Research on Photovoltaic Power Generations Installed in Veranda of Apartment Houses

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Abstract
The usage of the renewable energies is expected to be able to mitigate the energy problem. The application of renewable energy including photovoltaic power generation-PVG has been accepted and spread widely. Various innovative power conditioning systems for PVG have been also studied. In domestic utilization, the actual application of such solar panels is almost installed on top of the roof of the detached house. However, some residents living in the apartment house are having a fairly strong desire to contribute for energy saving due to natural energy generation. The generating power of such case is fairly reduced, so the system construction should be balanced with the reduced power. Thus, it is necessary to improve the construction toward simple one. In this paper, in order to give a reply, simple and concise photovoltaic power generating system having innovative power conditioner are proposed and examined. Considering fairly reduced generation power and narrow space of veranda for installation, the system constructions should be simple and concise. The system construction which gratified their wishes are presented and discussed. These solar panels can be easily connected like usual home appliances having attached plug for connection. Simple system circuit and construction will be presented and discussed.

Keywords**:** Veranda solar, PV power generation, Power conditioners, PVS, Solar panel, Flexible solar panel, Crystal solar panel, Organic thin film, Photovoltaic power, Power converter

Introduction

Various types of utility-interactive photovoltaic power generations have been reported and accepted widely. Some papers about power converters that interface between photovoltaic arrays and ac utility system have been also reported. Such innovative conditioning systems have been also studied. The actual application of such solar panel is almost installed on top of the roof of the detached house. However, some residents living in the apartment houses are having a fairly strong desire to contribute for energy saving due to natural energy generation. In this study, in order to give a reply, a simple and concise photovoltaic power generation system is to be presented and discussed which is installed in apartment house having verandas with the total power generation capacity of 8~24GW depending on PV panels all over Japan. Considering fairly reduced generation power and narrow space of installation, the system constructions should be simple and concise. In this study, the circuit which gratified their wishes are presented. These solar panels can be easily connected like usual home appliances having attached plug for connection. For reverse power flows and increasing harmonics, their protection circuits must be installed in the input power line if it is necessary. System circuit and their sophisticated construction will be presented and discussed.

In such discussions, there are many subjects to be solved to utilize the PV power in utility interactive power generation. Even more, various safeguard equipment required according to regulations make the cost increase. Thus, it is required to obtain even more low cost PCS. In an extremely lower capacity PCS like proposed one, a way of handling would be different compared to conventional ones. In such case of reduced generating power, quantities of reversed power to the power system would be small, where another mitigated regulation or deregulation would be approved. Thus, in such photovoltaic power generation systems, there are so many subjects to be resolved.

Under such circumstance accepted by electrical utility industry as recognitions and assessments for renewable energy, spread of application is strongly sustained by financial supports of public organizations, and a lot of consumers are hoping to install such photovoltaic power generation system. For ordinary homes, installation of solar panel is restricted to house having roof. However, a lot of residents wish to install the PV panel under supports by public finance. In addition, there are many residents living in the apartment house who wish to contribute the environmental improvement by means of renewable power generation such as PV generation.

In the present situation, however, there is no scheme to perform these requirements subject to such residents. This study is to reply such wishes of residences making contributions by renewable energies.

The specifications for PV panel according to installed place and installed configuration were discussed. According to efficiency of power generation, weight of panel, flexibility and cost of generation, optimum method is to be resolved. The PV panel for veranda solar is installed in narrow veranda

where panel should be arranged in well view point from appearance. As for satisfied solar panel, flexible amorphous Si solar panel, organic solar panel and Si hetero junction (crystal-amorphous) solar cell are fitted for these requirements. Among them, it can be seen that the organic solar cell is the best choice with regard to cost performance. With comparing various solar cells, the characteristic of converting efficiency vs. energy pay back time was resolved and discussed. Under such researches, we can obtain a resolution that the organic solar cell is most prospective one, because in 2020 (Tokyo Olympic year), the lowest power generation cost of 18.10 yen/kWh compared with Tokyo Electric Power Co. cost of 25 yen/kWh can be expected superb features with regard to flexibility, light weight and good design.

