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APPROACHES TO SMART GRID COMMUNICATIONS NETWORKS IN JAPANESE ELECTRIC POWER COMPANIES

by

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SUMMARY

Electric power companies in Japan are aiming to construct a smart grid that will achieve optimum operation of the whole electric power system to enable high-quality, highly-reliable power supply even when distributed renewable energy spreads on a large scale.

Selective combination of multiple systems is an effective approach for field area network communications systems that collect data from smart meters installed in the homes of low-voltage customers. Electric power companies are in the process of implementing undertakings to construct an ideal system based on verification testing or post-introduction verification of diverse communications systems.

Verification testing conducted by Hokuriku Electric Power Company of an automatic meter-reading system that uses the multihop wireless system (remote meter reading and remote control) has confirmed that there are no problems on the practical operational level. Kyushu Electric Power Company has introduced the power line communication system in more than 40 thousand households in apartment buildings and this has laid the foundation for stable network construction and operation to handle future expansion. Juniper Networks has proposed a wireless controller capable of centralized management of a vast number of smart meters and wireless access points in the multihop wireless system and provided descriptions of efficient operational methods.

KEYWORDS

Smart Meter, Multihop Wireless, Power Line Communication, Wireless Controller, Automatic Meter Reading System

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1. Background and Purpose

To contribute to the realization of a low carbon society and cope with the power supply-demand crunch in recent years, as well as introducing renewable energy sources such as photovoltaic and wind power, Japanese electric power companies are in the process of implementing undertakings aimed at achieving the early introduction of smart meters capable of functions such as automatic meter reading and demand response.

The various advantages and disadvantages of field area network communications systems that collect data from smart meters installed in the homes of low-voltage customers from the standpoint of elements such as the number of target smart meters, areas covered, construction speed and costs make the approach of selective combinations of multiple systems particularly important.

For this reason, Japanese electric power companies are promoting undertakings aimed at the realization of construction of an ideal system through verification testing or post-introduction verification of the various field area network communications systems.

This paper reports on items such as verification testing utilizing the multihop wireless system as the field area network communications system for smart meters installed in the homes of low-voltage customers and an example of introduction of such smart meters using the power line communication system.

2. Field Area Network Communications Systems

(1) Multihop Wireless System

The multihop wireless system is a communications system in which the wireless terminal itself can also operate as a relay node, enabling communications via multiple terminals. This system enables collection of power consumption measurement data and remote on-off control for large numbers of meters deployed over a wide area.

(1-1) Verification Testing using Multihop Wireless System

(1-1-1) Verification Testing Overview

Hokuriku Electric Power Company installed new meters using specified low power radio in the actual field and conducted verification testing using the system configuration shown below to assess the stability of the automatic meter reading system as well as the effects on data transmission of obstacles such as accumulations of snow typical in the Hokuriku area.

Table 1: Verification Testing Overview

Item	Specification
Testing Details	<Remote Meter Reading> Use of the multihop wireless system to collect meter readings transmitted by the new meters every 30 minutes, and verification of the success rates. <Remote Control> As upstream and downstream communications using simulated remote control, transmission of path information acquisition commands from the office to the new meters followed by receipt of responses from the meters by the office, and verification of the success rates.
Test Period	December 2011 to March 2013
Test Area	780m x 380m
Geographical Features	Urban neighbourhoods (Mixture of detached houses and apartment buildings)
Number of New Meters installed	500 (500 of the approximately 1,600 meters in the test area replaced by the new meters)

- The verification server installed in the office and pole-mounted base stations were connected via the communications network.
- The pole-mounted base stations and new meters were connected by a bi-directional multihop wireless system using 900 MHz-band specified low power radio.

