A PV-House Experience in Japan

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ABSTRACT

A PV-house with a 3 kW solar-cells panel roof was constructed and has been used for ordinary family life of one of the authors. The PV output is interconnected to the utility power network with a reverse current flow. Average power output of the solar panel exceeded 13 kWh per day for sunny days and 6 kWh for cloudy days in May. Time-sequential data of power consumption and supply have been recorded. The PV generation system is found to be capable of generating 300 kWh per month in average and supplying as large as 100-200 kWh per month to the utility power network. This system has been proved to be effective in reducing the peak power demand in the hot summer days in Japan.

1. Introduction

Utility scale interactive dispersed PV system for ordinary consumers' residences is expected to be effective for reduction of peak-power demands on daytime in hot seasons[1], as well as for reduction of delivery loss. For this purpose provisions to maintain the reliability and quality of power system has been required. On March 1993, a new guideline has been established in Japan for grid-interconnection of small scale PV generation system with reversed power flow[2]. (See the Appendix) Simplified interconnection relay is recommended. In addition, low cost integrated PV panels have been developed for roof use. These situation prompted one of the authors (K.S.) who is a researcher of solar cells materials to make his mind to build a house with the PV-roof.

He had his house built under the specification of "Eco-Energy House" which had been proposed by Misawa Homes Institute in preceding paper[3].

The house was built under the concept of reducing the energy consumption and loss as much as possible by adopting an architecture with high heat insulation and air-tightness.

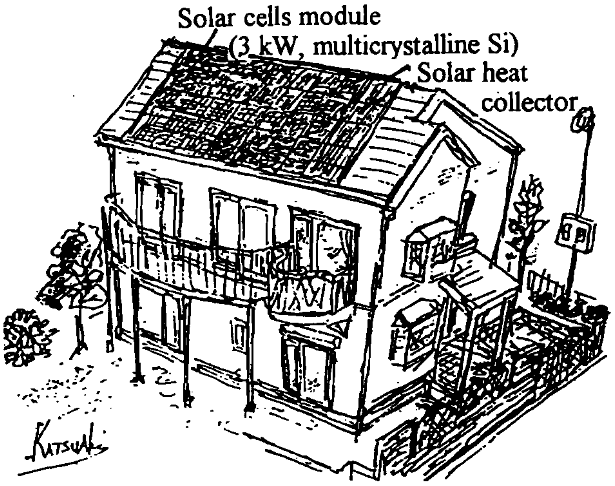

Fig. 1 An illustration of the PV-house for ordinary life use.

2. Specification

The newly built house (illustrated in Fig. 1), which was completed on March, 1994, is equipped with the solar power generation system consisting of roof-integrated 3 kW PV panels, an 3 kW inverter and the interconnection relay which follows the *new guideline*, as well as solar heat collecting system to warm utility pipe water before supplying to hot-water supply system which utilizes the low-cost night-time power. The total system is illustrated in Fig. 2. Total of 40 multicrystalline silicon PV modules, the area of one module being 90cm x 90cm, cover about 70% of the south-side inclination of the roof. The inclination angle of the roof is 26.5°. The inverter used has an efficiency of 90% in average. It has an ability of automatic shutoff, when the PV-power generated becomes less than that required to operate the apparatus.

A heat pump system described in ref. 3 is adopted for the air conditioning of this house. Owing to the low thermal conduction of the Eco-Energy House system (the measured heat loss coefficient being as small as 1.19 kcal/m^{2}hr °C) the power required to maintain0 the air conditioning has proved to be reduced by 85 % of that in ordinary wooden residences.

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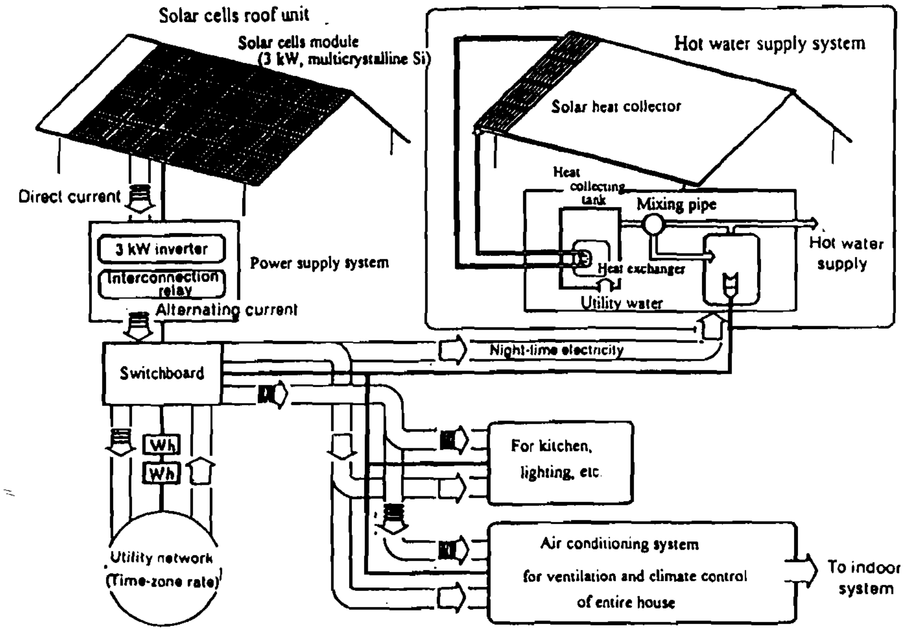


