Case study: Japan—U.S. Collaborative Smart Grid Demonstration Project in New Mexico

Part 1 Efforts in Los Alamos

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1. Introduction

For the period between FY2009 and FY2014, the Japan – U.S. Collaborative Smart Grid Demonstration Project in New Mexico was implemented at two sites, Los Alamos and Albuquerque in New Mexico State in the United States as NEDO's first Overseas Smart Community Demonstration Project. Headed by NEDO, the project was accomplished by a collaboration of 19 Japanese companies, the State Government of New Mexico, electric utilities, research organizations, and other stakeholders demonstrate technologies that allow for large scale penetration of renewable energy in the future, and offering some important clues on the promotion of smart grid in both Japan and the U.S. in the course of this demonstrative experiment.

This Document is a case study focusing on the efforts deployed in Los Alamos and report on the suggestions made by this experience.

2. Efforts made in Los Alamos

The smart grid system in Los Alamos was configured with the objective of perfecting the management of renewable energy that is expected to increase significantly in the future and provide residential consumers in energy domain with new values. As shown in Figure 1, it is μEMS (Micro Energy Management System), the next-generation energy management system that constitutes the core of the smart grid system. The μEMS is characterized by two functions which are (1) management of renewable energy using hybrid control of batteries and (2) Demand Response, as will be described later.

Also, a Smart House was added to the smart grid. Energy use in the home is optimized through the operation of an energy system that coordinates and controls equipment within the home (including appliances, rooftop solar array and EV-battery) in accordance with the needs of the consumer.

In this case study, the major efforts made in Los Alamos as stated above are described from the following three perspectives:

- Integrated energy management system (μEMS)
- Smart House built in Lost Alamos
- Development of transfer trip system using high-speed PLC

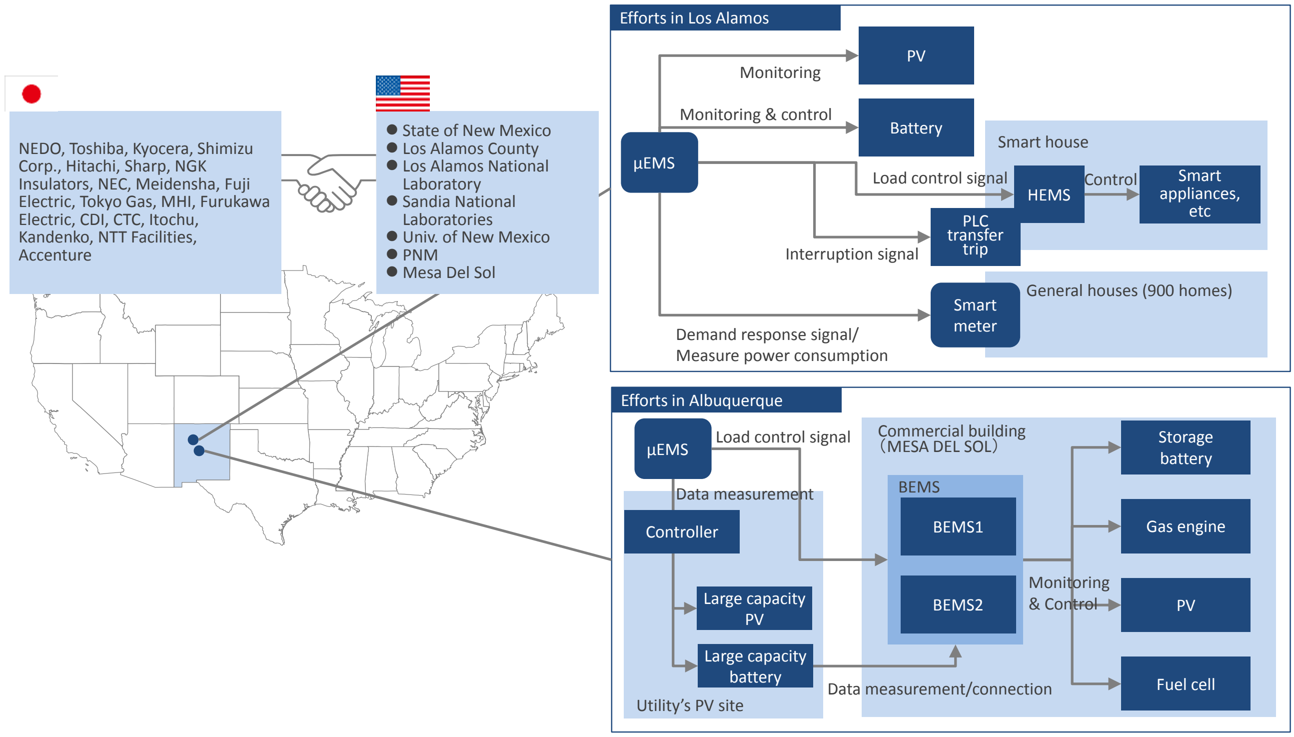


Figure 1 Whole picture of Japan-U.S. Collaborative Smart Grid Demonstration project in New Mexico

3. Integrated Energy Management System (μEMS)

3.1 System Overview

An energy management system at the electric distribution line level has been established in the Los Alamos site. Led by Toshiba, the system was installed to operate and manage a microgrid that incorporates a single residential feeder (a neighborhood with 1600 homes), PV generation (1MW), energy storage (NAS battery (1MW/6MWh)), lead acid battery (0.8MW/2.3MWh), etc. for TA-3 Substation, Townsite Substation, Battery Site (newly constructed), LAC Office and a NEDO Smart House (newly constructed). See Figure 2 for the overall system configuration.

