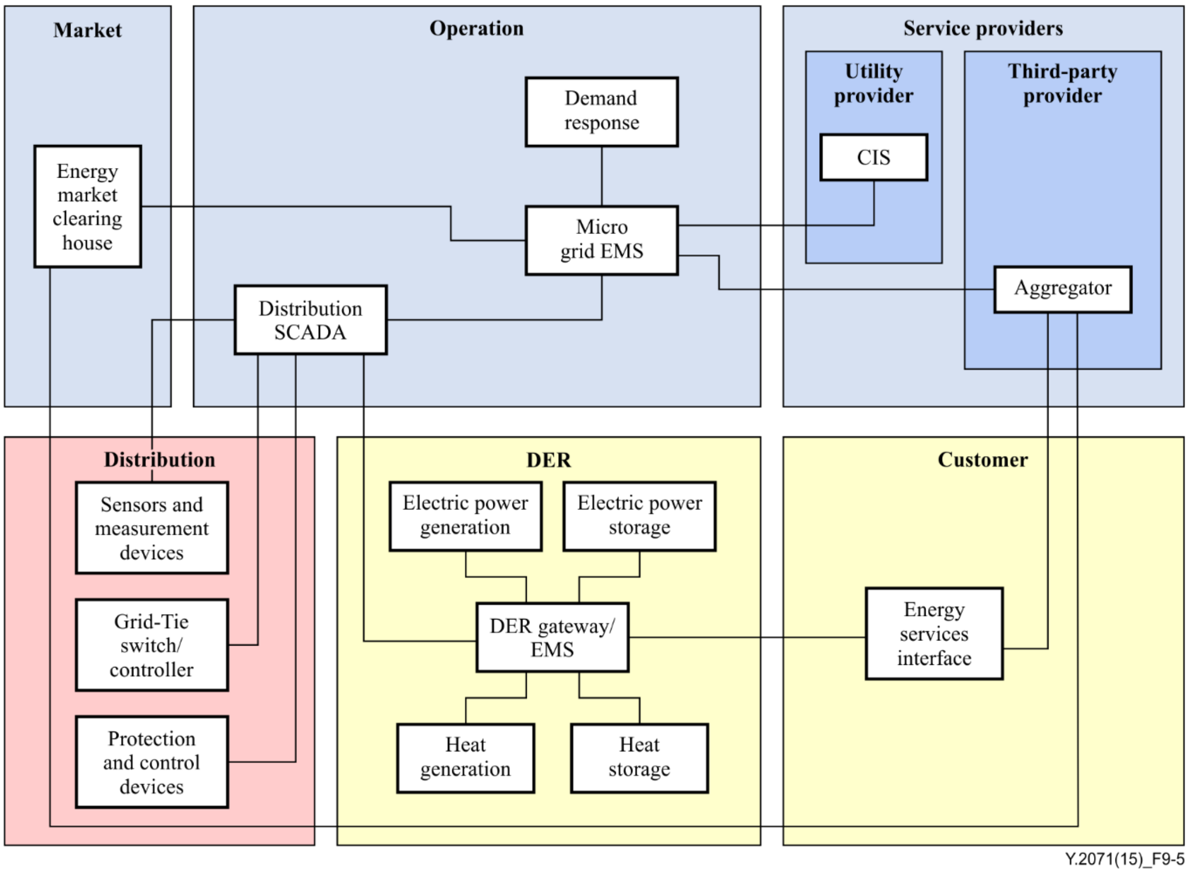

Figure 9-5 – A reference model for distributed energy grid management service

10 Core systems and components for a micro energy grid

10.1 Core systems for a micro energy grid

Figure 10-1 shows a configuration of core systems to support an MEG. The customer premises network domain includes a power trading system, an energy revenue calculating system and a customer energy management service provisioning system including other devices (e.g., customer energy devices, smart meter, control point and grid linked inverter, etc.). These systems are connected to each other through a customer premises network (e.g., home network, building network, etc.). Through the Internet, several kinds of servers are also interconnected to support various applications/services for an MEG.

NOTE 1 – the control point receives power purchasing and selling prices from the users and provides the accounting information about power purchasing and selling to the users.

NOTE 2 – the grid linked inverter converters power input to and output from the power storage system/device in accordance with requests from the power trading system while interlocked with the utility grid.

NOTE 3 – Energy revenue means income from the sale of energy generated from energy resources in the MEG to utility grids. Energy profits or net income generally implies total revenue minus total expenses in a given period.