Fig. 2 Schematic illustration of the PV-house with the concept of "Eco-Energy House"

Instead of city-gas cookers usually employed in ordinary Japanese home kitchens electrical heaters are used in order to reduce the CO_2 exhaust.

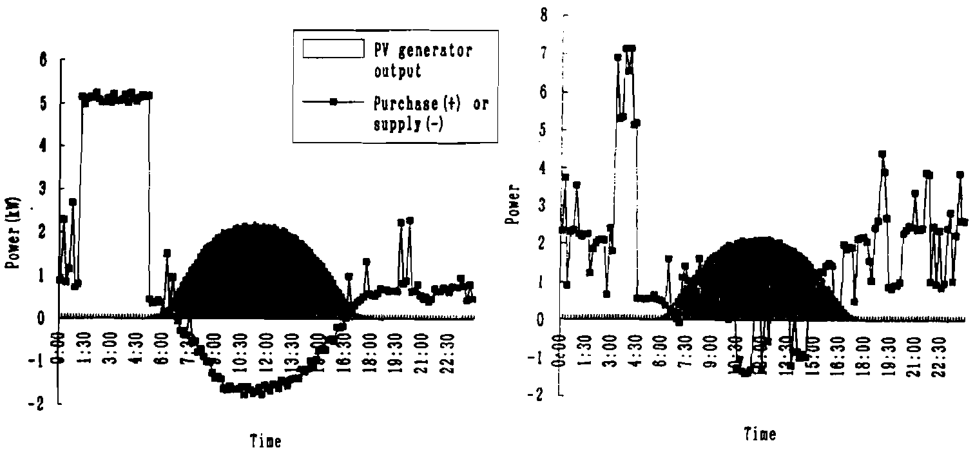
To save power consumption of lighting, ball-type bulb-shaped fluorescent lamps, the power consumption of which are 1/3 of incandescent lamps of the same brightness, have been employed for lighting of all rooms. Use of fluorescent lamps often leads to reduction of power factor due to inductors, which becomes a problem for grid-interconnection. However, such problem has been solved by use of bulb-shaped fluorescent lamps with built-in inverters.

3. Measurement and Results

The output power from the PV-module/ inverter system and the power consumption/ supply at the interconnection point are monitored using power transducers(PT) inserted into appropriate positions of the wiring. The output voltages of PTs are monitored by a personal computer system.

Fig. 3(a) shows as a typical example a time-sequential profile of the power supply/ consumption (white square) and the PV-output (black square) of the house for the entire day of May 19 (clear). Peak power generated by PV array was 2.24 kW at 11:20. The angle of incidence of the solar radiation at the time of culmination is nearly perpendicular to the surface of the PV modules in this season of the year. It is thus elucidated that the real energy production of the system is 75 % of the nominal power output of solar module. This value is quite reasonable if one takes into account the real radiation and inverter efficiency (90%). Total power generated for time period when solar radiation was available amouted to 17.38 kWh for the day. Total power consumption during the same time period was 6.44 kWh, resulting in the reverse power flow of 10.93 kWh. The total power purchased from the network amounted to 23.55 kWh for the night-time (23:00-7:00) and 4.60 kWh for the day-time (7:00-23:00). The strong jump of power consumption during the night-time seen in Fig. 3(a) was mainly due to the hot-water supply. The time duration for which the hot-water heater is switched on depends on the solar radiation of the preceding day since the water supplied is preheated by the solar-heat collector. Compare it with the data of August 14 shown in Fig. 3(b), in which heater is switched on as short as 90 min.

Total payment for purchase was as small as 313 yen for the entire day since the rate at night-time cost 1/4 of the day-time rate, whereas total sales amounted to 340 yen, resulting in 27 yen surplus.