The core of this system is the μEMS which is the energy management system to support energy management at the distribution level in a comprehensive manner with the following functions:

- Prediction (demand, PV output)
- Supply- demand scheduling
- Supply-demand balancing
- Optimum control of hybrid batteries
- Coordination with upper level system
- Demand response

Management of microgrid by μEMS

The basic concept of supply-demand management by μEMS is shown in Figure 3. In this demonstration project, it aims to stabilize the power flow at PCC, point of common coupling shonw in Figure 1, by the microgrid, which is considered to be a unit controlled by an EMS. Basically, hybrid batteries (NAS and lead acid batteries) are optimally controlled by μEMS to respond to the fluctuations of loads and PV output to stabilize the power flow at PCC i.e. to balance the supply and demand within the microgrid. Considering the characteristics of energy storage, long-term variations are controlled by NAS battery and short-term variations by lead-acid battery.

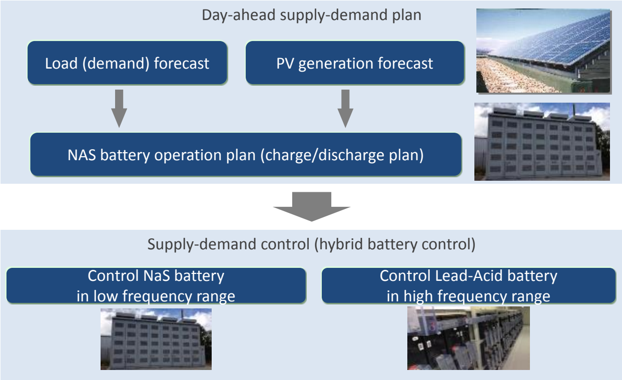


Figure 3 Concept of supply-demand management by μEMS

NAS battery that handles long-term variations can ensure long-term operational stability by scheduling the SOC (State of Charge) in its management scope.

The demonstration results of the control performance of the μEMS is shown in Figure 4. The target value for the power flow at PCC to be stabilized was calculated with an objective to maximize the load factor within μEMS.

