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Communication Architectures to Connect Renewable Energy Resources in the Residential Area

by

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SUMMARY

Renewable energy resources such as photovoltaic generation systems, electric energy storages, and electric vehicles are promoted to be used recently. Some of large utilities proactively install large solar/wind farms and storages for their own purpose, and customers in the residential area also utilize these renewables for their voluntary energy saving in addition to power generation.

The introduction of renewable energies in the residential area makes customers as producers as well as consumers for electricity. To promote installing renewable resources, several countries exercise FIT(Feed-In Tariff), which is the rate for utility to purchase electricity generated from the renewables typically much higher than they sell to the customers, and this naturally leads customers be interested in how much they are selling.

For example, after the nuclear power plant accident in Japan, the government offers subsidy as well as applying FIT to the customers who install the photovoltaic generation system at home as an effort to avoid a blackout. The government also expects a peak-cut or a peak-shift by using the subsidized BESS(Battery Energy Storage System) at home. Furthermore, several makers bring an idea to utilize the electricity that is charged in the battery in the electric vehicle whenever needed. To accommodate these newly introduced renewables, we need a dedicated communication architecture to connect the involved devices such as meters, inverters, storages, wallboxes for EV(Electric Vehicle) charging, HEMS(Home Energy Management System), IHDs(In-Home Displays), et cetera.

This communication architecture enables customers to monitor and control those resources and offer a chance for them to decide whether they would consume, store, or even sell the energy from/to the renewable resources. According to the communication environment, the architecture requires different way of communication such as wired lines based on RS485, narrow band and broadband PLC(Power Line Communication), wireless communications (400MHz, 900MHz, 2.4GHz), etc.

In this paper, we demonstrate several different communication architectures that are used for our installations. We compare and analyse advantages and disadvantages and deal with extensions for backward compatibility.

KEYWORDS

Communication Architecture, Renewable Energy, Residential Area, HEMS (Home Energy Management System), IHD(In Home Display)

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1. INTRODUCTION

The introduction of renewable energies in the residential area makes customers as producers as well as consumers for electricity. To promote installing renewable resources, several countries exercise FIT, which is the rate for utility to purchase electricity generated from the renewables typically much higher than they sell to the customers, and this naturally leads customers be interested in how much they are selling.

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In this paper, we demonstrate several different communication architectures that are used for our renewable energy installations. In particular, we show those architectures for Japanese home area applications and demonstrate step by step approach to maintain backward compatibility. We first refer several communication architectures for residential area without those devices for renewable energy in chapter 2. Chapter 3 shows communication architectures when renewable energies are introduced at home. We conclude in the conclusion.

2. COMMUNICATION ARCHITECTURES TO INCREASE ENERGY EFFICIENCY

Increasing energy bill comes to residential customers' attention recently. How to efficiently save the amount of electric energy so as to reduce their energy bill is of great concern and it leads to change residential customers' behaviour. Several researches[1][2] have shown that a direct display, which monitors usage data and display on its screen, can help reducing the electric energy waste. It is especially effective when the inclining block rate, in which the electricity price rates are divided into several tiers with different base rates and unit rates. For example, KEPCO (Korea Electric Power Corporation) has inclining block rates with six tiers that consist of five tiers of electricity consumption of every 100kWh up to 500kWh, and a tier of that of above 500kWh.

D. Kim et al. [3] demonstrated and analysed five different cases of so called IHD system, purpose of which is mainly to increase customer's energy efficiency and to save energy cost for customers with inclining block rates. The authors classified those systems into two approaches according to the way of implementing two way communication especially for two different network setups, i.e., star-connected system and point-to-point system. For the communication media, RS485 wired lines, IEC12139 based broadband PLCs, 424MHz RF, and 2.4GHz ZigBee are used.

Utilities' urgent needs to utilize mechanisms such as demand response to overcome the shortage of electricity generation leads some devices to be newly introduced at home. Utilities may deliver load control commands through their AMI(Advanced Metering Infrastructure) system via smart meters to directly control customer's electricity load with demand controllers inside customer premises and to expect customer's voluntary reaction to respond dynamic pricing of electricity. The pricing signal can be delivered to the smart appliances through HAN(Home Area Network) with appropriate communication media, and these appliances with intelligence helps customers proactively save their electricity usage.

Figure 1 shows an abstract level HAN communication architecture, which was suggested by Southern California Edison, USA.

