Suitable Combination of Photovoltaic Cell and Electricity Storage System in the Smart Community Connecting the Commercial and Residential Sectors

By Yoshiki Ogawa

OVERVIEW

The Paris agreement on post Kyoto GHGs reduction was finally approved by many countries including various developing countries in December 2015. In 2015, Japanese Government also determined the new target of GHGs to achieve 26% reduction from the emission level in 2013 up to 2030. This target seems to be somewhat mild. However, in the long-run, Japan must basically strengthen her GHGs reduction measures, because she already committed 50% (or 80%) reduction of GHGs in 2050.

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The GHGs emissions in Japan have increased to the large extent up to 2014 from the 1990 level (the base level in Kyoto Protocol). Especially, the continuous increases in GHGs emission in the commercial and residential sectors were remarkable and largely influenced to the whole increases in Japan.

In recent years, the storage system of electricity such as Lithium ion, NAS and redox flow batteries is also being made a large progress. The smart community connecting both commercial and residential sectors is widely noticed. Therefore, in this study, we would like to analyze suitable capacity combination of photovoltaic cell (PV) and electricity storage system (ESS, battery) in the smart community connecting the commercial and residential sectors.

METHODS

In this study, we made various simulations on the introduction of smart facilities such as PV and ESS as important functions of smart community connecting the commercial and residential sectors. First of all, the average electricity demand pattern in the commercial and residential sectors was estimated by month based on the METI report [1], EDMC data [2] and Cogeneration Comprehensive Manual [3]. We also surveyed present situations on PV and ESS on the basis of NEDO and METI reports [4, 5]. The average daily pattern of PV generation was estimated by month using NEDO Sunshine Database [6].

The number of households in the residential sector (abbreviated to RES in the figures) was assumed to be 1,000 and the total floor area in the commercial sector (abbreviated to COM in the figures) was also assumed to be 25,000 m2. The capacity of PV for each house in the residential sector was assumed at 4 kW.

As for surplus PV electricity, the direct supply to the own sector, the direct supply to the other sector, the charging into the ESS and the selling to the outside electricity company has a higher priority in this order. Thus, the last remaining surplus PV electricity was sold to the outside electricity company. The charging of electricity storage system is made from 0:00 to 6:00 for cheap purchased electricity in midnight if necessary and from 6:00 to 18:00 for surplus PV electricity, and the discharging of electricity storage system is made in necessary hours judging from electricity consumption.

The cost of PV was assumed to be 350,000 Yen/kW for the house use (small scale) and 300,000 Yen/kW for the mega solar use (large scale). The cost of ESS was assumed to be 200,000 Yen/kWh. The differences in electricity charge between daytime and night were assumed. Final surplus electricity generated by PV was assumed to be sold at FIT (Feed in tariff) price of 33 Yen/kWh for the residential sector and the 27 Yen/kWh for the commercial sector (actual FIT prices in 2014).

The investment return of smart facilities is checked by the simple payback years which is calculated by dividing the net initial cost (excluding cost covered by the subsidy) of required equipment by the annual profit brought by the reduction of purchased electricity and the sales of PV electricity to outside.

In the simulation, first, we determined the starting point in which purchased electricity from the power company outside could be made absolutely zero (a kind of extreme case). There were two cases: one was PV maximum case (PV capacity 40,000 kW and ESS capacity 20,000 kWh) and the other was ESS maximum case (ESS capacity 39,000 kWh and PV capacity 5,500 kW). Second, we analyzed suitable capacity combination of PV and ESS starting from the ESS maximum case by checking various performance indicators. Finally, we considered the future issues and subjects of smart community.

RESULTS

Comparison of two starting points (absolutely zero purchased electricity cases)

In the PV maximum case, in order to reduce the electricity purchased from the outside power company to absolutely zero for all months in the year, extremely large size of mega-solar is installed in the commercial sector and almost all the PV electricity generated is sold to the outside power company using FIT (Feed in Tariff) system.

The quite small part of PV electricity generated is supplied to the own sector firstly, supplied to the other sector secondly, and supplied to the ESS for charging thirdly. The electricity charged into the ESS is discharged for the consumption in the residential and commercial sectors from the evening to the early morning. As a result of these supplies, the electricity purchased from the outside electricity company becomes absolutely zero for all months in the year.

In the ESS maximum case, different from the PV maximum case, in order to reduce the electricity purchased from the outside power company to absolutely zero for all months in the year, the almost doubled large capacity of ESS is installed and the large part of remaining surplus PV electricity is charged into the ESS.