(a) (b)

Fig.3 Time-sequential data of PV-generator output (vertical bars) and Power purchased from or supplied to the utility network.
(a) May 19, without airconditioning, (b)August, 14, with airconditioning

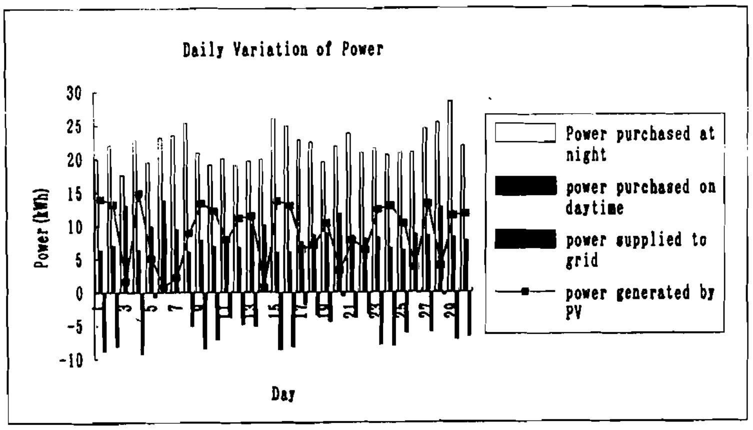


Fig. 4 Daily Variation of Power purchased from and supplied to the network. The power produced by the PV generation system is also plotted.

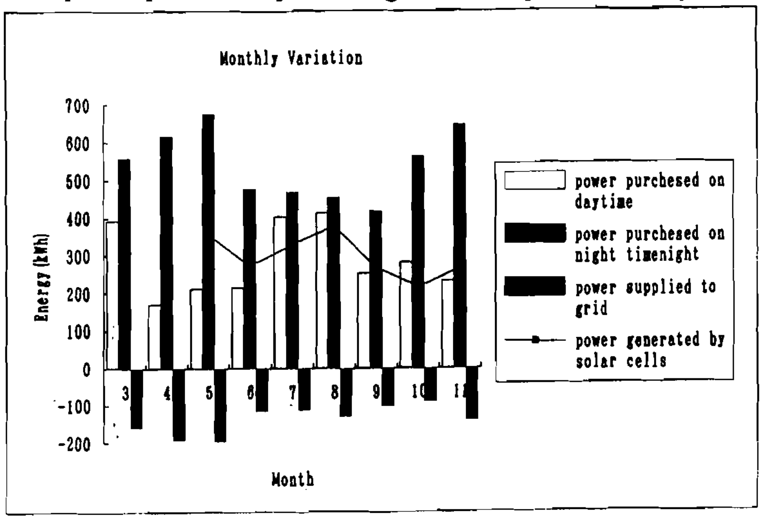


Fig.5 Monthly variatin of the power purchased from and supplied to the network. The power produced by the PV generation system is also plotted.

Fig. 4 illustrates daily variation of the power purchased from and supplied to the grid, as well as power generated by solar cells system in November. The figure shows that average power output of the PV generator exceeded 13 kWh per day for sunny days and 5 kWh for cloudy days. Average of reverse power flow to the network amounted to 4.6 kWh in average for november (8.2 kWh for sunny days and 3 kWh for cloudy days).

Fig. 5 shows monthly variation of the power purchased from and supplied to the network as well as the power produced by the PV generator. Average of 300 kWh was found to be generated per month by the PV system. The energy supplied to the utility grid amounted to 100-200 kWh per month. PV power generated is large on the month when the daytime consumption is large.

4. Conclusion

An experience of living in the PV-house which was constructed under the concept of Eco-Energy House is described. The PV-house proved to be capable of supplying considerable amount of power to the network maintaining comfortable family life, showing effectiveness of PV-system for peak demand reduction.

References

1. H. Kobayashi: Tech. Digest International PVSEC-7, Nagoya Japan 1993, pp.367-370.
2. E. Hashimoto: Tech. Digest International PVSEC-7, Nagoya Japan 1993, pp. 375-377.
3. H. Ida: Tech. Digest International PVSEC-7, Nagoya Japan 1993, pp. 343-344.

Appendix

Guidline for grid-interconnected operation of small PV generation system (for low voltage users)

Items	Requirements
Capacity of solar PV generation system	Capacity of PV gen. system which can be interconnected to low vtg. power distribution line is limitted to 50 kW
Power factor (when interconnected with allowable reverse flow operation)	The power factor at the receiving point of consumer should be 85% or higher. leading power facter not allowed
Harmonics	Should not exceed 5% (total current distortion) 3% (harmonic distortion of each order)
Protective coordination	Overvoltage, low voltage, low frequency relay should be installed. (Incorporation in the Inverter is allowed.) Prevention of islanding is required.
Voltage fluctuation	If the voltage is likely to exceed the rage 101±6V, 202±20V by the reverse flow, adequate measures should be taken to adjust the vtg. by the consumer.
Cost reduction and Simplification	The grid interconnection device should be desirably simplified and should be as compact as possible.

Comments: The grid-interconnected PV generators should have the interconnec-tion device incorporated in the inverter. Isolation transformer may be omitted if automatic cut-off circuit works when DC component is detected.