Efforts of Smart Community in Miyako Island

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Keywords: aggregation, renewable energy, solar energy, heat pump water heater

INTRODUCTION

There are 11 power grids in Okinawa. In 10 remote island power grids, excluding the main island, electricity is mainly supplied by diesel generators, and the generation cost is high. In Okinawa, 98% of the primary energy is dependent on fossil fuels. As a result, diversification of energy sources and non-use of fossil fuels are urgent issues. Population has been reduced in most remote islands except Okinawa main island. However, the maximum demand continues to rise because of the increase in tourists. Hence, the annual load factor (= average/maximum) has been getting worse, which has led to further increase in the generation cost. The situation is similar in Miyako island with a population of about 55,000, and its annual load factor is less than 50%. If we could raise the annual load factor to 75% or more, the generation cost would down, and we could solve the deficit of power generation. In Miyako, we have been making efforts to make Eco-Islands since 2007, and the CO2 reduction target is 44% in 2030 and 69% in 2050, compared to 2003. In order to realize it, we would like to raise the self-sufficiency rate of energy within the Miyako from 3% to 20% or more by introducing renewable energy sources (RESs) and other distributed energy resources (DERs).

TECHNICAL RESEARCH

In the past 2 years, we have conducted technical researches to increase the load factor and for maximum use of RESs. We focused on home appliances to obtain sustainable and inexpensive technical methods to meet the demand of islands. Home appliances of which prices decline such as Photovoltaic systems (PV), Heat Pump Water Heaters (HPWH), Battery Energy Storage Systems (BESS), and EV Charging System (EVCS) are chosen to controlled devices. In addition, because they are home appliances, control methods consider multi-vendors, adopt standard protocols and cloud control systems as much as possible (Fig.1). We have studied deployment models of the DER management systems and propose control methods of DERs. We also proposed the assumption of two kinds of aggregators in the future.

DEPLOYMENT MODEL

Deployment model of the controlled devices is a Third-Party-Ownership (TPO) combining a rooftop PV and a HPWH. For the Rooftop PV, we use a stand with a tilt angle of 5°, and an adhesive for bonding with the roof part. The HPWH is combined with the PV power conditioning systems (PV-PCS) to be mounted on a self-supportive stand, considering that there is no burden on housing. The self-supporting stand has a structure to extend cables for BESS and EVCS (Fig.2). Initially TPO-IPP (Independent Power Producer) model intends to sell PV power wholesale, and when the BESS is additionally installed, the deployment model will switch to TPO-PPA (Power Purchase Agreement) model which retails power to housings. In addition, hot water from the HPWH is planning to be sold to hot water retailers in the housing. This deployment model is expected to reduce the average energy cost of conventional housing by about 20%.

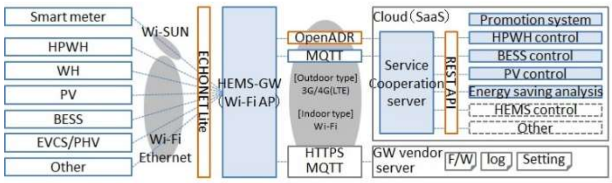


Fig. 1. Control methods of multi-vendor.

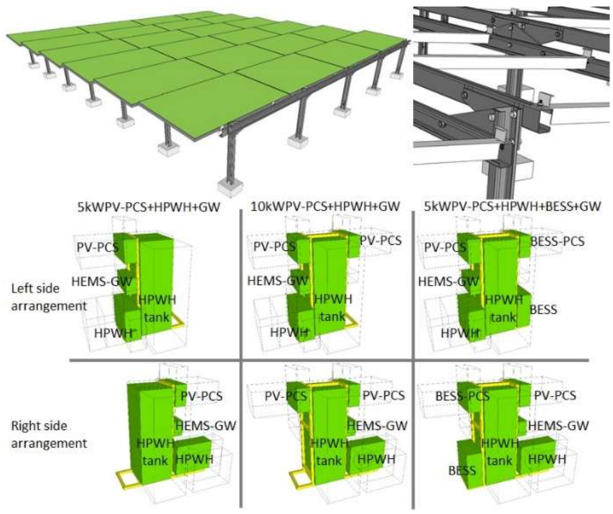


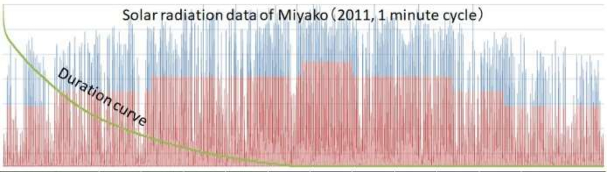
Fig. 2. Installation method of controlled devices.