Research for Installed Scale of Veranda Solar

Fig.1 shows results from "Statistical Handbook of Japan 2015", which represents community apartments are totally 22.09 million houses in Japan. The percentage against the total residences in Japan is gradually increasing finally to reach at 42.4% in 2013. As it is expected to continue to be increasing, the needs for veranda solar for community type houses would be increased. As a matter of course, for the community house having veranda with sufficient power by solar, it is required for the sunlight sufficiently to shine in the direction of the south or not to be blocked by obstructions.

In this research project, in order to derive the number of community houses, which is expected to be able to have veranda solar, some researches have been executed. For a case of two panels of 1.2 m^2, 44.18 million sheets of panel that is 53.02 million m^2 will be installed in verandas over the country. For a case of 200W panel, 8.8 GW power can be totally expected.

Hearing results for dummy samplings

Under considering for installation at veranda. The hearing research have been executed, for flexible panel (Fig.2) and crystal panel (Fig.3). Through over the hearing, an ideal appearance of setting as veranda solar or specifications of the products for users could be made clear, in which the users want to install. Hearing situations are as follows;.

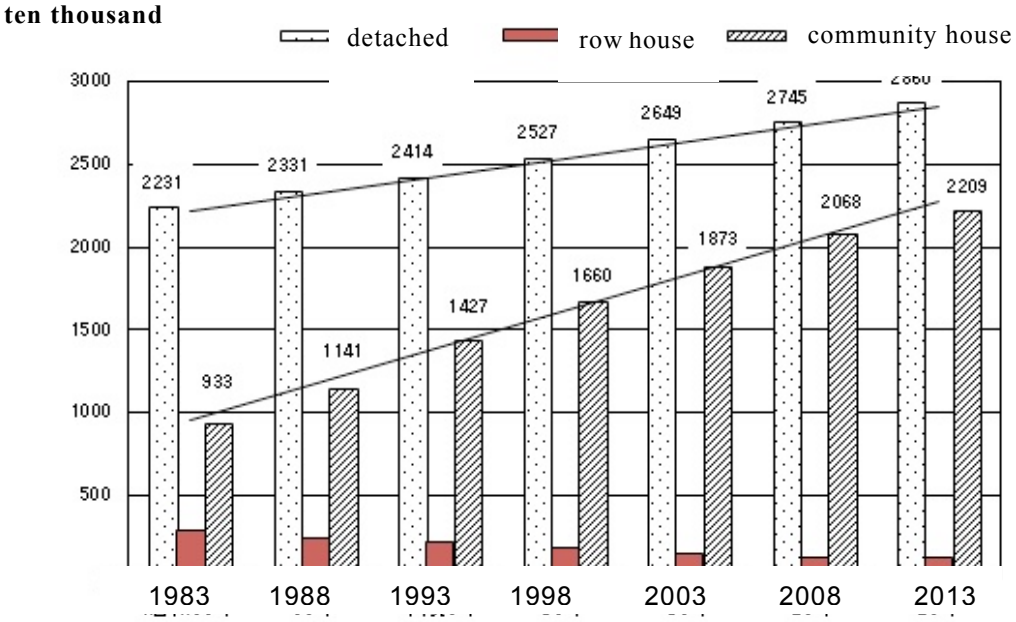

Fig.1. Transition on sort of houses in Japan
from "Statistical Handbook of Japan 2015"

(Q.) Which do you prefer flexible type which is light weight and well design characteristic, or crystal type which is high cost, but large power generation ?
(A) Crystal type is 25%. As fixing situation is good stable, higher power is delightful and it js easy to stand against a wall.
Flexible type is 65%. As the cost performance is superior. It is easy to handle even for women. Design performance is superior. It can be put back in a compact way when disuse.

