The diffusion of Distributed Grid-connected Photovoltaic power system use for residential areas in China: What are the barriers?

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China is facing increasing serious air pollution problems, one of the primary cause is coal power has an unusually high proportion.A feasible solution to this problem is to extend the application of renewable energy. Since China has not only get the leading role in PV manufacute, but also privileged to own abundant solar resources, the Distributed Grid-connected Photovoltaic Power system should be well developed. However, the application of DGPVPS is limited in practice due to various barriers. This paper studies obstructive factors and propose the recommendations. Data used in the analysis stem from multiple sources including statistical reports, literature, regulations, policies, and case studies. These findings not only help to understand the status quo of the DGPVPS, but also provide information to prevent potential risks of the DGPVPS in China.

Key Words : *Distributed Grid-connected Photovoltaic system, residential, China, barriers*

1. INTRODUCTION

(1) Research Background

During the winter of 2012, a large amount of Chinese cities have experienced severe air pollution. Yale Center for Environmental Law & Policy pointed out that one of the most significant contributing pollutants by far, is fine particulate matter (PM 2.5) and an important causes of the PM 2.5 is over increasing coal-fired power plants[1]. According to a report from International Energy Agency (IEA), since 2004 to 2012, the thermal power (its main resources including coal, oil and natural gas) has occupies around 78% of annual generated energy and keep increasing in China[2]. Chinese dependency for coal power is far more than the rest countries and areas, and consumes nearly as much coal as the rest of the world combined in 2011.

In order to decrease Chinese dependent on coal power, renewable energy has received increasing attentions. However, the renewable sources are not all equivalent, from the resource reserve to development cost. Solar resource is more over than 200 times larger than all the others combined[3]. Fortunately, China is privileged to own abundant solar resources-about 30% of the world's solar resource; its land surface receives an annual solar radiant energy of 1.7×1012tce (tons of standard coal equivalent), and more than two-third of the country receive an annual radiation of more than 5.02×106kJ/m2 and sunshine of more than 2000 hours annual[4]. Not only solar resource, but also China has rapidly positioned itself as one of top solar PV manufacturers and the fastest growing solar PV market in the world in the world during recent years.

PV products ought to have the distinctive advantages compared to other renewable energies in China. Unexpectedly, the development of Chinese domestic PV generation is far from satisfactory. During the past 2012, the grid-connected PV power only made up 0.1% of the gross generation which is smaller than other renewable energy power[5] (such as nuclear power, hydroelectric, wind power and biomass power).

As displayed in in Table 1, Chinese PV market is dominated by large-scale grid connected power plant or centralized grid-connected PV plants; while in the best practice countries of PV power (for instance Japan, German, and the US) the dominant PV system is distributed grid-connected PV power system

which installed in residential areas, a comparison is tabulated in Table 2 below. Obviously, the mainstream of PV generation is the distributed grid-connected PV power system. If China expects to decrease the dependency on coal power and increase the PV power, the distributed grid-connected photovoltaic power system should be expected to play more and more important role.

Based on IEA, the Grid-connected distributed PV power systems (DGPVPS) is one of the four primary applications for PV power systems, which is installed to provide power to a grid-connected customer or directly to the electricity network[6]. According to the difference in building areas and prices, the DGPVPS can be divided into three categories: industrial premises, public facility and residential area respectively. In this research, we would focus on the use in residential area.

To promote the use of DGPVPS in Chinese residential area has great significance as follows: 1) Optimize energy structure, decrease the proportion of coal power; 2) Expanding domestic market, reduce dependence on exports; 3) Improve the security of electricity supply, especially for emergency purposes; 4) Remarkable effective in energy conservation and emission reduction.

Although there are generous reseaches about Chinese PV industry,since the DGPVPS legally be available for residents in China only from the end of 2012, the study realtes to DGPVPS is hardly any.

However, as a new industry in China, the DGPVPS is immature and inexperienced. Its development is facing numerous difficulties and challenges while acquiring rapid growth.Therefore, it is necessary to provide a comprehensive analysis and evaluation to DGPVPS under the complicated and volatile environment in China.