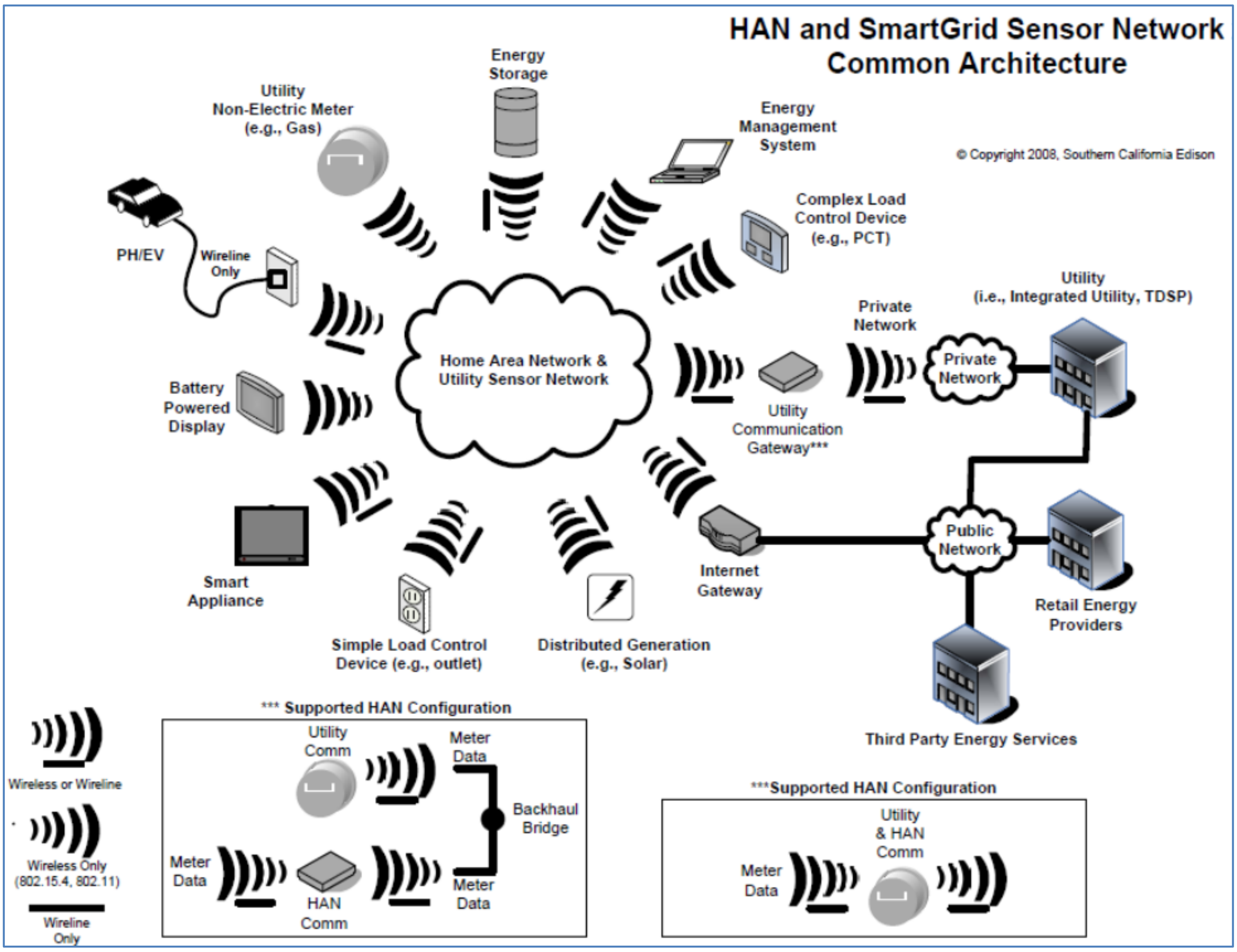

Figure 1. HAN and Smart Grid Sensor Network Common Architecture from SCE(Southern California Edison)

3. COMMUNICATION ARCHITECTURES WITH RENEWABLE ENERGIES AT HOME

Introducing renewable energies such as PV(photovoltaic) systems, EES(Electric Energy Storage), and even EV contributes to change customer's role from the consumer to the prosumer, who can generate electricity in addition to consume at the same time.