(Q) What for do you use the generated power?
(A) Smart phone, Tablet, Television set, Lap top PC, Gaming machine.

(Q) When do you use mainly?
(A1) The 30% person uses on weekday.
Because on holiday, they are hanging out the laundry, or want to let in the sunshine, so they want to make the power generate while not at home.

(Q) Do you install even for a case of higher cost than power charge of electric company.
(A) Yes is 20%. No is 40%. Dependence on design is 40%.

Under such descriptions, as a kind of solar batteries, the expectation for flexible type gets a majority. As compared to crystal type, accepted reasons are lower cost, light weight, easy treating and good design. In addition, they said, it is satisfied to be able to supply the small power appliance. As for the cost performance, when the power charge in veranda solar becomes higher compared to the electric company cost, they do not want to install, but it depends on their design performance. These are majority opinions.

They seem to want to install the PVG system if the design like flexible type is superior compared to the conventional crystal type. From these hearing results, it can be seen that the promising PV system is that power charge is lower than the one of power company and in addition having good design.

Specifications for Veranda Solar

As the veranda space is narrow, so the generating power is restricted. Consequently further strict cost performance is required. Under such conditions for PV system installed in veranda, suitable indoors wiring, simple power conditioner will be discussed and reported.

Circuit Configurations of PCS (Power Conditioners)

The veranda solar under discussion is that the generating power is small, so suitable PCS should be adopted compared to kW type PCS.

Because the cost of PCS cannot be reduced in proportion to the capacity reduction, the cost reduction is one of the most important objective to attain. Until now, there is little attempt to report a novel circuit itself with lower cost configuration, because the circuit configuration itself is very simple and it seems to be no room to improve the circuit. For large scale PCS with kW type, full bridge circuit is used for like ac motor control, which has many switching devices accompanied boost chopper. Such configuration brings high cost performance. In order to improve such conditions, a novel forward converter type is devised and discussed. In general, almost small scale converters are constructed by forward converters, so the circuit construction know - how and the like is established. And also, the mass production brings lower cost performance. In this research, among three circuit configurations, which are not used for PCS till now, will be discussed, so suitable characteristics and requirements will be made clear. These will be accepted according to their costs and efficiencies which is presented at the bottom in this chapter.

PCS by Forward Converter

Fig.2 shows the first presented PCS. From the dc source, the power with full wave rectified waveform is supplied and synchronized with commercial frequency of ac power supply. By means of inverter of commercial frequency, the dc power is converted to sinusoidal current. The dc power of primary circuit is translated to secondary circuit by single switch of forward converter[1]. The trouble current by abnormality of PV panel side is prevented by insulation transformer. By mean of use of transformer, the secondary circuit voltage can be boosted easily, because the primary voltage of solar panel side is usually lower voltage. This is superior characteristic, in which secondary voltage can be easily boosted by changing the turn ratio. The operation is performed as follows; When the main switch Q_m is turned on, the current flows through the primary winding ①. In the secondary winding, the current flows through secondary winding ②, diode D_2, inductor L_o and the inverter circuit, where the current flows through IGBTs Q_1, Q_2 or Q_3, Q_4.

When Q_m is turned off, the current flows through the flywheel diode D_4 towards ac power supply of inverter. The winding ③ is used for Q_m off period, when the stored energy in the core is discharged. As the waveform control method, the pulse width of sinusoidal wave is controlled by Q_m, while Q_1 to Q_4 are used for low frequency switching. The above mentioned utility interactive control is used for simple PCS as PV power generation, which is used for residential use of 3kW PV power generation system[1] having 92% efficiency. The forward converter is used up to several hundred watt, but in this case of 3kW PCS, higher efficiency can be obtained. The PCS of concerning veranda solar uses 200W/sheet and the like, which is provided in mass product, so there are rich of know-how at manufacturing. Even though it is very simple construction, the total efficiency is fairly high. A original lossless snubber is installed, which is very simple and suitable for this circuit.