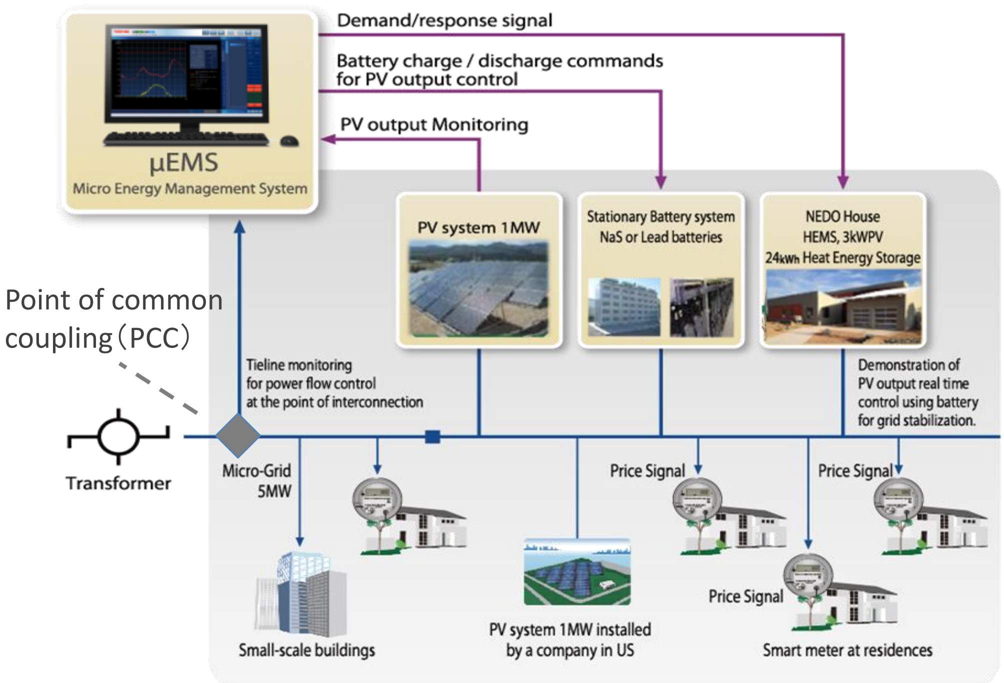


Figure 2 System configuration in Los Alamos site

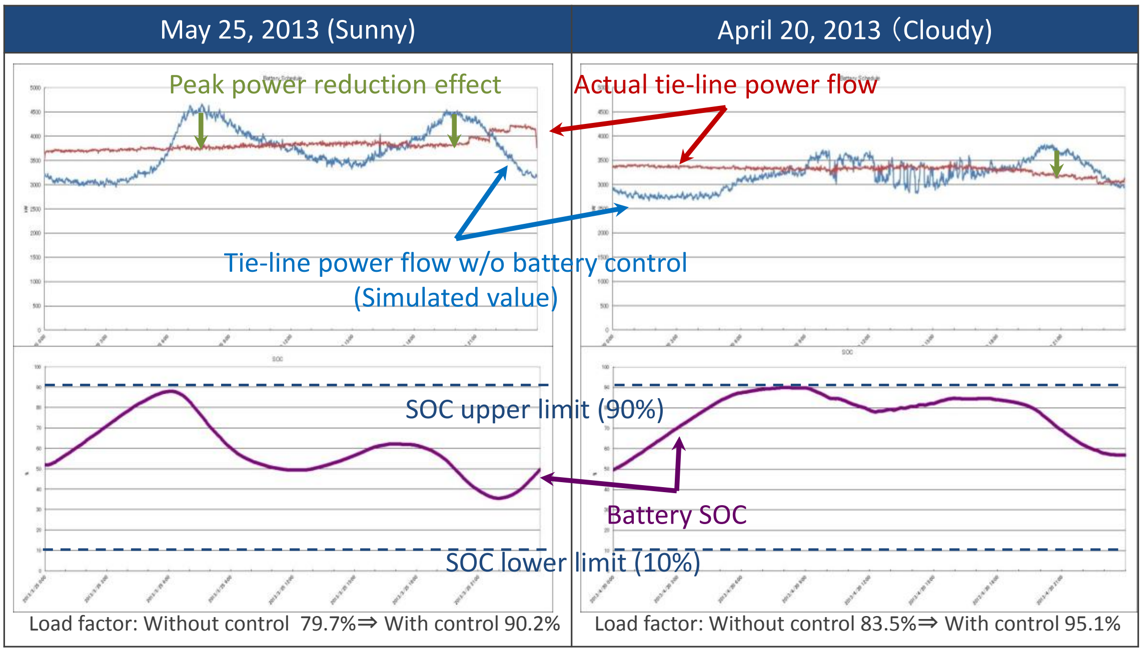


Figure 4 µEMS demonstration results

As shown in the results, the supply-demand fluctuations in the µEMS were mitigated and the power flow at PCC has become totally flat by the management of loads and PV output by µEMS. Also, SOC of the NAS battery fell within the range of operation and management.

Construction of Demand Response System

µEMS has another important function, which is demand response for the customers within its service coverage. In Los Alamos site, 900 out of a total of 1,600 households installed with smart meters volunteered to participate in the demand response demonstration.

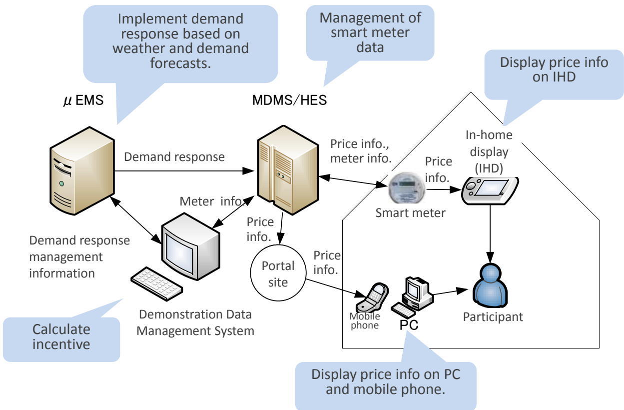


Figure 5 Demand response related system

In this experimental demonstration, demand response with customers was enabled by µEMS and MDMS as shown in Figure 5. The customers were able to check their power consumptions, etc. on the web portal and In Home Display.

There are three types of demand response programs applied in this demonstration: Opt-in CPP, Opt-out CPP and Opt-out PTR. CPP (Critical Peak Pricing) is designed to charge customers higher prices during peak hours and lower prices during off-peak hours whereas PTR (Peak Time Rebate) offers customers a rebate for energy saved during peak hours. PTR is calculated by comparing the consumer's peak-time consumption less their consumer's baseline consumption during off-peak hours. Combining these two pricing scenarios with Opt-in and Opt-out decision choices, the above three DR programs were established.

The experiment was implemented for three months in summer (Jul. – Sept.) and winter (Dec. – Feb.) respectively in FY2013 and FY2014. The dates of DR events based on the specific criteria were set for up to 15 weekdays each period.

Table 1 Demand response menu applied in the experiment

Group	Initial	Opt-in	Opt-out
Opt-in CPP	Flat	CPP	-
Opt-out CPP	CPP	-	Flat
Opt-out PTR	PTR	-	Flat
Control	Flat	-	-

In the experiment, choice probability of Opt-in CPP was 64%, choice probability of Opt-out PTR was 97%. In this way, customers chose demand response program with extremely high probability. The experiment results in summer and winter of FY2013 are shown in Table 2. The best result was obtained with Opt-in CPP in summer time where

TOT (Treatment on the Treated: The net peak cut effect when a treatment was given.) was 10.49%, showing very high peak reduction effect. The ITT (Intention to Treat: Choice probability x TOT effect) after taking the above-mentioned choice probability into account was 6.9% with summer time CPP to achieve a great effect even when the choice probability was included.

Table 2 Result of DR experiment in 2013

	Group	ITT effect	TOT effect
Summer	Opt-in CPP	-6.90%	-10.49%
	Opt-out CPP	-4.59%	-4.71%
	Opt-out PTR	-4.06%	-4.17%
Winter	Opt-in CPP	-4.78%	-7.12%
	Opt-out CPP	-4.27%	-4.41%
	Opt-out PTR	-3.26%	-3.37%

＊ TOT effect: Treatment on the Treated. Net peak cut effect when a treatment was given.