While these renewable energies sometimes find hard time to be installed due to their high cost and low efficiency, several countries nevertheless have tried to increase renewables. Germany is one example and Japan is the other. Ever since the Fukushima catastrophe, Japanese government made every effort to avoid blackouts. Promoting the installation of renewable energy is one way and the government decided to continue its financial support to install renewables such as PV systems and apply the FIT for the electricity generated from the PV panels, which is almost double the price of what customers would purchase from the utility for ten years. In addition, the government found that showing how much the residents are currently using by itself can make residents reduce their usage, and hence it promotes the installation of HEMS and IHDs by giving incentives.

Residential customers hence become interested in installing PV systems and HEMS at home. Especially those who install the PV system are very interested in how much they are selling the electricity generated from the PV panel to the grid (since FIT is applied) after they try to reduce their energy usage at home, and hence a type of user interface such as IHD is naturally introduced in the system.

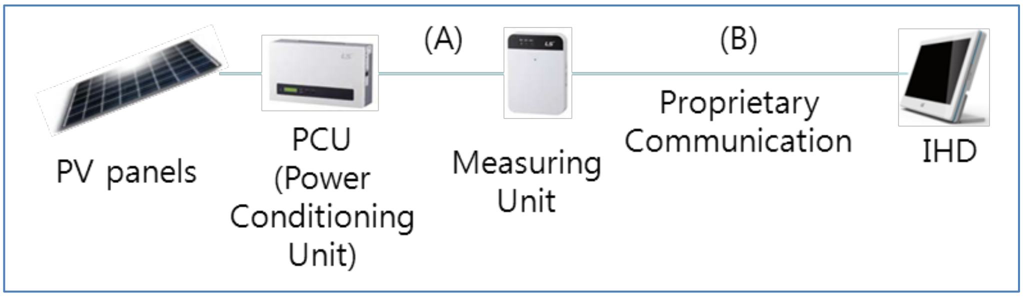

Figure 2. PV System Architecture

Figure 2 shows a residential PV system architecture, which is currently commercialized for Japanese market. This system consists of PV panels, PCU(Power Conditioning Unit), a measuring unit, and an IHD. PV panels are typically installed on the roof of a house and the PCU converts DC(direct current) power generated from the solar panels into AC(Alternating Current) power to be used at home. The most interesting information that the customer wants to see is how much they are selling the electricity that is generated from the PV panel and left and fed in to the grid after necessary consumption at home. To provide these information, we install a measuring unit near the distribution panel(or box) at home. The measuring unit measures current electricity usage at home by itself and store this data inside. It communicates with PCU and gathers from the PCU the information regarding how much power generated from the solar panel. The amount of power fed in (i.e. how much customer is selling the electricity to the grid) is then calculated by the power generated from the solar panel minus the power consumed by the customer. These data stored in the measuring unit are delivered through communication channel to the IHD, and IHD shows them to the customer.

As we can see in the Figure 2, we need two communication channels, i.e., channel (A), which is between the PCU and the measuring unit, and channel (B), which is between the measuring unit and the IHD. Regarding communication media, we use RS485 wired lines for (A), and both RS485 and 400MHz RF (wireless) for (B). For both channels (A) and (B), we use proprietary protocols based on Modbus.

In addition to the PV system, the government also subsidizes BESS system such that one third amount of installation cost can be subsidized. This BESS system can store electricity during the night when overnight tariff, which is about a half compare to the normal tariff, is applied, and utilize the electricity when the critical peak happens. The government expects a peak shift or a peak cut by utilizing these BESS systems.

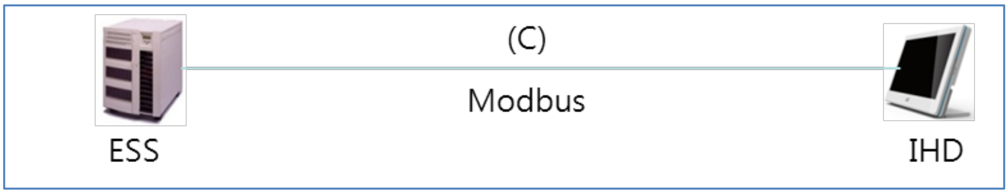

Figure 3. A BESS System Architecture

Figure 3 shows a BESS system architecture. It consists of an ESS communicating with an IHD. IHD shows all the information gathered from the ESS and provides a chance to the customer to program and control the ESS. Similar to the PV system shown above, we use RS485 wired lines to communicate between the ESS and the IHD. We also use our proprietary protocols based on Modbus.