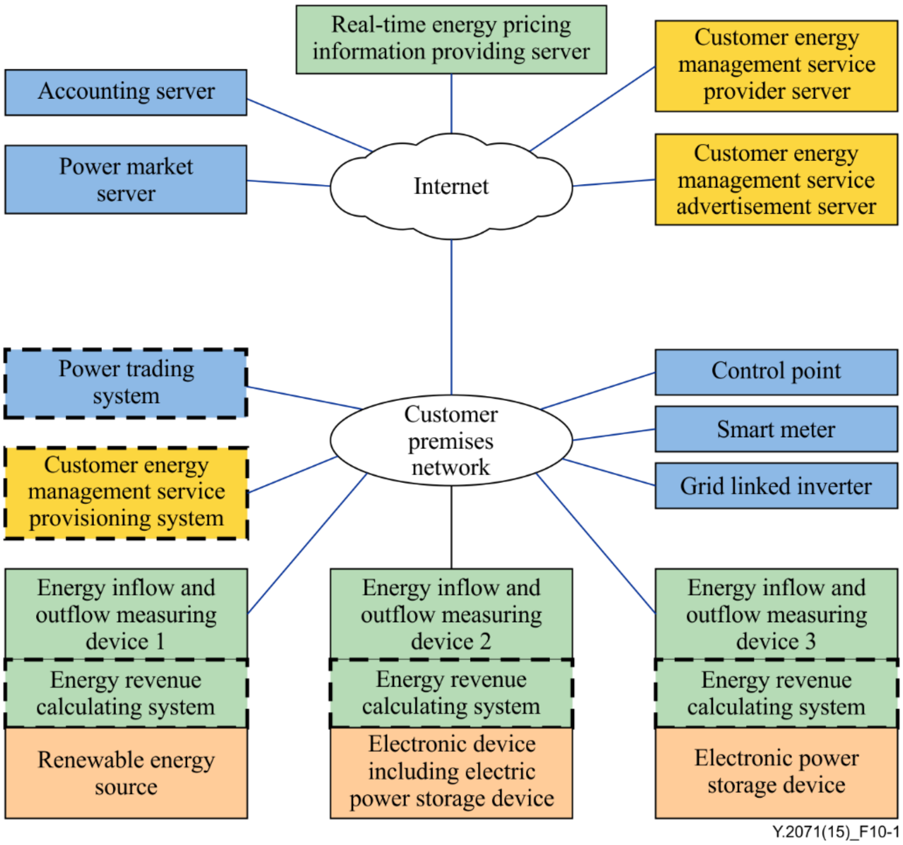

Figure 10-1 – Configuration of core systems to support a micro energy grid

A **power trading system** calculates power usage and sales charges of users with power prices that change in real-time based on time synchronization in an MEG environment and automatically purchases and sells power in accordance with power trading prices set by the users.

The power trading system includes the following components:

- **Time synchronous unit**: This unit synchronizes at least one of a power market server and a smart meter and an authorized time information providing server with time so that the users may purchase or sell power at desired prices among power prices that change in real-time.
- **Power trading price setting unit**: This unit sets power purchasing and selling prices that are input by the users as reference prices for power trading.
- **Power purchasing and selling price monitoring unit**: This unit receives power purchasing and selling price information from the power market server or a utility service provider system, monitors power purchasing and selling prices that change in real-time based on the received power purchasing and selling price information. The unit then compares the received power purchasing and selling prices with the reference prices for power trading that are set by the power trading price setting function in order to analyse the comparison result.
- **Inverter and power storage system controller**: This controls the power conversion of an inverter as well as the charging and discharging of the power storage system/device in order to purchase and sell power at the reference prices set when the power purchasing and selling prices received by the power purchasing and selling price monitoring unit match the reference prices set by the users.
- **Accounting and information output unit**: This unit outputs accounting information about power purchases and sales based on power charger information generated by purchasing power at the reference prices when the users request to purchase power or in real-time and also outputs incentive information obtained by selling power.

An **energy revenue calculating system** is used for calculating energy revenues of electric power devices based on real-time pricing.

The energy revenue calculating system includes the following components:

- **Time synchronizing unit**: This unit communicates with a real-time energy pricing information providing server and an authorized time information providing server. It receives time information from the real-time energy information providing server which is the authorized time information providing server. Then, the time synchronizing unit synchronizes time between the energy revenue calculating system and the real-time energy pricing information providing server, based on the received time information.
- **Real-time energy pricing information synchronizing unit**: This unit receives real-time energy sale price information that changes in real-time from the real-time energy pricing information providing server. It synchronizes an energy sale price previously stored in the energy revenue calculating system with the received real-time energy sale price, based on a price change schedule received from the real-time energy pricing information providing server. The unit then stores the synchronized energy sale price in a database.
- **Energy flow and outflow measuring unit**: This unit measures an amount of energy that flows into and out of electric power devices (e.g., a renewable energy source, an electric power storage device, an electric device including an electric power storage device). In Figure 10-1, the renewable energy source, the electric device and the electric power storage device are connected to one another over a customer premises network. The amount of energy is determined using measuring devices included in each of the renewable energy source, in the electric device including an electric power storage device and in the electric power storage device.
- **Real-time energy revenue calculating unit**: This unit calculates energy revenues with respect to each of the renewable energy source, the electric device including an electric power storage device and the electric power storage device for a predetermined time period, based on the synchronized energy sale price and the measured amount of energy.
- **Real-time energy revenue output unit**: This unit outputs the energy revenues calculated by the real-time energy revenue calculating unit so that a user verifies the information about the energy revenues through the electric power devices in real-time. It provides the energy revenues with the renewable energy source, the electric device and the electric power storage device, which are connected to one another over a customer premises network.

A **customer energy management service provisioning system** allows a service user to selectively subscribe to a variety of the customer energy management services under an MEG environment, automatically searches for the customer energy devices that are capable of interworking with a subscribed service and forwards the customer energy management messages to the customer energy devices, thereby provisioning the customer energy management service provider server of the third party at a remote location.

A customer energy management service provisioning system includes the following components:

- **Customer energy management service subscription unit**: This unit receives the service advertisement information from the customer energy management service advertisement server, extracts a list of the customer energy management services and supplies the service user with the list of the customer energy management services that the subscription of the service user allows. Furthermore, when the service user requests to subscribe to a service, the customer energy management service subscription unit mutually authenticates with the customer energy management service provider server which provides the service selected by the service user and receives a secret key for encryption and decryption of the message.

- **Security memory area management unit**: This unit manages a secret key that is received by the customer energy management service subscription unit and a memory area for securely storing security information related to the service provisioning.
- **Customer energy device management unit**: This unit searches for customer energy devices on the customer premises network to assign unique identifiers (IDs) to the searched devices and transmits a list of the searched customer energy devices to the customer energy management service provider server.
- **Encryption/decryption processing unit**: This unit encrypts and decrypts the message, which is transmitted to and received from the customer energy management service provider server, using the secret key which is managed by the security memory area management unit.
- **Customer energy management message processing unit**: This unit performs a data processing operation such as data conversion on the customer energy management message being transmitted and received between the customer energy management service provider server and the customer energy devices, to provide the processed message to the customer energy devices.

10.2 Key components for selective delivery of distributed energy resources information

This clause illustrates the system for delivering only selected information from a distributed energy management server in real-time after collecting DER information from multiple slave devices such as switch controllers (e.g., automatic transfer switch (ATS), closed transition transfer switch (CTTS), etc.) and sensors for checking vibration, temperature, noise, etc.