＊ ITT effect: Intention to Treat. Choice probability x TOT effect.

3.2 Key Findings – Lessons Learned

The following lessons were learned from the construction of the integrated energy management system in Los Alamos.

Lesson (1): Solution to the issue of high RES penetration

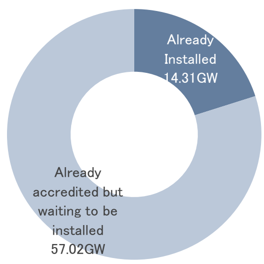
A solution was established that mitigates the output fluctuations of large PV and minimizes the effect on power system by using the μEMS to control the hybrid battery (lead-acid and NaS batteries). Although the capacity to be addressed by μEMS was around 5MW, the capacity of PV introduced was 1MW. Mr. Yoshimasa Kudo of Toshiba commented as follows on this point:

Comment by Mr. Yoshimasa Kudo
In this demonstrative experiment, the proportion of PV introduced onto the microgrid was 20% under heavy load condition and 50% under light load condition on distribution line level. I am satisfied that we could establish solutions to reliably manage renewable energy in such high PV penetration situations.

Dr. Scott Backhaus of Los Alamos National Laboratory (LANL) also gave us the following comment:

Comment by Dr. Scott Backhaus
The demonstration experiment showed that the PV output power fluctuations could be controlled by the μEMS. I believe the μEMS constructed for this demonstration project is transferable to large scale renewable energy generation.

According to Japan Photovoltaic Energy Association (JPEA), the total capacity of PV installations, including those already accredited but waiting to be installed, reached almost 71.33GW by the end of 2013 (See Figure 6). Even under such a high PV penetration situation, μEMS could be a reliable solution to effectively manage renewable energy.



Source: Japan Photovoltaic Energy Association[1]

Figure 6 PV penetrations in Japan

Lesson (2): Demand response found to be highly effective

Results from the demand response research, which was another function implemented by μEMS, demonstrated that consumers in the Opt-in CPP category reduced peak load by up to 10.49% in summer. We must admit that this was a tremendous effect when compared to the achievements of other demonstration projects in the U.S.

What is noteworthy here is that the demonstration site in Los Alamos is located at a high altitude where climate is cool in summer and warm in winter. As such, the majority of people do not own air conditioners. This means that consumers do not have much margin for energy savings. It deserves attention that the 10% peak load reduction can be achieved even in such an environment.

On this point, a questionnaire survey was conducted with volunteers during the experiment. The result showed that many households understood the significance of demand response and actively contributed to the project. This is largely because of the fact that Los Alamos has a highly educated population, and many residents have advanced degrees and high income.

In Japan, on the other hand, the supply-demand situations during peak hours in summertime have been very constrained due to the suspended operations of nuclear power plants since the Fukushima disaster in 2011. However, such difficulties have been overcome by each individual consumer who was well aware of the importance of saving energy and thereby supporting the smooth operation of power systems.

[1] http://www.meti.go.jp/committee/sougouenergy/shoene_shinene/shin_ene/pdf/002_02_00.pdf

The circumstances in the U.S. and Japan may be different, but consumers are actively interested and strongly intend to contribute to a reliable operation of the power system. We learned from the demonstration how important it is to continue the study on the power system operation in a comprehensive manner not only with advanced technologies but also with the involvement of consumers.

These findings were a surprise to the local utility Los Alamos County Department of Public Utility (LAC-DPU), and will significantly influence their decision-making moving forward. Mr. Robert Westervelt and Ms. Julie Williams-Hill of LAC-DPU commented as follows:

Comment by Mr. Robert Westervelt and Ms. Julie Williams-Hill

Prior to our partnership with NEDO it was business as usual. We are a small utility, with limited resources. We just don't take risks and as a result hadn't prepared for the rapidly changing electric industry. In the short time that we partnered with NEDO, we learned the enormous value of these demonstration projects. The concept of utilizing the μEMS to manage a utility scale PV array using batteries to firm the power was new to us. Further, the demand response research conducted in Los Alamos yielded tremendous insight into the behavior of our consumers. It clarified for us which method could be implemented in the Los Alamos service area with the most success in reducing peak loads.

When this project began, we weren't sure what the outcome would be. Now, we understand the real-world practicality of using the μEMS to couple the demand response with the utility scale photovoltaic array with the batteries to reliably manage the microgrid.

As a result, we are now investigating how we can expand this to our other electric feeders, creating new microgrids, adding more renewables and incorporating other demand response loads.

Lesson (3): Identifying issues for further development

Control of hybrid batteries by μEMS can be a reliable solution for the operation of power systems with significantenewable energy penetration. In addition, it is clear that demand response could also be an effective method to manage a power system.

These two methods were demonstrated by the μEMS in two different approaches. In this project Toshiba conducted research on the effect of integrating these two solutions. Figure 7 shows the result from this research, which indicates that an integration of demand response with storage batteries can reduce the number of batteries required. Since batteries are still expensive, this could present a cost savings solution.