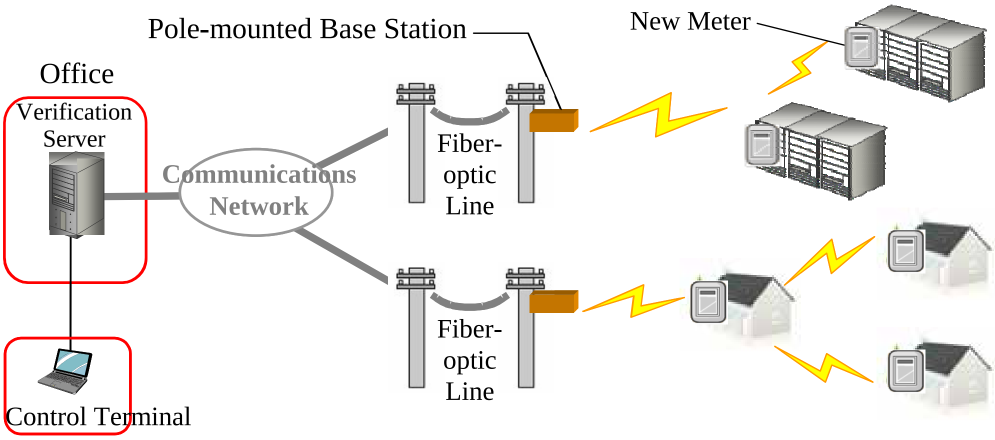


Fig. 1: Verification Testing System Configuration

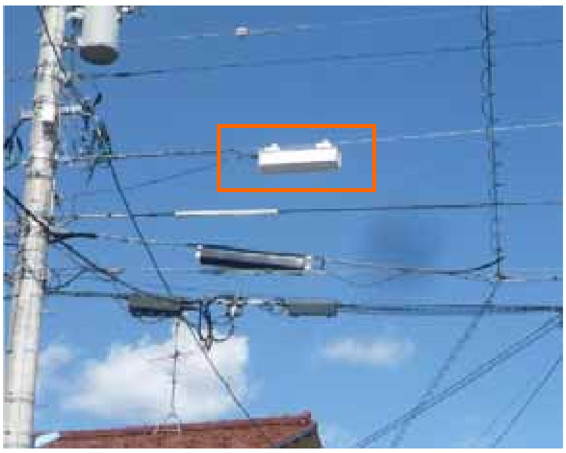


Fig. 2: Pole-mounted Base Station

Fig. 3: New Meter

(1-1-2) Verification Test Results

During the test period (remote meter reading: a total of 256 days, remote control: a total of 188 days), high success rates of 99.926 % for remote meter reading and 98.212 % for remote control were verified. In the event of unsuccessful remote meter reading and/or remote control failure, recovery processing such as re-acquisition of data

Table 2: Success Rates of Remote Meter Reading and Remote Control

Evaluation Items		Test Results
Remote Meter Reading	Total number of remote meter readings (Total number of missing readings)	6.06 million (4,474)
	Success rate	99.926 %
Remote Control	Total number of remote controls (Total number of failures)	100 thousand (1,786)
	Success rate	98.212 %

is performed, with the result that performance is of level on which, in practical terms, there are no operational problems.

It should be noted that no impact on the success rates caused by weather phenomena such as snowfall or lightning were observed during the verification testing.

(2) Power Line Communication System

The power line communication system uses power lines laid to supply electricity as communication lines. This system is applied in locations that radio waves cannot reach, such as pipe shafts in which smart meters are deployed in large-scale apartment buildings.

(2-1) Example of Introduction of Automatic Meter Reading System using Power Line Communication System

With the aim of improving work efficiency and customer services, Kyushu Electric Power Company began trial introduction of smart meters in 2010. To date, smart meters using the power line communication system have been deployed in more than 40,000 households in apartment buildings in urban areas.

An example of the configuration of the automatic meter reading system using the power line communication system is illustrated in Fig. 4.

Smart meters (Fig. 5) installed in locations such as pipe shaft interiors in large-scale apartment buildings transmit information such as meter reading data via power lines to the PLC repeaters (Fig. 6) connected to the secondary side (low-voltage service line side) of pole-mounted transformers. The role of the PCL repeaters is to collect information from each of the smart meters and then relay this data to the automatic meter reading server installed in the office. The section between the PLC repeaters and the automatic meter reading server is configured with an IP network that uses fiber-optic lines employing the PON (Passive Optical Network) method or any other appropriate method.