CONTROL METHOD

Controlled devices such as PV+HPWH are operated from cloud control systems via the HEMS-GW. Among them, control devices for PV always restrict maximum PV output to a certain level, unless PV-PCS capacity is much lower than PV panel capacity. In winter, the maximum output level decreases. By this operation, we aim for stable power supply by enhancing predictability of PV output without large loss of PV generation. For example, even when we restrict the maximum output to 70% in summer and 40% in winter, annual power generation can be secured to 90%. (Fig.3).

The HPWHs, installed as an initial plan, and the BESS, added in the future, are both scheduled on the previous day and the operation time shift control is performed. This demand response scheme is called Shift Demand Response (Shift-DR), in which DERs are controlled with local groups, and form the demand of the whole island power system of the next day. It is called “Area aggregation”.

The purpose of Area aggregation is to improve the load factor of the whole power system and the maximum use of renewables. In addition, we explore possibilities with appropriate control method.



Output limit rate	PV Monthly power generation rate												
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
100%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
90%	100.0%	100.0%	99.9%	99.8%	99.7%	99.8%	99.6%	99.8%	99.9%	100.0%	100.0%	100.0%	99.8%
80%	100.0%	99.9%	99.3%	98.7%	98.7%	98.3%	97.5%	98.4%	99.1%	99.9%	100.0%	100.0%	98.9%
70%	99.8%	98.9%	97.7%	95.6%	96.5%	95.2%	93.2%	95.0%	96.2%	99.2%	99.6%	99.9%	96.4%
60%	98.7%	95.8%	94.6%	90.4%	92.9%	90.2%	87.1%	89.9%	91.0%	96.2%	98.3%	99.4%	92.3%
50%	95.4%	90.2%	89.7%	83.1%	87.7%	83.0%	79.0%	83.1%	83.8%	90.9%	95.0%	97.1%	86.1%
40%	90.6%	82.3%	82.6%	73.7%	80.2%	73.4%	69.1%	74.2%	74.0%	83.1%	89.4%	92.7%	77.7%
30%	83.3%	71.3%	72.1%	61.6%	69.4%	60.9%	56.7%	62.8%	61.4%	71.9%	80.1%	85.3%	66.4%
20%	70.5%	55.3%	56.6%	45.9%	53.6%	45.1%	41.6%	47.3%	45.3%	55.5%	65.3%	72.2%	51.0%
10%	47.7%	32.8%	34.9%	25.9%	31.3%	25.0%	22.9%	26.7%	25.2%	32.4%	40.9%	47.1%	29.8%
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Fig. 3. PV always restrict output.

NEGOTIATION WITH HOME APPLIANCE VENDORS

In Japan, remote control of household electrical appliances is still not used as standard. Even though it is possible to adapt them to fit specialized functional equipment it is just not a sustainable method. However, it is possible to purchase equipment that is already on the market and then consult with each vendor about its standard specifications, and verify how far it can control repeatedly but not deviate from it, and then choose a method that is simple and applicable to a wide range of equipment.

Specifically, PV is realized by instructing it to use the output restriction function possessed by PV - PCS. HPWH instructs the power consumption timing by the starting and stopping of boiling point. Because old-fashioned electric water heaters (WH) can not receive a signal on the equipment side, it controls the on / off breaker with 8-hour time sets. EVCS such as VtoH will be another way, but considering its deploying, it only instructs the charging timing by the on / off control of the circuit breaker. We have confirmed that other domestic household appliances can be controlled via infrared remote control, but it’s application needs further study.

NEGOTIATION WITH LPG SUPPLIERS

There are about 200 propane gas (LPG) suppliers in Okinawa, and 13 companies are located in Miyako island for about 25,000 households. Large companies supply 8000 households, and small companies supply 500 households LPG. We negotiated with each suppliers about the deployment model of PV + HPWH. Although they understood the necessity of this model, most of them could not deny that it might cause their companies bankruptcy if this model spreads rapidly.

If a collapse of the energy supply occurred, it may cause a lot of confusion, so it is necessary to keep attention to its popularization. Therefore, we are so far gradually planning to introduce the LPG equipment hybrid system. (Fig.4)

In the LPG equipment hybrid system, HPWH is operated by power from PV, and the HPWH supplied 50°C hot water to the LPG water heater. It will restrict the LPG water heaters to operate and reduce LPG consumption as much as possible. After years of confirming this operability, we are able to abolish the LPG water heater and replace them to LPG equipment hybrid system. We will promote the original deployment model, but gradually entrust the island's LPG operators to spread its business management, and aim to expand their business closely with the local sites.