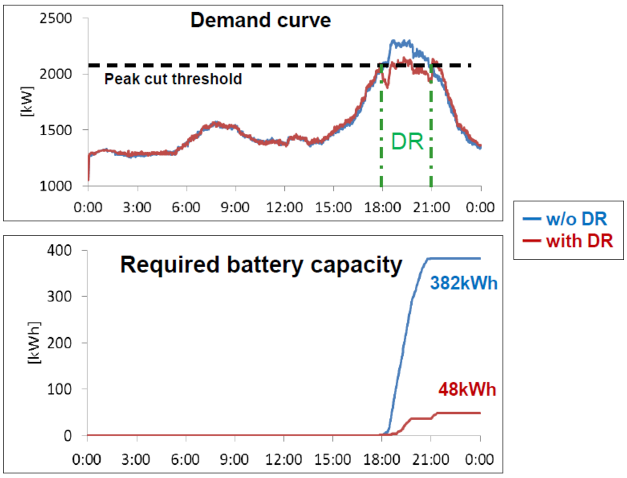


Figure 7 Reduction in battery capacity by the integration of Demand Response

By integrating different energy solutions available, we can realize optimum energy management. Every energy solution has its own characteristics (e.g. battery storage is extremely effective in power control but quite costly; demand response is relatively inexpensive but entails uncertainty in how consumers' will respond day-to-day). Moreover, there are various alternatives that could influence the optimum energy management solution, such as electric vehicle and hydrogen energy, which were not demonstrated in this project. These other energy solutions may present future innovations and may increase the variety of options available. Dr. Scott Backhaus of LANL gave us a clue as to how we should consider the system configuration for the future uncertainty.

Comment by Dr. Scott Backhaus

The demonstration was completed successfully and displayed the capability of this next-generation system to deal with high renewable energy penetration. Further spread of advanced systems can be expected by expanding this kind of effort and by pursuing scalable and flexible systems that can support a range of solutions

The demonstration project ended successfully. However, there is still room to expand on this outcome, and Toshiba and other participants are starting to address this challenge. It is necessary for us to continuously seek the future energy system based on this successful demonstration as a foothold.

4. Smart House Constructed in Los Alamos

4.1 System Overview

The second approach in Los Alamos was the Smart House. This case study focused on the energy management demonstration for a home, which was implemented by three Japanese companies of Kyocera, Sharp and NEC. Kyocera played the leading role.

The Smart House was newly built for the demonstration as a local, standard home for a four-member family (Figure 8). It has four bedrooms a dining kitchen, a living room and a garage with gross floor space of 230m^2 (excluding garage). Three of the four bedrooms were assigned to Kyocera, Sharp and NEC as their demonstration room respectively.

Figure 8 Appearance of Smart House

Figure 9 illustrates the energy management system of the Smart House. The system incorporated 3.44kW PV cells and 24kWh lithium ion batteries. All the equipment of the system is connected to the house's energy system by a Hybrid Controller (Power Conditioning System: PCS). Besides the heat pump water heater (300L) which has been widely prevailing in Japan, central air conditioning equipment, LED lightings and various smart electric appliances have also been incorporated in the system.

Furthermore, different types of sensors (humidity/ temperature, motion and power) have been installed. All of them were connected in a wired or wireless information communications network, enabling the management of energy within the house. The HEMS (Home Energy Management System) and the Smart Gateway (SGW) to convert interface arranged by the three companies play the central role in this network. HEMS is a controller which optimizes the energy use in the home with the following three functions:

- Optimizing energy consumption in accordance with TOU(Time of Use) rate
- Reducing energy use in response to demand response signal from grid-side µEMS
- Islanding operation of Smart House

Optimizing energy consumption in association with TOU

HEMS minimizes energy costs of the home in association with TOU, the pricing that varies based on the time of day consumers use electricity. As shown in Figure 10, storage battery, water heater and home appliance controller are equipped to minimize the electricity cost of the home in consideration of the electric rate, estimated PV generation and actual electric load, water heater, etc. What is special with the home appliance control is that there is a learning function based on the sensor information so as not to disturb the resident's comfort (daily life).