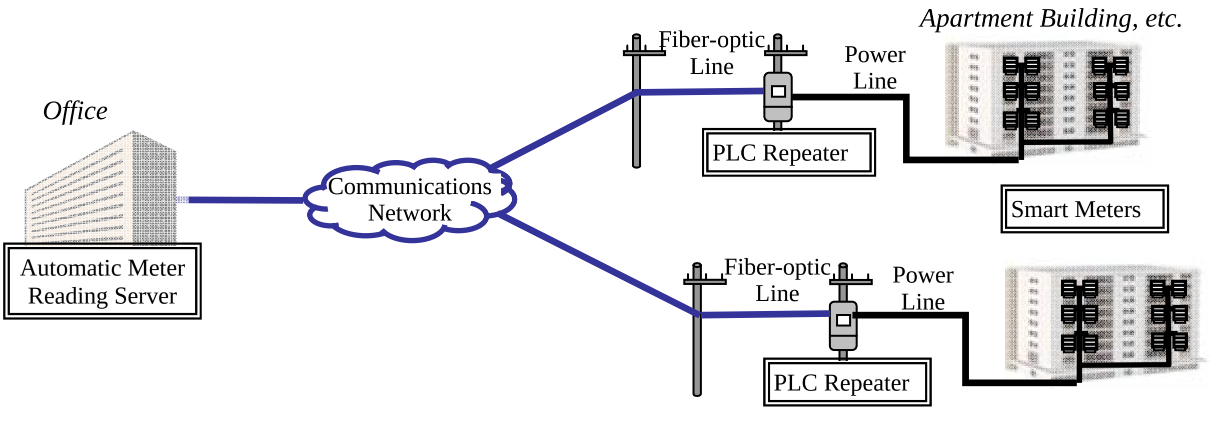


Fig. 4: Example of Remote Meter Reading System Configuration using Power Line Communication System

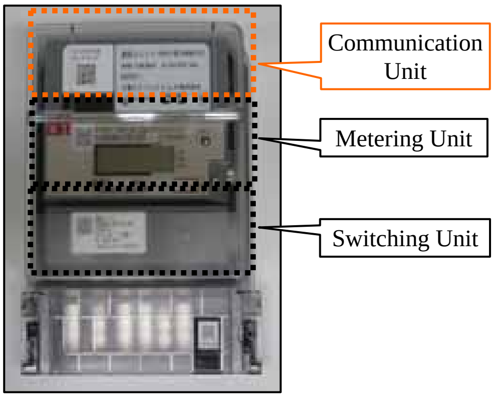


Fig. 5: Smart Meter (Unit Type)

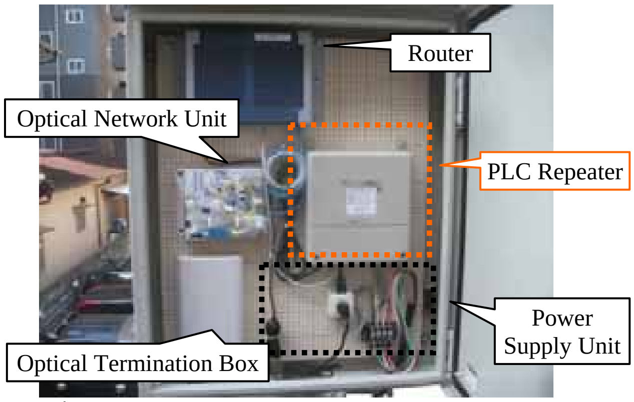


Fig. 6: PLC Repeater (Installed in the Pole-mounted Box)

(2-2) Evaluation of Power Line Communication System

At the time of its introduction, the system was configured as a flat "Layer 2" network to realize a simple, low-cost network configuration. Increases in the number of smart meters using the power line communication system, however, presented the risk of degraded network quality. Problems relating to this concern are detailed below.