(2) Research method

This paper focuses on the analyses for the inner and exterior conditions which hinder the development of DGPVPS' popularization in China. And then some recommendations will be proposed for the government and business sectors in the application of DGPVPS.

Qualitative method is adopted and data used in this study stem from multiple sources including literature review, statistical reports government regulations and policies. We hope these findings will provide a valuable reference to assess and evaluate the development of DGPVPS in China.

Table 1 The installed PV capacity in five sub-markets in China of 2011

	Market Sectors	Annual Ins. (MWp)	Share (%)
Stand-alone PV system	Rural Electrification	10	0.4
	Communication & Industry	5	0.2
	PV Products	5	0.2
Grid-connected PV system	BIPV & BAPV	480	19.2
	Large-scale PV	2000	80.0
Total		2500	100.0

Source: IEA, National Survey Report of PV Power Applications in China 2011

Table 2 Cumulative grid-connected PV capacity of four countries in 2010 (MW)

Country	Distributed	Centralized	Share of distributed
German	14900	2420	86.02%
Japan	3496	23.3	99.33%
USA	1727	367	82.47%
China	256	637	28.67%

Source: IEA:Survey report of selected IEA countries between 1992 and 2010

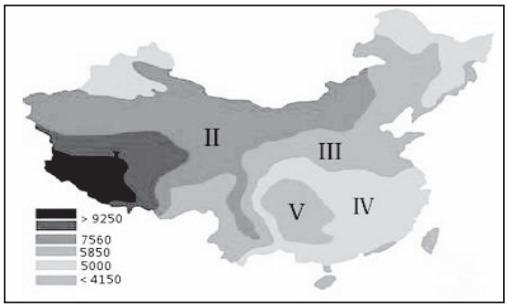


Fig.1 China's solar resource distribution pattern
Source: Chinese Weather Bure

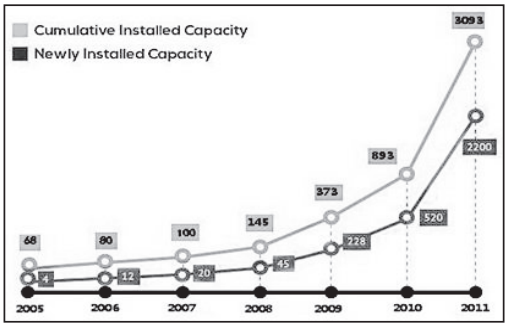


Fig.2 China cumulative and newly installed solar capacity 2005 - 2011 (GW)
Source: Energy Digital

2. The status quo of China's DGPVPS

(1) Resource situation

As previously mentioned, China is privileged to own abundant solar resource. According to Chinese Weather Bureau, areas located in different latitudes have different level of solar irradiation, as shown in Fig.1. And in the areas Ⅰ, Ⅱ and Ⅲ,because of their long annual sunshine hours and the high annual solar radiation, we can suppose the three areas are abundant in solar energy, and these lands have taken up two-thirds of China.

(2) Potential market

China's total building area of houses is about 40 billion square meters, of which the total usable area of the building roofs is about 0.316 billion square meters[5]. Suppose the 100W/m^2 installation density and 1000 hours annual operation, the total electricity output will be 31.6 TWh[7]. Besides, Chinese Renewable Energy Industries Association estimated the technical potential of PV applications in China. Two million families without power may install 400MWp of distributed systems, assuming the average scale for each family is 200 Wp. Twenty percent of rooftops and building facades in China may install 100 GWp of distributed PV systems, and on 1% of its deserts China may install 1000 GWp of distributed PV systems[5].As a result, we can expect sustained growth of Chinese domestic DGPVPS market.