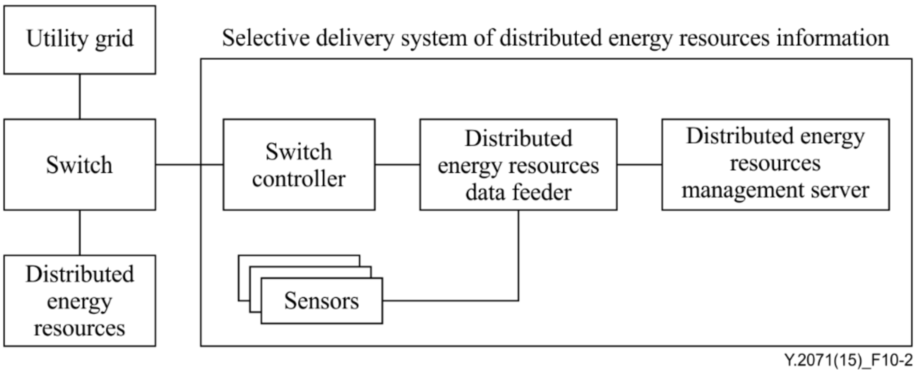

Figure 10-2 – System architecture of key components for selective delivery of distributed energy resources information

Figure 10-2 shows the selective delivery system with key components for DER information with multiple slave devices. A switch controller enables the DER to interwork with the utility grid. It also controls the switch for independently establishing the MEG and receives DER status information. Sensors are installed near the DER in order to sense vibration, noise and temperature, etc. A DER data feeder collects information from the switch controller and sensors and delivers only selected information to the DER management server from among the subscribed data. The DER management server receives the subscribed data from the DER data feeder and utilizes the information to manage the DER.

10.3 Key components for calculating basic electricity charges

This clause illustrates the system for calculating basic electricity charge per a partitioned owner in an aggregate building based on periodic electricity usages from smart meters and shares owned by a partitioned owner in an MEG environment of aggregate buildings.

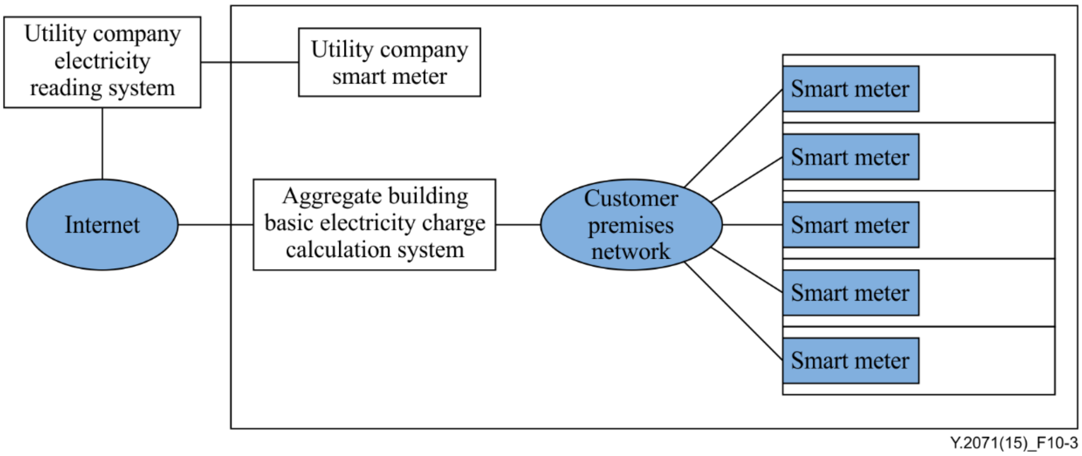

Figure 10-3 – System architecture of key components for calculating basic electricity charges per a partitioned owner in an aggregate building

Figure 10-3 shows the system with key components for calculating basic electricity charge considering shares owned by a partitioned owner and peak demand electricity of an individual owner based on electricity usages.

The **aggregate building basic electricity charge calculation system** periodically collects electricity usages of partitioned owners and calculates basic electricity charge per a partitioned owner. Smart meters provide the meter reading information periodically to the aggregate building basic electricity charge calculation system. A customer premises network is used for communications between the aggregate building basic electricity charge calculation system and smart meters. The aggregate building basic electricity charge calculation system also receives the total charge of electricity usages of an aggregate building from the utility company smart meter and related information for electricity usage from the utility company electricity reading system via Internet.

11 Security considerations

The security considerations in an MEG should be in accordance with the security requirements in [ITU-T X.1111] and [ITU-T Y.2701].

An MEG should consider various security aspects in terms of physical security, system security, and operation security as follows:

- Verifying the identity of an entity (e.g., user, process, or device) for accessing to resources in an MEG system;
- Determining the adequacy of security requirements and ensuring compliance with the established security policy and procedures for an MEG;
- Authorization to use various services in an MEG system;
- Supporting cryptography and validation mechanisms for data integrity in an MEG;
- Providing the privacy considerations with respect to an MEG.

Appendix I

Key functions for a micro energy grid

(This appendix does not form an integral part of this Recommendation.)

This appendix shows key functions for an MEG from the functional model of a smart grid [b-ITU-T FG-Smart-Arch].

The functional model of a smart grid identified the principle functional groups for a smart grid, including the end-user functions, the application functions, the smart metering functions, the energy control functions, the power grid functions, the network functions, the management functions and the security functions. These functions can be applied for an MEG. Specifically the power grid functions and the energy control functions are quite important in supporting core roles for distributed energy characteristics of an MEG. Other functions can be used commonly by both the smart grid and MEG without significant changes.

For an MEG, key functions within each functional group are shown in Table I.1.