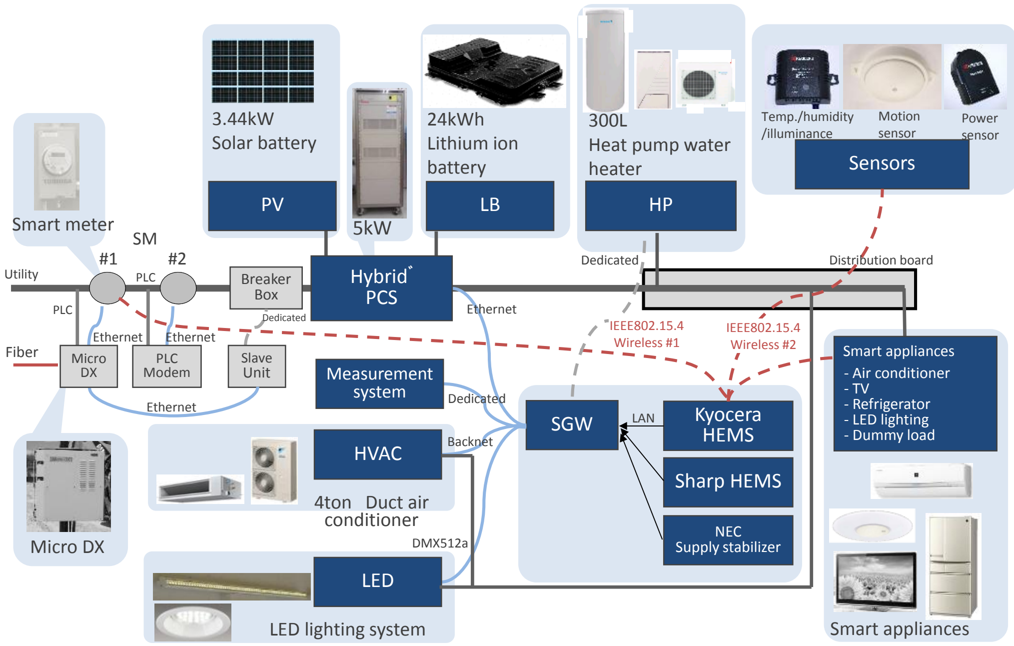


Figure 9 Energy system of Smart House

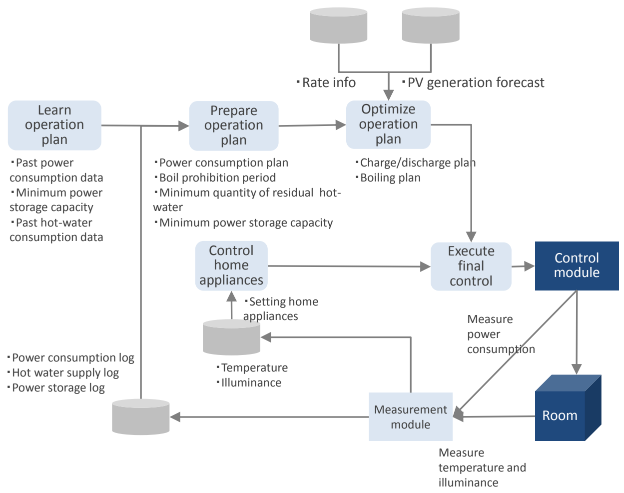


Figure 10　Energy management by HEMS

The demonstration results of this function are shown in Figure 11. The demonstrative experiment was conducted with virtual TOU rates shown in the upper part of the figure. As a result, a maximum profit of 20 dollars per day was realized by consuming as much electricity as possible during hours with lower electric rates and also by selling electricity to the utility provider during hours with higher electric rates.

Reducing energy use in response to the request from µEMS

Energy consumption in the home can be reduced in response to the utility provider's needs if the HEMS can coordinate with the µEMS (Toshiba's solution as mentioned in the previous chapter) on the grid side. The "demand response signal" by µEMS is a form of demand curtailment request which is issued depending on the electric system's condition. Once receiving this signal, the HEMS within the Smart House generates a target value at the PCC with the grid and operate hybrid controller to perform PV generation and battery charge/discharge.

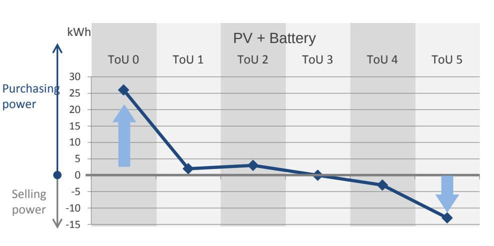
	Rate category	ToU0	ToU1	ToU2	ToU3	ToU4	ToU5
Virtual ToU rates	Selling price(cent/kWh)	15	25	45	65	85	99
	Purchasing price (cent/kWh)	10	20	40	60	80	90
Performance in power trading for a smart house (Sept. 25, 2013)							
Findings	■ An introduction of PV and battery produces $11.5 of income per day. ■ $20.5 of profit can be made compared with the case when PV and battery are not introduced resulting in $9 of spending per day. ■ Impact on grid can be reduced and customer can expect great economic value.						

Figure 11　Result of demonstration of TOU control

Figure 12 shows the results of demonstration of this control conducted on 20-22 December 2013. The horizontal axis represents the target electric energy values at PCC calculated by the HEMS and based on the demand response signals from µEMS and the vertical axis shows the response results.　The HEMS and the hybrid controller perform the controlling function to successfully follow the target value almost completely, responding property to the utility providers needs on the grid-side.

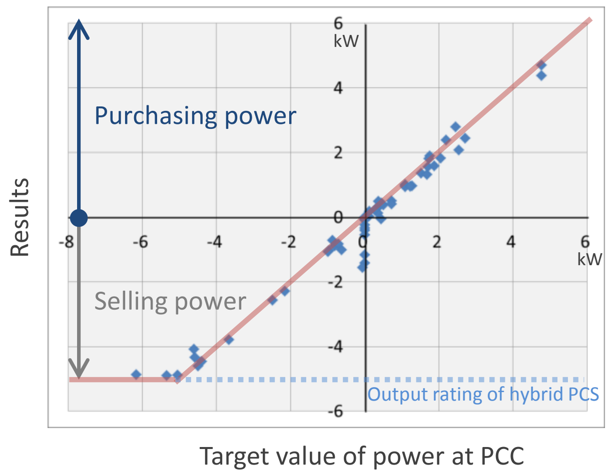


Figure 12　Result of control in response to µEMS' request (20 – 22 December 2013)

Islanding operation of Smart House

In the event of a grid failure, the Smart House switches to the islanding operation mode utilizing the PV and storage batteries in accordance with the request from the grid, and gets back to normal grid-connected operation mode when the grid is recovered. This function is implemented in the solutions of NEC.