(3) PV industry

a) Manufacturing capacity

At present, four of the top five solar cell producers are Chinese; three of the five module producers are in China[8]. China has become the largest producer of cell sand modules since the year of 2007.

b) Installations

As illustrated in Fig.2,the cumulative installations in China were comparatively small, but the annual growth rate of new installations was comparatively higher. Only behind German, reached the second place, with 5000 MW installed in 2012. This performance is in line with the ambitions of the Chinese government to continue developing its internal PV market, pushing for 35 GW by the year 2015 and annual new PV installations reaches 1GW during 2013 to 2015[9].

c) Price and cost

Fig.3 reveals that Chinese PV modular price is always the lowest during the leading countries, because of the comparatively inexpensive labor cost, lower energy prices, cheaper infrastructures, some access to low-cost finance and no customs duty.

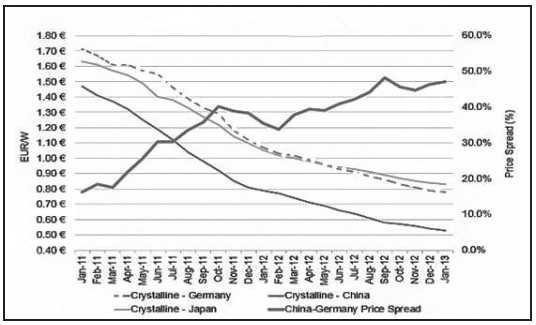


Fig.3 Module spot price by region of production, 2011-2013

(4) Legislation

a) National Planning Policy

As a crucial important document, Five-year plans (FYP) provide a blueprint for domestic economic agenda that is supposed to be executed by China's ministries and commissions and provincial leaders, with the premier at the helm [10].

As illustrated in Fig.4, from the '10th FYP' which set target to promote the productive capacity and PV demonstration project in 2001 to the '12th FYP' which set the same size of installed capacity for distributed PV generation and LSPV for the first time. We can consider that the Chinese central government amidst increasing emphasis on the distributed PV generation and grid –connected power system.

b) Support policies related to distributed generation and DGPVPS

In 2006, 'Renewable Energy Law' created Chinese national framework of promoting renewable energy development, in which State Grid companies are officially required to purchase all of the electricity generated from the renewable generators (including PV generator), and provide grid connection services. In the next year of 2007. In the same year, as 'Rationing Transaction' for the renewable energy was proposed by NDRC, in 2009 the PV installations has reached 160 MW which is 16 times compared with 2006. Along with the financial support program of 'Golden Sun program' and 'Temporary Measures for Financial Subsidies for BIPV & BAPV', the polices became no longer only focus on the large PV plants. In 2011, the State Council announced 'Decision of the State Council on Accelerating the Fostering & Development of Strategic Emerging Industries' , in which 'expanding diversified solar PV market' was put forward. Then the installation of 2011 achieved 2500 MW that made 5 times compared with the former year. Since in 2012 the installation was at its highest ever of 5000MW, the policies has become more detailed and practical.

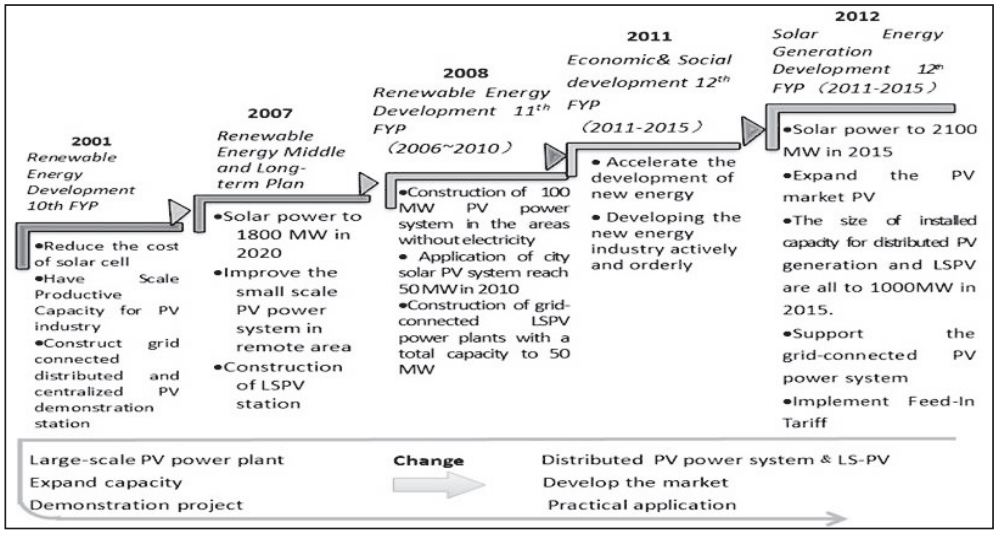


Fig.4 Milestone of national plans in the development of distributed PV generation