Table I.1 – Key functions for an MEG from the functional model of a smart grid

	Functional group	Key functions
1	Customer functions	• Local energy generation and storage • Home/building energy management and automation • Electric vehicle charging • Energy demand response
2	Micro energy grid functions (Power grid functions*)	• DER • Distributed energy storage • Integration of distributed renewable generation • Efficient intelligent energy distribution
3	Network functions	• Reliability and failure protection • End-to-end reliable data transport • End-to-end communication management • QoS control and management
4	Smart metering functions	• Meter control, maintenance • Meter reading and data management
5	Micro energy control functions (Energy control functions*)	• Monitoring and management of DER • Electric vehicle charging • Management of energy capacity planning
6	Application functions	• AMI service support • DR service support • Group-BEMS service support • MEG management service support
7	Management functions	• Application management • Device management • Network management
8	Security functions	• Identification and authentication • Audit and accountability • Access control • Data integrity • Privacy preserving
*: This symbol stands for the functions' names in the functional model of a smart grid.		

Appendix II

Deployment models for a micro energy grid

(This appendix does not form an integral part of this Recommendation.)

Communication networks connect various power systems for generation, transmission, distribution and consumption and the information and operation software platforms. Information containing the real-time data that reflects the status of the utility grid is transmitted and exchanged bi-directionally among the grid operators, consumers and ecosystem operators.

In general, smart grid networks can be categorized into several logical components based on their coverage, such as home area networks (HANs), local area network (LANs), neighbourhood area network (NANs), wide area networks (WANs) and access networks as shown in Table II.1.

Table II.1 – Major components of smart grid networks (source: [b-ITU-T FG-Smart])

Term	Definition
Wide area network	A wide area network (WAN) is a communication network that covers a wide geographical area and accommodates terminals and LANs. This is typically called a "back haul" network in a smart grid environment.
Local area network	A local area network (LAN) is a network that connects computers and devices in a limited geographical area such as a home, a computer laboratory, an office building and a closely positioned group of buildings.
Home area network	In smart grid applications, home area networks (HANs) refer to the networks in the homes that interconnect energy devices, including appliances, energy management stations, plug-in electrical vehicle chargers and energy sources.
Access network	An access network refers to a network which connects subscribers to their immediate service provider. It is contrasted with the core (or transport) network in a wide area network.
Neighborhood area network	A neighborhood area network (NAN), is an access network that allows a smart grid end-device and home area networks to connect to a wide area network.

The MEG concept is the division of a large scale utility grid into small community utility grids. Each of these small community grids contains local traditional power generation and RERs; i.e., dividing the large metropolitan smart grid area into smaller segments. Each of the segments is an autonomous stand-alone grid that can be called an MEG. This MEG can be managed locally and can be integrated to the larger grid to trade power and exchange information when needed.

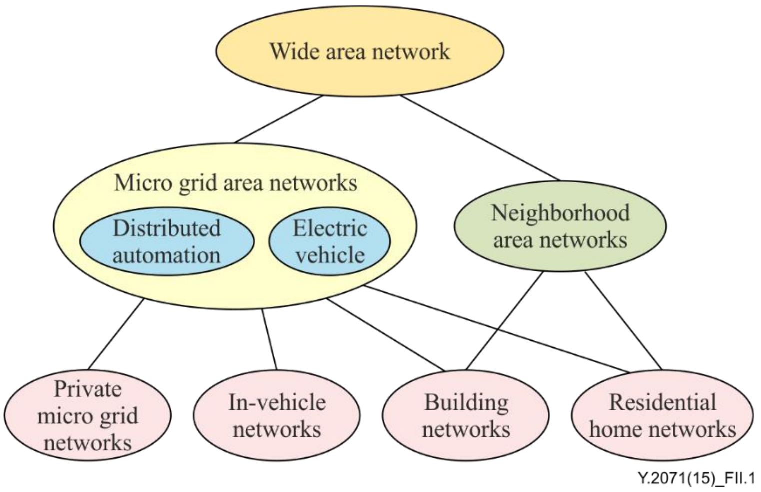

Figure II.1 – Deployment model for micro energy grid networks

Figure II.1 shows an example of a deployment model for MEG networks which consists of micro grid area networks, private micro grid networks and customer premises networks (e.g., building networks, residential home networks, etc.) which provide the communications between the appliances and equipment with the customers' premises.

Appendix III

Operations and information flows for micro energy grid scenarios

(This appendix does not form an integral part of this Recommendation.)

III.1 Automated power trading

The following illustrates detailed operations for a time synchronization based automated power trading method for real-time pricing:

- **Operation 1**: The power trading system synchronizes at least one of the power market server and the smart meter and the time information providing server with time in order to purchase or sell power at the prices set by the users in real-time pricing.
- **Operation 2**: The power trading system receives power purchasing and selling prices by the users to set the received power purchasing and selling prices as the reference prices for power trading.
- **Operation 3**: The power trading system receives power purchasing and selling prices that change in real-time based on the power purchasing and selling price information and compares the power purchasing and selling prices to the predetermined reference prices for power trading.
- **Operation 4**: When the power purchasing and selling prices reach the reference prices, the power trading system controls the power conversion of the inverter and the charge and discharge of the power storage system/device in order to purchase and sell power at the reference prices.

Figure III.1 is an information flow diagram illustrating a time synchronization based automated power trading method for real-time pricing.

1. In order to calculate the power using and selling charges of the users with the power prices that change reflected in real-time based on time synchronization and to automatically purchase and sell power in accordance with the power trading prices set by the users, a smart meter first synchronizes a power market server with time information.
2. A power trading system receives time information from the smart meter whose time is synchronized with the power market server so that the time information coincides.
3. When the users set the power trading prices in the power trading system through a control point, the power trading system receives power purchasing and selling price information from the power market server to monitor power purchasing and selling price in real-time.
4. The power trading system controls the power conversion of a grid linked inverter when the power purchasing and selling prices reach the reference prices set by the users.
5. The power trading system controls the charge and discharge of a power storage system.
6. The smart meter informs an accounting server of a changing amount of input and output power.
7. When the users request accounting information through the control point, the power trading system requests the accounting server to verify the accounting information.
8. Subsequently, the accounting server verifies and analyses the power input and output amount history information from the smart meter in order to analyse user accounting information.
9. The accounting server transmits the analysed information to the power trading system.
10. Then, the power trading system transmits the transmitted information to the control point so that the accounting information is output.