A sequence of actions of the islanding operation control is illustrated in Figure 13. The "Disconnect from grid" request is issued by the utility provider and sent to the HEMS (described as Supply Stabilizer in Figure 13) and the smart gateway via the communication units (Micro DX, Slave Unit) implemented by NEC so that the Smart House can switch to an islanding operation mode. The current status of the grid (i.e. how much time would be required until the grid recovers) is updated several times while the house is in an islanding operation, and the HEMS will make the optimum operation plan for the PV, batteries and smart electric appliances within the Smart House based on the estimated restoration time to enable a long-hour islanding operation.

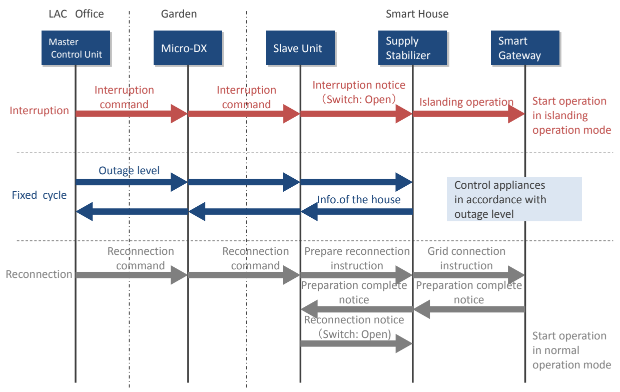


Figure13 Sequence of action of islanding operation control


Figure 14 Smart House observation tour

4.2 Key Findings – Lessons Learned

Following lessons were learned from the above-mentioned demonstrative experiment for Smart House:

Lesson (1): Market potential of energy solutions for homes

This Smart House aspect of the project has important implications for both Japan and the U.S. It verified that the energy management of homes has a huge market potential in the U.S. After the completion of the Smart House, Los Alamos County has organized and conducted many tours of this new facility for the interested individuals. It has been very well received. Mr. Robert Westervelt and Ms. Julie Williams-Hill from LAC-DPU mentioned the following:

Comment by Mr. Robert Westervelt and Ms. Julie Williams-Hill

The overwhelming interest in this project from various individuals and organizations that have partaken in the many tours is the Smart House. Visitors were especially drawn to home energy management systems that can automatically optimize the electricity costs, control the appliances and operate the home in an islanding mode for prolonged periods of time. . The ask questions like "How can I buy a home energy management system like this?" When can I buy these appliances?" "When will it be brought to the market?"

The Smart House in the U.S., was able to demonstrate to consumers how the smart grid could be beneficial to them, how it could help them meet their own personal goals to save money and contribute to a cleaner environment. It was a good opportunity to connect the consumer to the larger changes occurring in the electric industry.

Although the market for home energy management solutions has been emerging in Japan after the Great East Japan Earthquake, it has been unclear whether such solutions could be accepted in other countries or not. The biggest reason was that the needs for Smart House had not been clear for Japanese solution providers. There was also the challenge that U.S. consumers didn't fully comprehend what a Smart House was, although they knew the term.

In order to create a market for HEMS and other home energy management solutions, the first step will be to have consumers understand the solution offered by the HEMS so that they will want one. The construction of the Smart House made a significant contribution to the future development of smart grid. Primarily to the extent that it set the stage for U.S. consumers to realize the electric grid challenges and then interact with the Smart House where they could feel and experience how these future energy management solutions could be beneficial.

Lesson (2): Solution that does not interfere with the comfort and convenience of residents

In this demonstrative experiment, the HEMS technology with two major functions of (1) optimization of energy consumption associated with TOU rates and (2) reduction of energy use in response to demand response signals from grid-side µEMS, was established for the operation of the Smart House under a grid-connected state. The important point in considering the performance of HEMS' functions is that HEMS is designed to be able to control and implement its functions without hindering the residents' comfortable lifestyle.

In order to minimize energy cost with TOU, it is normally required to reduce energy consumption during peak hours (i.e. hours of the day when consumers want to use electricity most). That is to say, a limitation is imposed on the energy consumption by consumers who will be forced not to use energy during the hours when the electric rates are high. Furthermore, if one wants to implement this manually, he/she has to watch the electric rate all the time, bringing about the phenomenon that he/she lives his/her life for the sake of energy consumption.

The HEMS built for the project operates the PV, energy storage system and smart electric appliances in an integrated manner and adds QOL (Quality of Life) as a constraint in the control logic so that consumers do not have to worry about when they consume energy. No one lived in the Smart House during the demonstrative experiment period, but the energy consumption pattern for a typical four-member local family was simulated using smart appliances. The electricity consumed by the appliances was separated from the HEMS control as the "given condition." Therefore, the figures shown in the abovementioned results of the demonstrative experiment for the Smart House were based on the premise that the residents' energy consumption would not be affected. Mr. Kazuya Kiuchi of Kyocera mentioned as follows:

> ***Comment by Mr. Kazuya Kiuchi***
> *Requirement for a house is to provide comfortable environment as living space. For the smart house built for this project, we fully considered this point and sought the utmost comfort.*
> *Based on this, high performance was delivered for the optimization of energy costs and contribution to power system, in which we can see the significance of this demonstrative experiment.*

As described above, it is apparently attractive to the U.S. consumers that they can minimize the energy cost automatically and contribute to the operation of electric system by simply living their normal life without being aware of electric prices. It is of great significance that such a solution was created, and further promotion of the solution to consumers is strongly expected.