Center tapped Type PCS

Fig.3 shows the original circuit proposed by Isao Takahashi[2]. Fig.4 shows the circuit construction proposed by one of the authors[3]. The PCS under discussion can be realized in small size of outer box. In the case of Takahashi, the outer size is thickness 10.0mm, height×width 85×115mm. It uses high frequency transformer whose operating frequency is 90kHz. The external form of the box is suitable for attached on the back board of PV panel. The selection for these three methods can be performed according to those priorities of the efficiency and the cost. With comparison beteen Fig.3 and Fig.4, though the construction is a little different, the efficiency is almost the same.

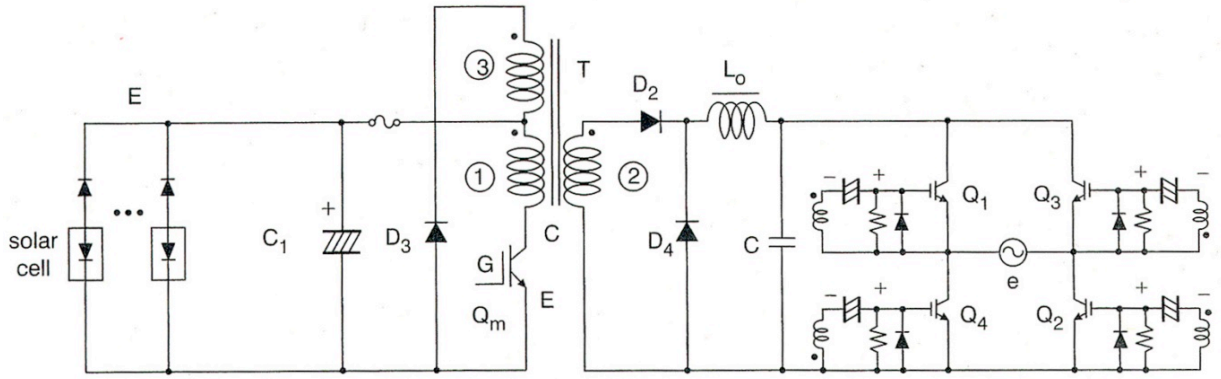

Fig.2. Power Conditioner by Forward Converter with Single Switch Type.