[Problems]

- Limits on the number of units imposed by the Ethernet standard (Maximum of 1,024 units)
- Broadcast frame problems (e.g. Increased server CPU load, line bandwidth consumption, risks of transmission delays and data loss)
- Problem of expansion of the range of effects of failures (Bandwidth crunch due to loop failure, system crashes)

These problems prompted a change in 2012 of the network configuration from the previous "Layer 2 network" to the "Layer 3 network" that employs the PPPoE (Point to Point Protocol over Ethernet) method used for fiber-optic broadband services (See Fig. 7). This change not only resolved the problems listed above, but also enabled stable network operation through realization of a "closed" network with "stability and "expandability."

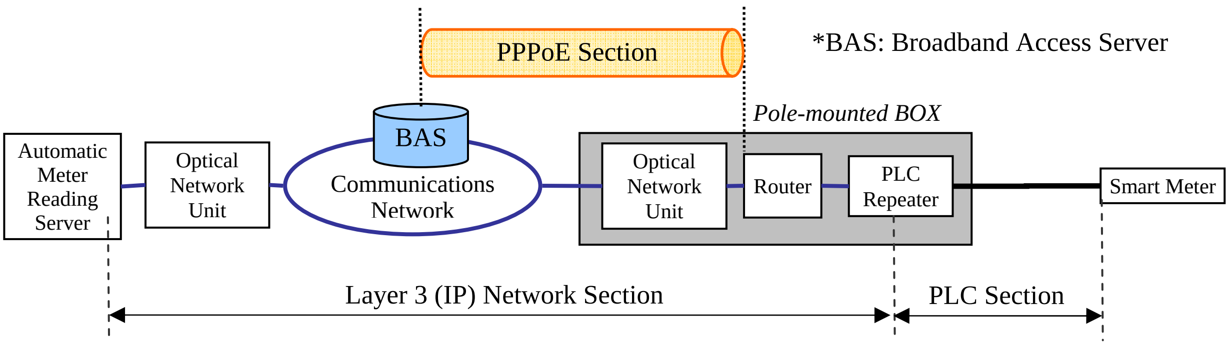


Fig. 7: Layer 3 Network using the PPPoE Method

Kyushu Electric Power Company has plans in place for the future full-scale introduction of smart meters and is scheduled to continue to expand the application of the power line communication system to smart meters as a method of communication to supplement wireless systems. Meanwhile, it is anticipated that the future introduction of the power line communication system in areas where fiber-optic lines are not available will necessitate the application of mobile phone lines, for example, as higher-order lines for PCL repeaters, and studies into this issue are planned.

3. Proposal of Operation and Management Method for Field Area Networks

(1) Method of Operating and Managing Access Points used by Wireless Communications Systems

As the introduction of automatic meter reading systems expands, the number of smart meters deployed will grow, adding to the complexity of operation and management. As an example, matters of concern regarding operation and management of the multihop wireless system are described and strategies for resolution are proposed below.