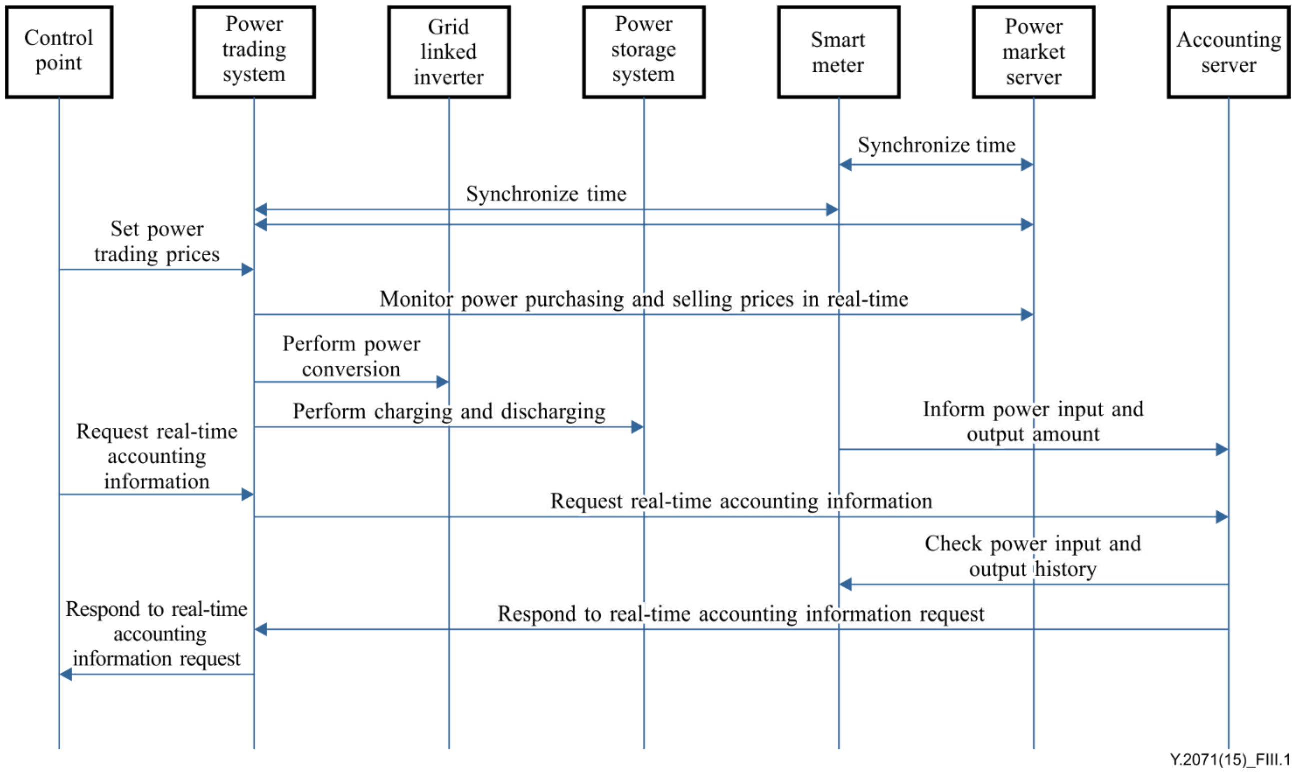

Figure III.1 – An information flow diagram for automated power trading

III.2 Real-time energy revenue calculation

The following illustrates detailed operations for calculating the energy revenues of electric power devices based on real-time pricing:

- **Operation 1**: In order to calculate the energy revenues of electric power devices under a micro energy grid based real-time pricing environment, an energy revenue calculating system receives accurate authorized time information from a real-time energy pricing information providing server or an authorized time information providing server and synchronizes time information of the energy revenue calculating system with the received time information.
- **Operation 2**: The energy revenue calculating system receives real-time energy sale price information and price change schedule information from the real-time energy pricing information providing server and continuously synchronizes information about an energy sale price stored in the energy revenue calculating system with the received energy sale price information.
- **Operation 3**: The energy revenue calculating system measures the amount of energy that flows into and out of electric power devices, for example, a renewable energy source, an electric power storage device or an electric device including an electric power storage device, which interwork with the energy revenue calculating system.
- **Operation 4**: The energy revenue calculating system calculates real-time energy revenues based on the amount of energy that flows into and out of the electric power devices at a current point in time or for a predetermined time period and the received real-time energy sale price information.

Figure III.2 is an information flow diagram illustrating a method for calculating energy revenues of electric power devices based on real-time pricing.

1. When an energy revenue calculating system is provided in a renewable energy source, an electric device including an electric power storage device and an electric power storage device, an operation of the energy revenue calculating system calculates for the entire system

the energy revenues of the electric power devices under a micro energy grid based real-time pricing environment.

2. The energy revenue calculating system receives accurate authorized time information from a real-time energy pricing information providing server (or an authorized time information providing server) and synchronizes time information of the energy revenue calculating system with the received time information.

3. The energy revenue calculating system receives real-time energy sale price information and information about a price change schedule from the real-time energy pricing information providing server and continuously synchronizes information about an energy sale price stored in the energy revenue calculating system with the received energy sale price information.

4. The energy revenue calculating system measures the amount of energy that flows into and out of the renewable energy source, the electric device including an electric power storage device and the electric power storage device.

5. The energy revenue calculating system calculates the real-time energy revenues, based on information about the amount of energy measured at a current point in time, or for a predetermined time period and the received real-time energy price information.

6. The energy revenue calculating system provides information about the real-time energy revenues so that a user may verify the information about the energy revenues through a corresponding electric power device, for example, the renewable energy source, the electric device including an electric power storage device, the electric power storage device, or a mobile terminal of a user.