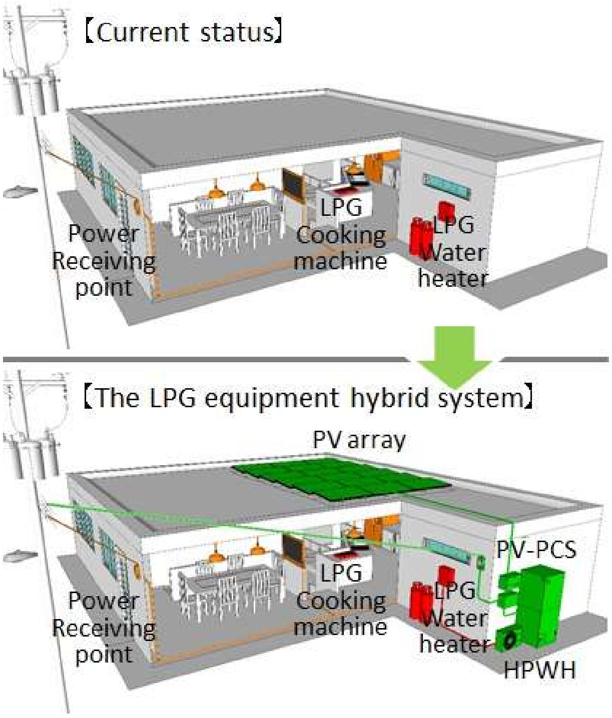


Fig. 4. The LPG equipment hybrid system.

NEGOTIATION WITH POWER COMPANY

Negotiations with electric power company is proceeding smoothly. Although RES connection capacity has already been reached, in order to further expand RES, we have an understanding of improving predictability by the PV constant output limit and controlling Shift-DR value by DER control. At the same time as the TPO-IPP business is established, we are considering selling cheap PV surplus electricity to electric power company and promoting the settlement of the deficit balance of remote island power supply. Under the current rules, we are also considering necessary conditions for system connection to the deployment models at the same time.

On the other hand, if deployment models of PV + HPWH spread widely, and creating next day power demand by Area aggregation, we predict that electric power fluctuation will hardly occur, even in a small-scale electric power system of a remote island. However, the current situation like this transition period is severe. At present, the RES connection capacity has already been reached due to the increase of tourists in recent years, so that there is a remarkable tendency to have a shortage of the diesel generators' raising and lowering capacity. In a small scale electric power system, the RES output variation and the load variation are rapidly changing within several minutes.

In this project, we have planned to only employ the gentle control of the Shift-DR, but it is necessary for us to find out the Fast-DR by minutes. If it will be realized by LTE, we can make it possible with the technology which has already exists, but there is concern the communication cost will be increased by this minute response.

Therefore, we divided the communication into UPLINK and DOWNLINK, and decided to use LoRa communication which is a type of LPWA (Low Power Wide Area) for UPLINK. Then, we install LoRa to the GW equipped in the DER, and report the PV output value and the HPWH power consumption value, etc. by every minute to the nearest relay GW tablets. A relay GW aggregates reports from a maximum of 500 DER-GWs and reports the PV total value and the total HPWH power consumption value to the cloud-system in 1 minute cycles.

By application of this system, the diesel power station would be possible to carry out real-time monitoring and it is useful for PV output monitoring at regular times. In addition, and in times of emergency such as insufficient lifting capacity or the lack of remaining capacity of the diesel generator, control command such as PV stop and HPWH operation / stop will be transmitted by LTE communication.

By choosing such a method, we believe that even if monitoring and controlling DER in real time, operational costs can be realized at low cost. (Fig.5)

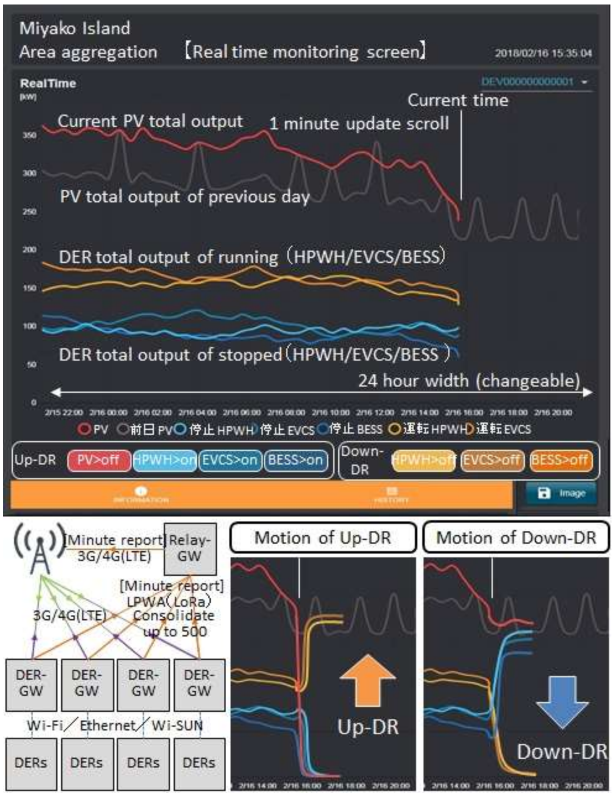


Fig. 5. Real-time monitoring and Fast-DR.