The quite large part of PV electricity generated is supplied to the own sector firstly, supplied to the other sector secondly, and supplied to the ESS for charging thirdly. Then the small part of PV electricity finally remained as the last surplus is sold to the outside electricity company using FIT system. The electricity charged into the ESS is discharged in the same way as the PV maximum case. As a result of these supplies, the electricity purchased from the outside electricity company also becomes absolutely zero for all months in the year.

The results of PV maximum case are brought especially by the special favorable treatments using higher FIT prices. Because the required size of PV capacity to generate PV electricity sold to the outside is quite large, the various risks on the investment recovery are also expected. If we pursue the sound developments of smart community connecting the residential and commercial sectors, the large dependence on investment recovery to the FIT revenue is not always desirable. Thus, in the next step, we focus only on the ESS maximum case.

Simulations on ESS maximum case and the suitable combination

Figure 1 shows various ratios related to purchased and sold electricity by the smart community. At the starting point of ESS maximum case, though the purchased electricity can be reduced to absolutely zero at any time, the payback year of 29.5 in this case is too long and the final remaining PV electricity sold to outside is also large. As judging from the balance ratio of purchased and sold electricity in the smart community shown in Figure 1, the purchased electricity from outside is almost balanced with the sold PV electricity to outside throughout the year if the installed PV capacity is 4,100 kW.

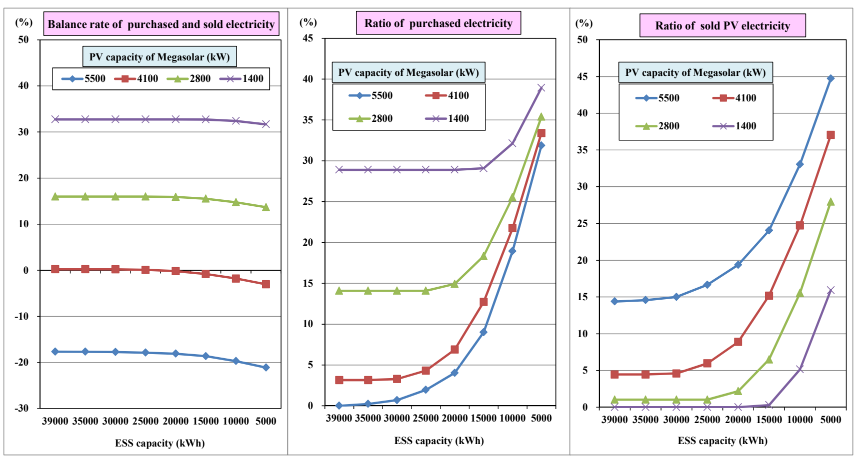

Figure 1 Changes in various ratios related to purchased and sold electricity

Figure 2 shows various ratios related to ESS performances. If the capacity of ESS is positioned at between 39,000 and 20,000 kWh, various ratios shown in Figs. 1 and 2 are not changed so largely. If the capacity of ESS is lower than 20,000 kWh, these ratios are changed drastically. The payback year of smart community is more improved as the capacity of ESS is lowered.

Based on these results, the PV capacity of 4,100 kW and the ESS capacity of 20,000 kWh would be the suitable combination. The payback year of this case is lowered to 21.6 and the operation rate of ESS rises to 61.6% as shown in Fig.1. Figure 3 shows the electricity supply pattern of the commercial and residential sectors and the electricity storage system on the suitable PV (the large scale of 4,100 kW finally reached in the commercial sector and 1,000 [Max] houses installed the small-scale of 4,000 kW) and ESS (20, 000 kWh finally reached) installation case.

It is quite difficult and not efficient to reduce the electricity purchased from the power company outside to absolutely zero in the winter season and summer season, as shown in Figure 3.

CONCLUDING REMARKS

First, the special environment brought by the preferable acceptance price of PV electricity by FIT makes large distortion to the decision making of investments to smart community. We need to reconsider desirable and sustainable FIT system more carefully. The special treatments by FIT are not suitable for the sound developments of smart community.

Second, the absolutely zero purchased electricity at any time is often pursued in the smart community as an achievable target. But the realization of this target is quite difficult and extremely inefficient. Instead of this target, the balancing between the purchased electricity and the sold PV electricity would be an important target which should be considered.

Third, we also need to consider the balancing between the economics of smart community and the role of installed ESS capacity. In order to reduce purchased electricity more, the larger ESS installed capacity would be required. However the economics of smart community becomes worse rapidly as the ESS capacity becomes larger.

Forth, under the present cost conditions, the economics of smart community would not be so preferable. For the expansion of smart community connecting the commercial and residential sectors, the cost reduction of smart facilities, especially for ESS, would be quite important.The quite lower price of electricity storage system announced by TESLA is gratifying information for smart community. As for the large-scale ESS (Batteries), Japanese companies also have advanced technologies such as NaS (Nihon Gaishi) and redox flow (Sumitomo Denki) batteries.