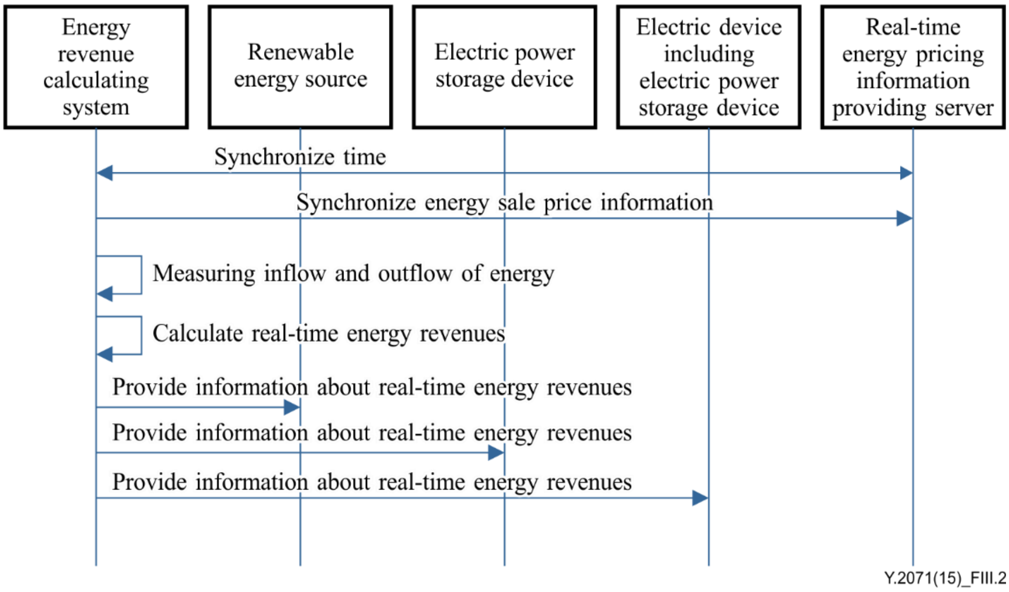

Figure III.2 – An information flow diagram for real-time energy revenue calculation – 1

Figure III.3 is an information flow diagram illustrating a method of calculating energy revenues of electric power devices based on real-time pricing.

1. The energy revenue calculating system integrally manages energy revenues of electric power devices, without being part of the electric power devices, for example, a renewable energy source, an electric device including an electric power storage device and an electric power storage device. In addition the energy revenue calculating system operates under a micro energy grid based real-time pricing environment.

2. The energy revenue calculating system receives accurate authorized time information from a real-time energy pricing information providing server (or an authorized time information

providing server) and synchronizes time information of the energy revenue calculating system with the received time information.

3. The energy revenue calculating system receives real-time energy sale price information and information about a price change schedule, from the real time energy pricing information providing server and may continuously synchronize energy pricing information of the energy revenue calculating system with the received energy sale price information.

4. The energy revenue calculating system collects information about an amount of energy that flows into and out of each of the renewable energy sources, the electric device including an electric power storage device, the electric power storage device, from a first energy inflow and outflow measuring device, a second energy inflow and outflow measuring device and a third energy inflow and outflow measuring device.

5. The energy revenue calculating system calculates the energy revenues of the electric devices based on the received real-time energy sale information and the collected information about the amount of the energy that flows into and out of each of the electric power devices.

6. The energy revenue calculating system directly outputs information about the energy revenues, or provides output information to a mobile terminal of a user so that the user verifies the information about the energy revenues of the electric power devices.

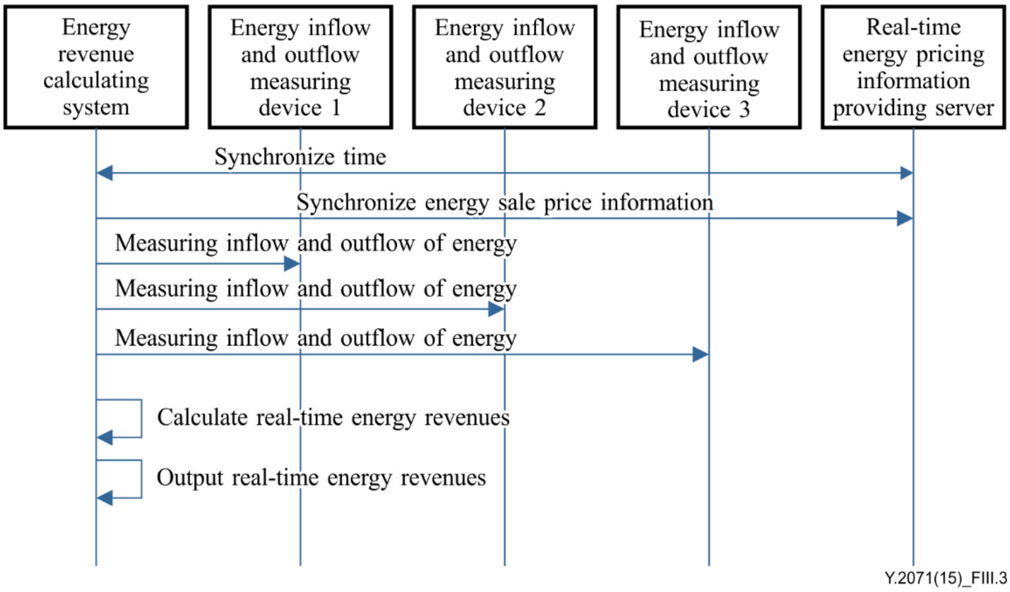

Figure III.3 – An information flow diagram for real-time energy revenue calculation – 2

III.3 Customer energy management services provisioning

The following illustrates detailed operations for securely provisioning the customer energy management services by the customer energy management service provisioning system.

- **Operation 1**: In the operation of receiving an advertisement of the customer energy management services, the customer energy management service provisioning system receives the service advertisement information from the customer energy management service advertisement server and provides a list of the customer energy management services to a service user.
- **Operation 2**: In the operation of performing an authentication by the customer energy management service provider server, the customer energy management service provisioning system mutually authenticates with the customer energy management service provider server, that provides the service to which the user requests to subscribe and then receives a secret key for the encryption and decryption of the message.

- **Operation 3**: In the operation of searching for the customer energy devices, the customer energy management service provisioning system searches for the customer energy device on the customer premises network in order to assign unique identifiers to the searched customer energy devices and transmits a list of the searched customer energy devices to the customer energy management service provider server.