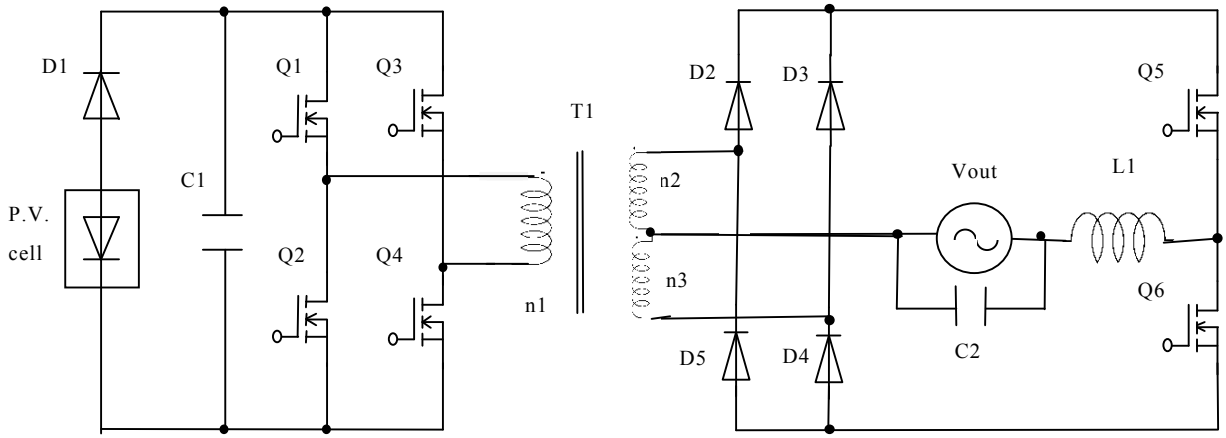

Fig.3. Power Conditioner by Forward Converter with Center tapped

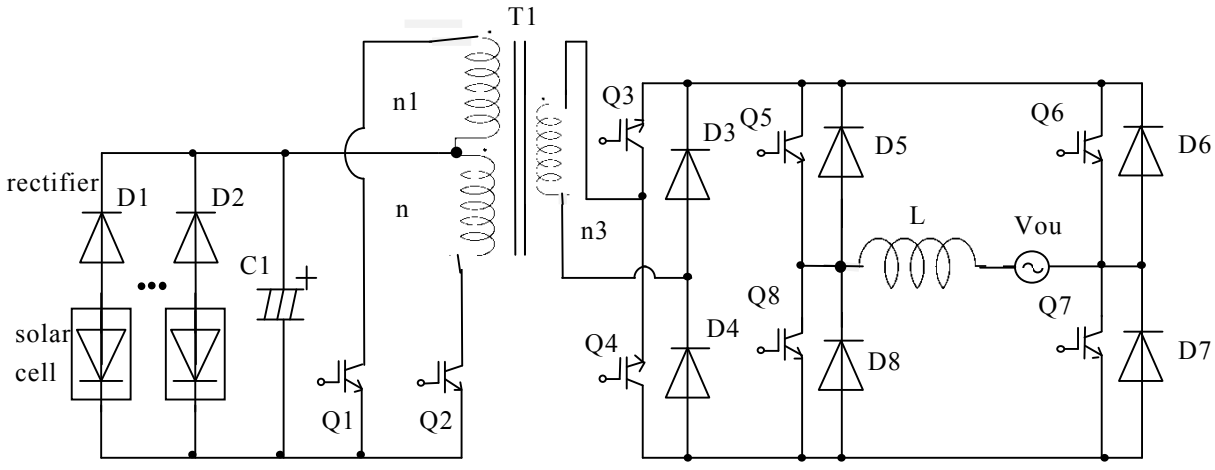

Fig.4. Power Conditioner by Forward Converter with Double Switches Type [3].

Table1. Comparison and Characteristics

Circuit strategy	Characteristics and advantages	Disadvantages
Forward converter[1]	Preventing of dc flow. easy to boost voltage Unified chopper and inverter Single high frequency switch (HFSW) Easy control	Large transformer Double voltage for HFSW Many number of LFSW
Center tapped converter [2]	Preventing dc flow out. easy to boost volt. Smaller transformer Unified chopper and inverter Small number of low frequency switches (LFSW)	Many number of HFSW Complicated control
Center tapped forward converter by double switches [3]	Preventing dc flow out. easy to boost volt. Smaller transformer Unified chopper and inverter Small number of HFSW	Complicated control Large number of LFSW

Characteristics of this System

Among discussed panels for veranda solar, possible product is to be selected and presented in this research.

・The generated power by solar panel is converted to utility ac 100V network, by which usual home appliances can be used in conventional way.

・The generated power by solar panel is stored in the battery, which is used in the night or all the day.

・When the stored power of the battery is disappeared, it is switched to ac utility network, by which the electric appliances in current use can be supplied continuously.

・The installation operation is easy, that is only simple way to connect by plugs.

・The necessary power can be obtained by outlet on the accommodation box.

Discussion on Solar Panel

Flexible Type

As a flexible type solar panel, the amorphous silicon and organic thin film are treated. Assuming a generating power efficiency of 8% in five years later, 400W power at maximum can be generated for $5m^2$ space at veranda. As comparing between amorphous silicon and organic thin film solar panel, it is different in the cost of module, the power generating cost is 21.20 yen/kWh

for amorphous silicon and 18.10 yen/kWh for organic thin film solar panel.