While PV system and BESS system shown in Figure 2 and 3 are sold and operated separately upon customer's request, we found that we can provide further advantage to the customer if we configure a hybrid system, which includes both PV and BESS system together. First of all, customers don't need two IHDs; one IHD can display all the information needed. Second, a device called "HEMS server" that monitors and controls all the renewables with intelligence based on the time varying tariffs and the policies is required. This server gathers all the information from the renewables and delivers them to the customer interfaces such as custom IHDs, smart phones, PADs, PCs, etc. so that the customers can have flexibility to choose an interface to monitor and control the devices upon their preferences. This is shown in Figure 4. The gray colored part shows our legacy systems and the dotted lined part shows the newly added hybrid system.

In this system, our HEMS server communicates with PCUs and ESSs through RS485 wired lines with proprietary Modbus protocol to maintain backward compatibility for channel (A) and (C). For the channel (E), we provide several options to the customer; i.e., 2.4GHz WiFi, 920MHz RF, which utilizes Japanese specific frequency band, or Ethernet, and we use our proprietary protocols.

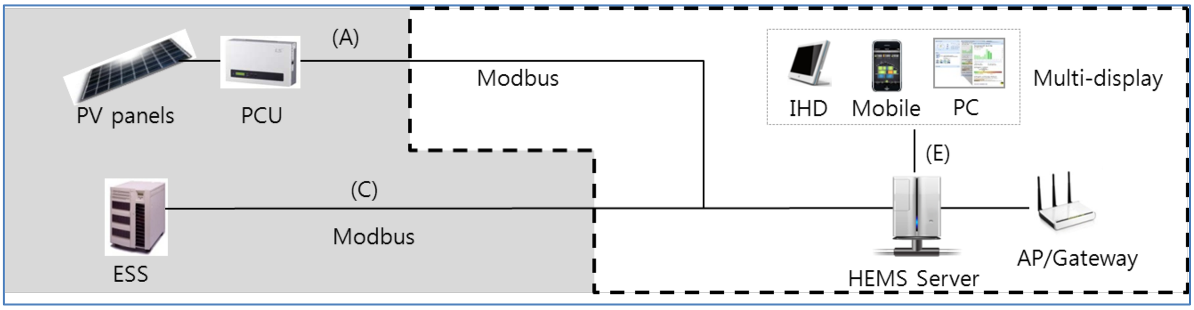

Figure 4. A HEMS Server Based Hybrid System Architecture

In Japan, to promote interoperability among home devices such as appliances, lightings, security systems, etc., Echonet consortium has been formed and published "Echonet"[4] standard. Echonet has been extended to "Echonet Lite" to accommodate energy related devices together.

To support Echonet Lite protocols, we extend our HEMS server to support Echonet Lite protocol. Since our legacy systems might exist and run in the customer premise, we develop Echonet Lite Adaptor to maintain backward compatibility. As we can see in the Figure 5, the adaptors converts Echonet Lite protocols at HEMS server to the proprietary protocols at legacy system side and vice versa. Note that channels (D) and (E) may have their communication media as 2.4GHz WiFi, 920MHz RF, and/or narrow band PLC.

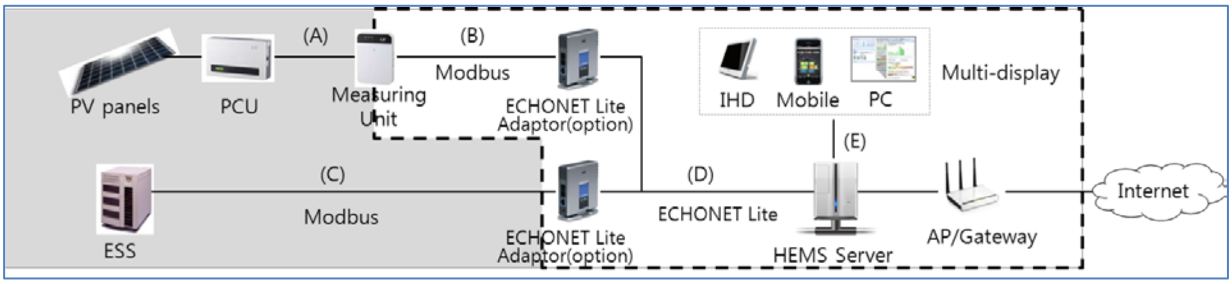

Figure 5. A Home DER(Distributed Energy Resource) System Architecture

In the future, we expect that all the systems at home support Echonet Lite without any adaptor so that full interoperability among devices can be realized. The HEMS server will play a centric role to connect, monitor, and control all the devices, and offers various opportunity for customers to save energy and the cost of energy with intelligence. This is shown in the Figure 6.