  Accordingly, the customer energy management service provider server receives the list of the customer energy services and generates the customer energy management message on the basis of the list of the customer energy devices in order to transmit the message to the customer energy management service provisioning system.

- **Operation 4**: In response to the message, in the operation of transferring the customer energy management message, the customer energy management service provisioning system performs an encryption/decryption of the message between the customer energy management service provider server and the customer energy devices and exchanges the encrypted/decrypted message.

Figure III.4 is an information flow diagram illustrating a method of securely provisioning customer energy management services under a smart grid environment.

1. The customer energy management service information from the third party service providers is registered in the customer energy management service advertisement server and the customer energy management service advertisement including the registered services is sent to the customer energy management service provisioning system of the user who desires to subscribe to one or more the services.
2. The customer energy management service provisioning system receives a list of the customer energy management services that are registered in the customer energy management service advertisement server and pushes the received list of the customer energy management services to a mobile terminal of the service user.
3. In response, the service user reviews the list of the customer energy management services and selects a desired service to make a request for a subscription to the selected service.
4. When there is the subscription request to the customer energy management service from the service user, the customer energy management service provisioning system transmits a subscription request message to the customer energy management service of the customer energy management service provider server in order to process the subscription request to the service to which the user wants to subscribe from among the list of the customer energy management services.
5. When the subscription request message to the customer energy management service is transmitted, a mutual authentication for the performance of the customer energy management and an exchange of the secret key for the encryption and decryption of the customer energy management message are performed between the customer energy management service provider server and the customer energy management service provisioning system.
6. Subsequently, when the exchange of the secret key between the customer energy management service provider server and the customer energy management service provisioning system is successfully completed, the customer energy management service provisioning system searches the customer energy device for energy production, energy consumption or energy management connected to the customer premises network.
7. When the customer energy devices are searched, the customer energy management service provisioning system makes a list of the searched customer energy devices and encrypts the list.
8. The customer energy management service provisioning system transmits the encrypted list of the customer energy devices to the customer energy management service provider server.

9. The customer energy management service provider server generates the customer energy management message capable of performing the customer energy management of the customer energy devices on the basis of the list of the customer energy devices and transmits the encrypted customer energy management message to the customer energy management service provisioning system.

10. The customer energy management service provisioning system decrypts the encrypted customer energy management message that has been received using the secret key that has been received during the operation of the authentication and key exchange.

11. The customer energy management service provisioning system relays the customer energy management message decrypted to the customer energy devices that are specified.

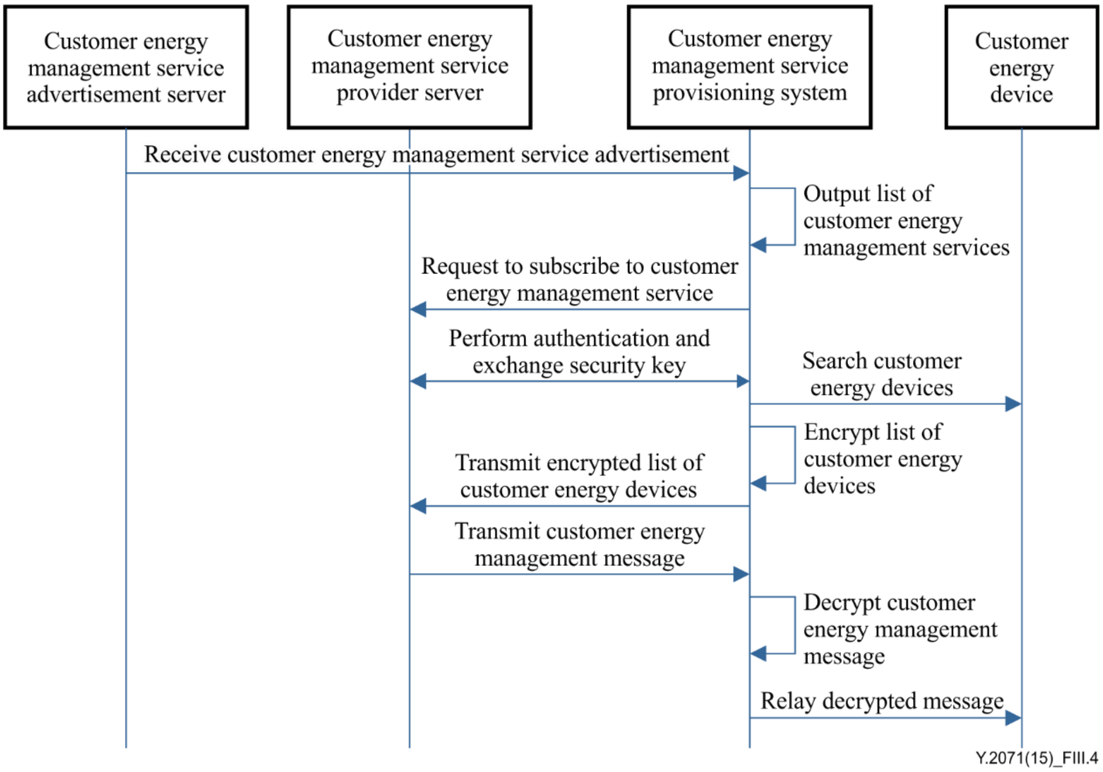

Figure III.4 – An information flow diagram for customer energy management services provisioning

Appendix IV

A mechanism for selective delivery of distributed energy resources information from multiple slave devices

(This appendix does not form an integral part of this Recommendation.)

This appendix illustrates a mechanism for delivering only selected information from a distributed energy management server in real-time after collecting DER information from multiple slave devices. This mechanism can be used for security management and control of DER (e.g., an emergency generator) which are connected to utility grids.

Based on Figure 10-2 in clause 10.2, the DER data feeder has the following functionalities.