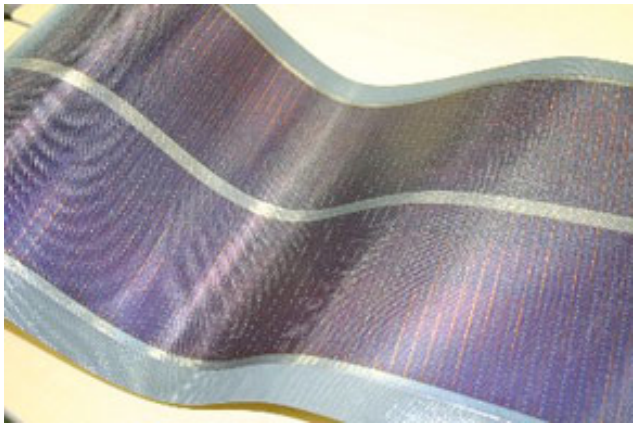

Fig.5. Amorphous Silicon Solar Panel.

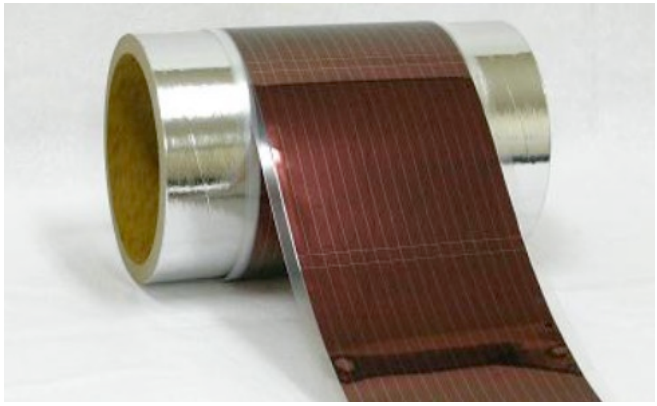

Fig.6. Organic Thin Film Solar Cell.

Crystal Type

For solar panel of crystal type, hetero junction solar cell (HIT) is treated. Assumed power efficiency y is 22%, the generating power is 1,100W for $5m^2$ panel. The power generating cost is 20.07 yen/kWh for ten year operation. As mentioned above of comparing to usual utility network charge in five years later, the charge of veranda solar is estimated to be reduced compared to present 25.91yen/kWh. The veranda solar by crystal type, amorphous silicon, or flexible organic thin type will be realized.

Conclusions

Through this research, an adequate and possible installation method as veranda solar have been reported and discussed, which have been not introduced widely. As a whole installation scale, if such veranda solar are installed all over Japan, where additional 44.18 million sheets/$53.02m^2$ are installed still more, which is 8% efficiency of flexible type, 4.24GW at maximum could be obtained. If 22% efficiency of crystal type is installed, 11.7 GW at maximum could be realized as a veranda solar. Furthermore, by means of devising the installment method at verandas, 8.8GW can be expected by using flexible type of 8% efficiency, or 24.3GW can be expected by using crystal type.

On the base of hearing result that the power generation cost due to veranda solar is cheaper than by electric company, various types of solar panels are proposed according to users' needs. The feature of proposed PCS systems is to pursue a lower cost one including the construction cost. According to reducing the capacity, the cost of solar panel is reducing in proportion. The cost of PCS, however, is not reduced in proportion to capacity. A novel PCS suitable for small capacity is proposed. This system can be performed at minimum wiring work at construction.

By means of Feed-in Tariff, the PV power generation has been developed widely. It is very important that the end user feels an economic merit which brings wide spread of PV power generation like as social phenomenon. The most important thing of proposed veranda solar is that the cost is lower than charge of electric company.

In additional important thing, the visualization tool could be mentioned, in which the generating power can be easily viewed like handy smart phone. By means of this tool, if the power can be measured as a "negawatt", economical merit can be realized and confirmed by viewing. If our visualization tool is realized with "Trade of Negawatt", which is promoted by Ministry of Economy, Trade and Industry. The veranda solar could be widely spread.

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