FUTURE ASSUMPTIONS

The price drop of domestically produced PV panels and PV-PCS is also progressing rapidly due to the influence of price drop of overseas PV panels. Also, there is also a sign of the BESS price drop. Under these circumstances, we are making future assumptions for stable power supply (Fig.6).

First of all, we will deploy PV+HPWH to low-voltages line using the TPO-IPP model. In the future, we add BESS+EVCS and switch to the TPO-PPA model. Using the controlled devices, the Master aggregator cooperates with Area aggregators and their servers to form island's total demand on the next day, which is called "Area aggregation". In Area aggregation using Shift-DR, precise settlement is unnecessary for each demand shift because the total power consumption itself doesn't increase or decrease. However, only the time of the electric usage changes, when requesting down-DR or up-DR of minute speed response, settlement is required.

Next, with the deployment of the TPO-PPA model mentioned above, kWh value falls and the kW value rise. For that reason, we assume that BESS for peak-cut will become popular in high-voltage lines. Further, market price of BESS drops with the massive installation of BESSs, and automatic driving technology will be realized. In addition to this, the deployment of EVs is also accelerated, and the number of EV charging stations will increase rapidly. In order to cooperatively control large amount of PV and wind power with controlled DERs connected to high-voltage lines, the Master aggregator instructs supply and demand control to Resource aggregator which controls high-voltage DERs and adjusts supply and demand. This scheme is called “Resource aggregation”, which requires down-DR or up-DR of minute-speed response. Therefore, basically it requires precise settlements.

By enriching Area aggregation and Resource aggregation, large amount of DERs will be installed. In such a situation, it may be necessary to add a Step Voltage Regulator (SVR) or a Static Var Compensator (SVC) on the high-voltage line. When the thermal power generator stops, it is necessary to maintain the system stabilized storage battery and secure the inertial force. Therefore, there is necessary to implement functions for performing reactive power adjustment and frequency adjustment in many controlled devices.

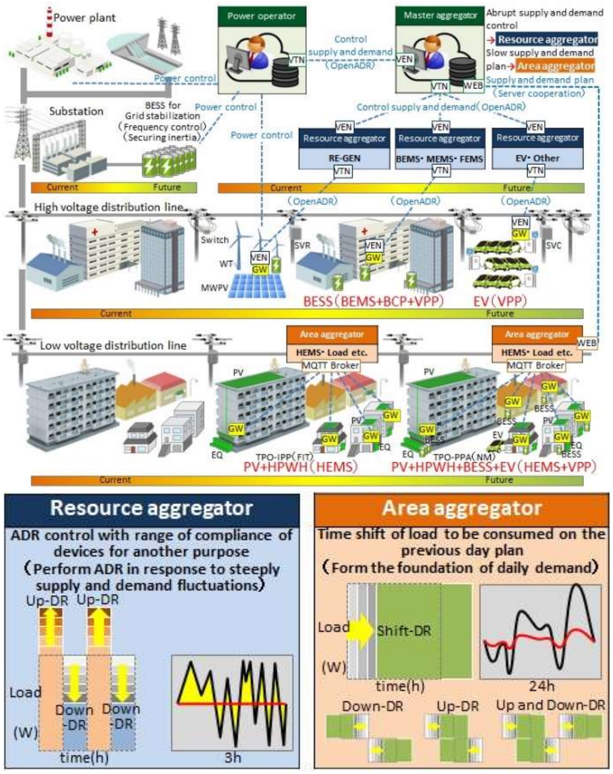


Fig. 6. Future assumptions.

RECENT PLANS

At Miyako Island, there are plans to verify the effectiveness of Area aggregation by deploying up to 5000 units of set of DERs in the TPO-IPP model over the next 3 years. The basic configuration of one unit is a combination of PV5kW+PCS5kW+HPWH. By this project, we are planning to double the PV of about 24 MW currently being introduced to about 50 MW to Miyako Island, whose current load is 25 MW - 60 MW. At the same time, plans are in progress to deploying control devices (PV+HPWH) by TPO-IPP model to other areas of Okinawa.

In order to promote DER sustainably with the TPO-IPP model, it requires extensive funds that is difficult to provide for ourselves, so that it is important to establish a collaboration system with LPG suppliers in the 3 years deployment project in Miyako Island.

Therefore, we will establish the control value of DER which is the control target equipment, and establish a hot water selling method, equipment procurement method and system connection method. Also, we will consult with the electric power company on the composition of PV surplus power sale unit price and aim for a persistent and versatile operation.

By combining these, we would like to realize Area aggregation, and make PV a main power source, while improving the self-sufficiency energy rate within the island from 3% to 20%, and produce a power system with low power generation cost.