5. Development of transfer trip system using high-speed PLC

5.1 System Overview

The last topic of the Los Alamos demonstration case study is the development of the transfer trip system using high-speed PLC. With this technology, which was established by NEC in association with the demonstration of the Smart House, a quick, reliable and simultaneous remote-control of consumer equipment in a broad area based on the electric system's request becomes possible.

The overview of the system is shown in Figure 15. The Master Control Unit installed on the utility provider side is the source of information. This unit generates and outputs signals including Suspend, Disconnect and Reconnect (Recover). These signals are transferred to the Slave Unit on the consumer side via Micro-DX which is mounted on a utility pole near the consumer. Upon receiving the signals, the Slave Unit operates the consumer's switch and then responds with the Operation Complete message to the electric system.

In addition to high-speed PLC, low-speed PLC and a wireless network (915MHz) were also implemented as last-mile communication system in this demonstrative project for comparison purposes. Table 3 shows the measurement results of each communication system for the period between January 2013 and February 2014. Concerning the speed, the average response time of high-speed PLC is 5.6msec, indicating that an extremely high-speed system can be constructed. For the reliability of communication, all communications' systems achieved a packet error rate of less than 1%. The reliability can be improved if the function that enables retransmission from the Master Control Unit is added in cases where an error occurred.

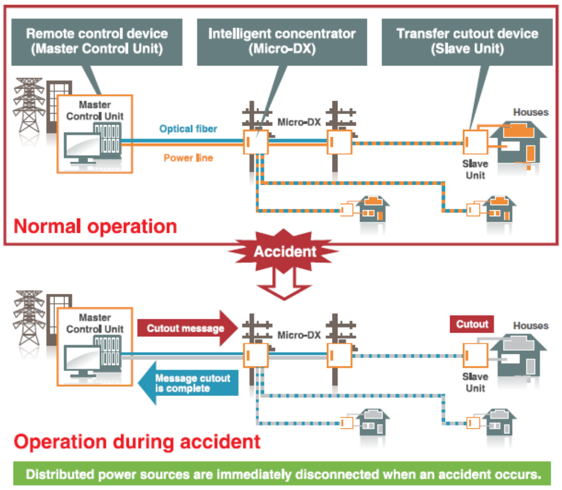


Figure 15　Configuration of transfer trip system

Table 3　Measurements results of high-speed PLC and other communication systems

Communication	Response Time (mean value) [msec]	Error Rate (mean value) [%]
High-Speed PLC (MHz)	5.6	0.589
Low-Speed PLC (kHz)	239.2	0.146
Wireless (915MHz)	9.4	0.080

Also, it has been assured in the demonstration that an effective and stabilized communication could be performed even in the high network load condition by packet aggregation, prioritized transfer and other measures. Moreover, it was verified that highly reliable communication that withstands a long-term operation was possible under harsh environments with drastic temperature changes.

5.2 Key Findings – Lessons Learned

The validity of high-speed PLC in last-mile communication was confirmed in this demonstration as described below:

Lesson (1): Applicability of high-speed PLC to electric system

In Japan, the use of high-speed PLC had been restricted to indoors at the time of the demonstrative experiment. The outdoor use was not allowed. Therefore, no demonstration for high-speed PLC could be held in an actual environment although its convenience had been recognized. And this is why I think it had great meaning that the validity of high-speed PLC could be demonstrated in the U.S.　Later, the Ministry of Internal Affairs and Communications of Japan solicited comments from the public on the proposed ordinance for the partial amendment of

Ordinance for Enforcement of the Radio Act, etc., to revise the relevant ordinances on the outdoor use of high-speed PLC[2]. If the outdoor use is allowed, the high-speed PLC could be a powerful communication option for smart grids.

The assumed high-speed PLC for smart grids is multicast based technology which supports the utility provider's electric system to manage and control countless numbers of distributed energy resources and consumers collectively through communication. It was clear in the demonstration that the utility provider's electric system would be able to provide remote centralized control at high speed with high reliability, and could possibly implement a function that had been too difficult to implement via communication (e.g. anti-islanding of distributed generators which has to be implemented reliably and at high speed). The functional verification focusing on remote trip application was also conducted in the demonstrative experiment, but it has become apparent that the solution developed at this time was applicable to such purposes as remote activation and output/consumption control.

Regarding large-scale integration of PV energy, there is ongoing debate on the output control depending on the grid condition in Japan[3]. The need for remote control of countless numbers of consumer equipment via communication is expected to grow in Japan and the U.S. We have to leverage the technological development and experiences in demonstrative experiments like this particular effort to create the power system for the future.

6. Acknowledgment

The author gratefully acknowledges the contributions of the following people to this work: Mr. Yoshimasa Kudo and Dr. Daisuke Takeda (Toshiba), Mr. Kazuya Kiuchi (Kyocera), Mr. Satoshi Terasawa (NEC), Mr. Robert Westervelt and Ms. Julie Williams-Hill (Department of Public Utilities, Los Alamos County) and Dr. Scott Backhaus (Los Alamos National Laboratory).

This Case Study was commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

7. Reference

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