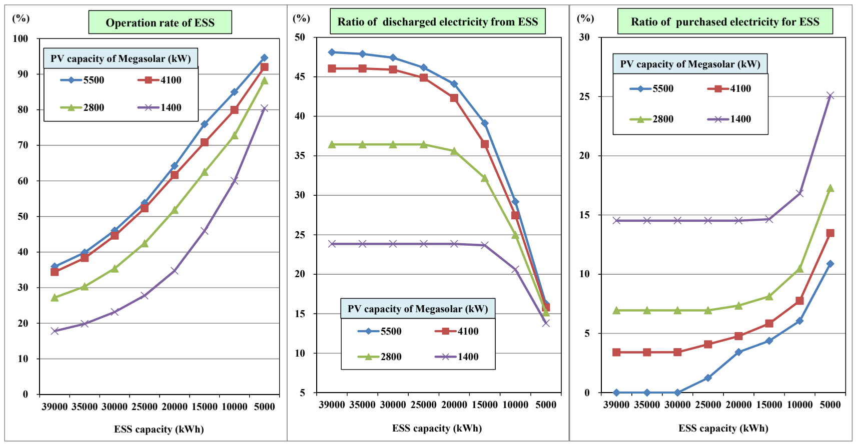

Figure 2 Changes in various ratios related to ESS performances

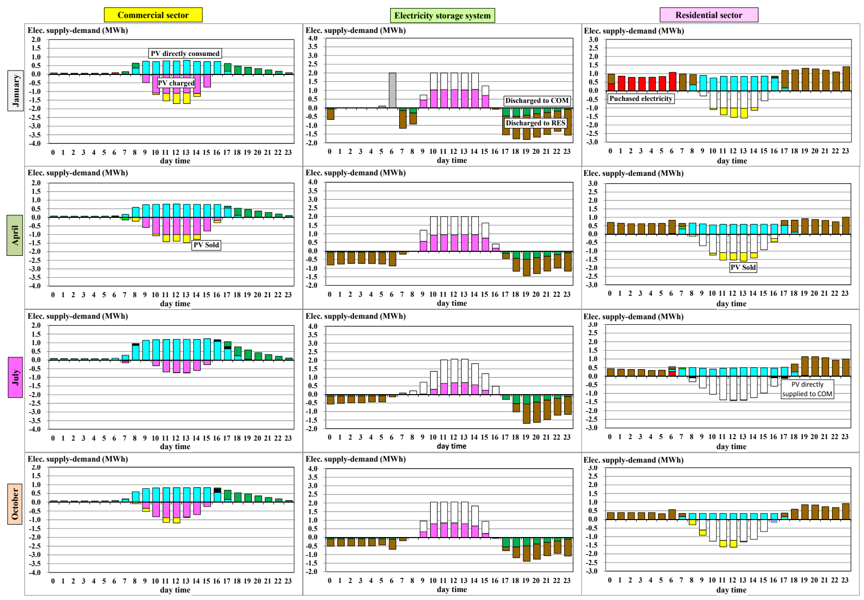

Figure 3 Electricity supply patterns in the suitable installation case (ESS: 20 MWh, PV: COM = 4.1 MW, RES = 1,000 houses)

References

1. METI [2012], "Survey report on energy consumptions in the residential sector," http://www.meti.go.jp/ meti_lib/report/2012fy/E002203.pdf, (referred on March 20, 2016), March 2012.

2. EDMC [2015], "Energy Statistics 2015," Energy Conservation Center, 2015

3. ACEJ [2004], "Comprehensive manual on cogeneration system," Tsusan-shiryo-shuppannkai, 2004.

4. METI [2013], "Survey report on movements of introduction of photovoltaic cells etc." http://www.meti. go.jp /meti_lib /report/2013fy/E002502.pdf, (referred on March 20, 2016), February 2013. JPEA [2013], "JPEA PV Outlook 2030," http://www. jpea.gr.jp/pdf/pvoutlook2013-1.pdf, (referred on March 20, 2016), December 2013.

5. METI [2010], "Future prospect on electricity battery industry," http://www.meti.go.jp/ report/ downloadfiles/ g100519a02j.pdf, http://www.meti.go.jp/report/downloadfiles/g100519a03j.pdf, (referred on March 20, 2016), May 2010. NEDO [2013], "Battery Road Map 2013," http:// www.nedo. go.jp/content/100535728.pdf, (referred on March 20, 2016), August 2013.

6. NEDO [2006], "Sunshine database," http://www.nedo.go.jp/library/nissharyou.html, (referred on March 20, 2016), 2006.