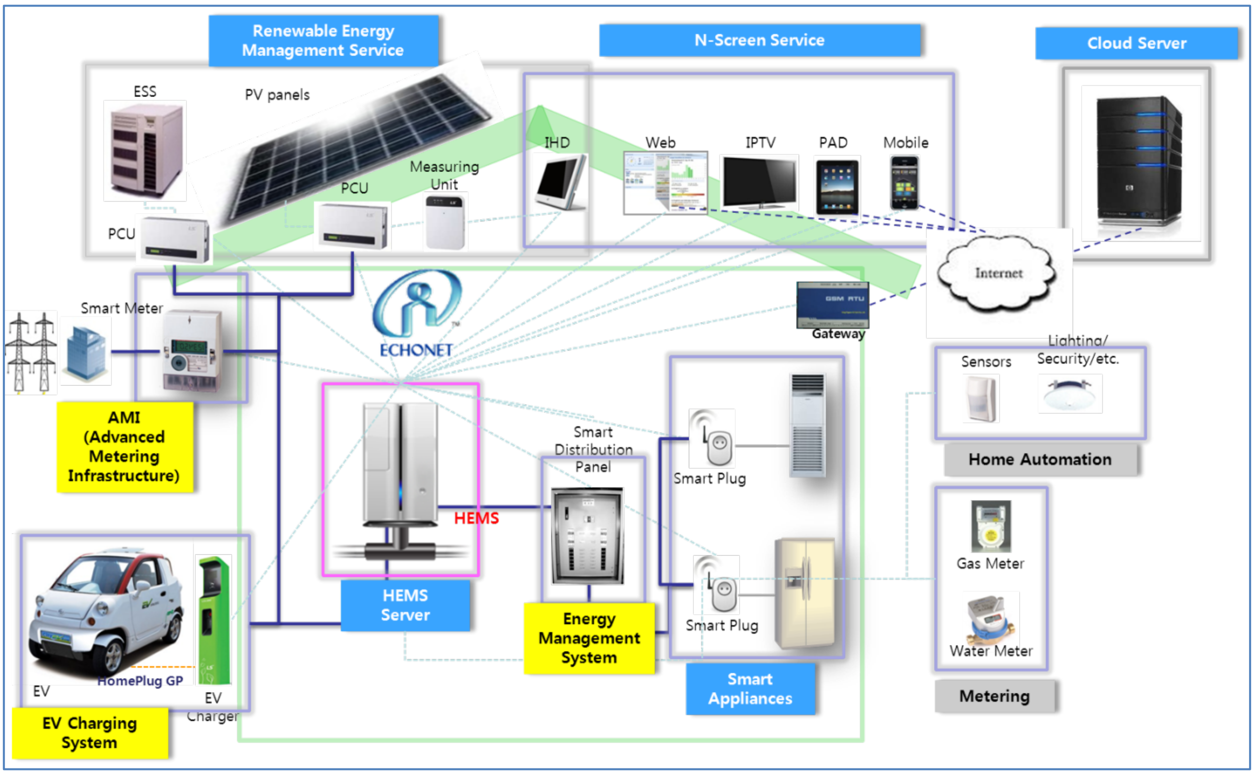

Figure 6. An HEMS based Home Area Network and Service Architecture

3. CONCLUSION

In this paper, we have demonstrated several different communication architectures that are used for our renewable energy installations. In particular, we show those architectures for Japanese home area applications and shows step by step approach to maintain backward compatibility.

As we show in the main topics, to maximize utilization of all the renewable energy resources, communicating to/from all the devices including other home area devices such as home appliances, home automation devices, meters, etc., is required, and for this purpose interoperability among them is a must. International communication standards for each layer including protocols, media are definitely needed, and we expect experts from international organizations such as Cigre will play an important role in this route.

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