- **Slave connection**: As a master in master/slave communications, it maintains connections among slaves (e.g., the switch controller and multiple sensors).
- **Slave data collection**: It collects data stored in the registries of multiple slave devices using a polling method.
- **Hash table management**: It stores and maintains related values in an appropriate hash table after calculating a hash key with collected data.
- **Subscribed data configuration**: It configures and maintains related items of data which the DER management server wants to subscribe to.
- **Slave data conversion**: In the case where the subscribed data of the DER management server are changed, the DER data feeder converts the data format in order to deliver the changed data to the DER management server.
- **Subscribed data delivery**: It delivers the data packet requested through the subscription of the DER management server.

Figure IV.1 illustrates details of the selective delivery mechanism of DER information from multiple slave devices in a micro grid environment.

- **Step 1 – Slave connection and subscription establishment**: It establishes master/slave connections with slave devices (e.g., the switch controller and sensors) and configures related items of subscription request data from the DER management server.
- **Step 2 – DER collection**: It collects DER management information from multiple slave devices.
- **Step 3 – Hash table data storing**: It calculates a hash key of collected data and stores the key in a hash table.
- **Step 4 – Subscription establishment data change check**: It checks if the subscription request data of the energy resources management server among data in the hash table are changed.
- **Step 5 – Hash table data reading**: If the subscription request data are changed, it reads the data from the hash table.
- **Step 6 – Subscription data transform**: It transforms the data format for the energy resources management server to receive.
- **Step 7 – Subscription data packet delivery**: It delivers the subscription data packet to the energy resources management server in a real-time manner.

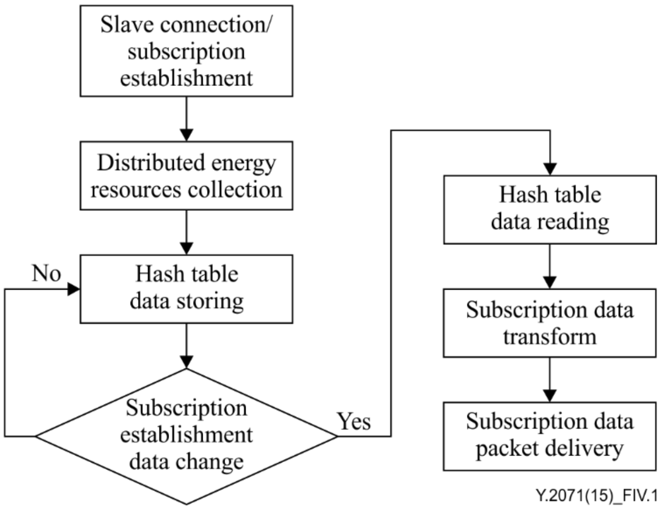

Figure IV.1 – Selective delivery mechanism of distributed energy resources information from multiple slave devices

Appendix V

A mechanism for calculating basic electricity charges for partitioned owners in an aggregate building

(This appendix does not form an integral part of this Recommendation.)

This appendix illustrates a mechanism for calculating the basic electricity charge per a partitioned owner in an aggregate building based on periodic electricity usages from smart meters and shares owned by a partitioned owner in a micro grid environment of aggregate buildings.

Based on Figure 10-3 in clause 10.3, the system for basic electricity charge calculation per a partitioned owner in an aggregate building has the following functionalities.

- **Network connection**: An aggregate building basic electricity charge calculation system is connected with smart meters of partitioned owners through a customer premises network in order to deliver the electricity usage information which a smart meter measures.
- **Input of basic information for an aggregate building**: The information for shares owned by a partitioned owner and for the monthly basic electricity charge of an aggregate building are input.
- **Electricity usage collection per a portioned owner**: It periodically collects the measurement information of electricity usage from smart meters of partitioned owners.
- **Storing of electricity usage and basic/peak electricity charge**: It stores the collected information for electricity usage as well as the calculated information for the basic electricity charge and the peak electricity charge.
- **Calculation of the basic electricity charge per a portioned owner**: It calculates the basic electricity charge per a partitioned owner during a month or a year using the stored information.
- **Output of electricity information and basic electricity charge information**: It outputs electricity information and basic electricity charge information for a partitioned owner based on contracted electricity and peak demand electricity.

Figure V.1 shows details of the mechanism for calculating basic electricity charge per a partitioned owner in an aggregate building based on electricity usages of partitioned owners.

- **Step 1 – Aggregate building information input**: As an input, the information for shares owned by a partitioned owner and for contract electricity with a utility company are given.
- **Step 2 – Power usage information collection**: The information for electricity usage is periodically collected and stored from smart meters of partitioned owners in an aggregate building.
- **Step 3 – Peak demand electricity calculation and announcement**: Using the information collected in Step 2, it calculates and announces the peak demand electricity which is the maximum value among average electricity usages of every hour.
- **Step 4 – Basic electricity charge calculation**: So that the owner of an aggregate building collects a basic electricity charge per a partitioned owner, it requests the balance of basic electricity charge from the aggregate building basic electricity charge calculation system based on the total charge of the aggregate building from a utility company.
- **Step 5 – Basic electricity charge calculation and output**: Based on all information collected in the previous steps, it calculates the basic electricity charge per a partitioned owner and gives the information to the owner.

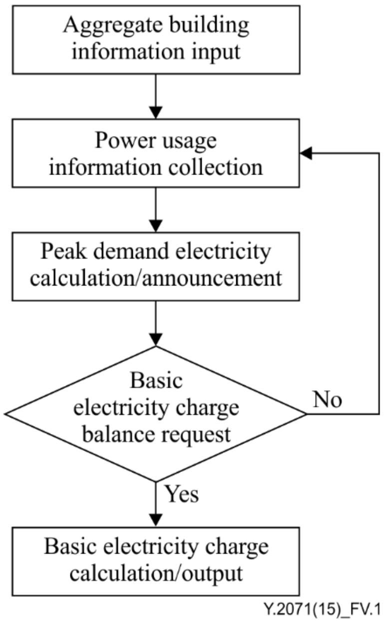

Figure V.1 – Mechanism for calculating basic electricity charge per a partitioned owner in an aggregate building

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Printed in Switzerland
Geneva, 2016