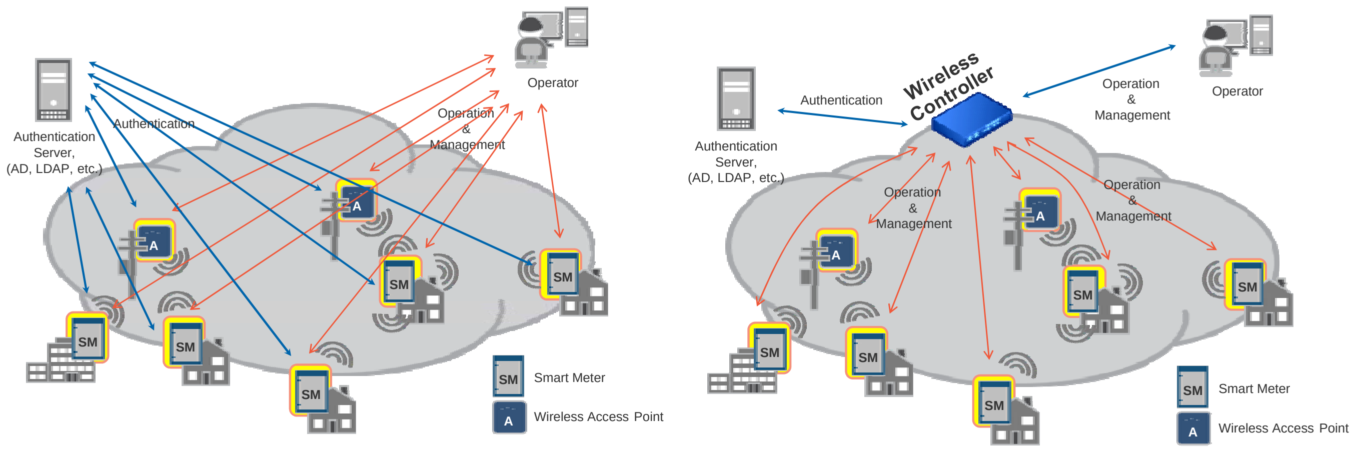
It is assumed that there are three major elements of the operation and management of smart meters and access points as shown in Table 3.

Table 3: Elements of Operation and Management required for Wireless Communications

Item	Description
Asset and configuration Management	Management of smart meters and access point devices themselves and operation and management of their configurations are required.
Authentication	Linkage with an authentication infrastructure is required to protect smart meters and access points from unauthorized access where wireless systems are applied.
Health Check	The health of smart meters and access points needs to be checked constantly and abnormalities such as degradation of communication quality due to radio wave interference must be detected immediately.

To realize efficient operation and management, the introduction of wireless controllers that implement centralized management of smart meters and access points is proposed as shown in Fig. 8.

In cases where communications are not routed through a wireless controller, all operation and management must be implemented through direct communication between management terminals used by operators and smart meters and access points and this results in a vast number of communication channels.



System Configuration
without Wireless Controller

System Configuration with
Wireless Controller

Fig. 8: System Configurations

The introduction of wireless controllers will have the following beneficial effects regarding the three elements of operation and management detailed above. It is worth noting that, as a precedent, 4 wireless controllers were introduced for approximately 600 access points at a certain university in Japan in 2013 and, as a result, the number of devices under operation and management was reduced from 600 to only 4.

(a) Asset and Configuration Management

Normally, wireless controllers are furnished with functions that enable batch updating of software versions of wireless slave devices (smart meters and access points) and batch changing of their configurations. Use of these functions eliminates the need to make changes to individual devices separately, enabling major reductions in work time.

(b) Authentication

Previously, each access point needed to communicate with the authorization server to implement authentication. This gave rise to concerns over the increasing complexity of management as the number of access points increased. Introduction of wireless controllers enables batch authentication through communication by the controllers with the authentication server, eliminating the previous need for separate communication by each access point with the authentication server. In addition, this will also resolve the problem of the increasing complexity of operating and managing vast numbers of access points including tasks such as management of individual smart meter authentication statuses and unauthorized access.

(c) Health Check

The wireless communication quality of smart meters and access points and the health of devices can be managed centrally. Constant monitoring of the health of devices enables immediate detection of abnormalities and is expected to lead to improvements in overall wireless system quality.

4. Future Outlook

This paper has presented the status of verification testing and examples of introduction of field area network communications systems as approaches to smart grid communications networks in Japan.

Full-scale introduction of smart meters in Japan is planned and it is expected that electric power companies will step up promotion of research and development and verification testing of various communications systems for field area networks from the standpoint of selective use depending on the situation. As an example of this, Kyushu Electric Power Company is now in the process of conducting verification testing of the WiMAX communications system, the results of which will be reported in the next colloquium.

BIBLIOGRAPHY