2. The problems of DGPVPS in China

(1) Economic barriers

a) High initial and repair costs

The initial cost of a DGPVPS comprises hard ware and installation cost. Hardware cost includes PV panels, mounting hardware, circuit breakers and inverters and cables. Such items can be very ex-pensive. In China, the average cost (for 3kW) so far is around 30.000 RMB(around US$ 4900) and the cost is covered by the consumer itself.

b) Long payback period

The payback period is an economic measure, indicating the number of years an investment takes to pay for itself. We suppose that in China, if the government subsidy for DGPVPS is 0.43RMB for 1 kWh; the initial installation cost is 30.000RMB for a 3kW DGPVPS and the daily average generating capacity is 10 kW, despite the repair costs, the payback period will be at least 10 years. Oppositely, if the consumers use the electricity from the grid, instead of made by their own DGPVPS, they do not need to wait for the 10 years. For this reason, the longer payback period baffles citizen's enthusiasm to DGPVPS.

(2) Technical barriers

First of all, a renovation and transformation for Chinese distribution management system is needed; Secondly, the PV cells material key technology also restricts the PV industry development in China; Thirdly, the limited efficiency levels for PV system; what's more, there are severe environmental concerns as advanced technologies are required to deal with the toxic substances accompany with the silicon purifying; and currently, most of China's PV cells manufacturers purchase the technology license from overseas[11].

(3) Imbalance of resource

China is privileged to own solar energy and on top of that coal resource is rich too. However, the distribution of these two resources is uneven. For instance, Shanxi province deposits about one third of China's coal total, meanwhile, it enjoys the secondary abundant solar energy as well; Gansu, Xinjiang etc. are in the same circumstances. Rich in coal resource which made the coal power in low price and low-cost. As a result, despite of abundant solar energy, the higher DGPVPS will not be attractive as coal-power, and the development of PV would be impeded in these places.

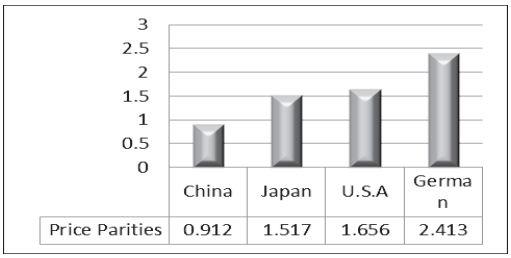
(4) Lack of financial support

There are two important and main national solar subsidy programs in China. One is 'Solar Roofs program' which is announced by the Ministry of Finance (MOF) and the Ministry of Housing and Urban–Rural Development of China (MOHURD) in 2009; and the other is 'golden sun program' which was initiated by the MOF, the Ministry of Science and Technology (MOST) and the National Energy Administration (NEA) in the same year. The former one requires that the scale of a PV project should be more than 50kWp, which is apparently too much for DGPVPS; however, the later one is for projects of 300kWp capacities and above, which are in service for a minimum of 20 years. Obviously, existing national subsidy programs rule out the DGPVPS, and

the practical financial support to it is almost empty. As a public product whose environmental and social benefit is much more than its economic benefit, it's hard to be improved without enough funds.

(5) Lower residential electricity prices

The existing Chinese pricing system is quite complicated. There are eight basic categories: residential, non-residential lighting, commercial, non-industrial, general industry, major industry, agricultural production and an eighth "other" category. And the residential electricity price is the lowest level which is totally different from DGPVPS well-developed countries, as shown in Fig.5. For the residential customers, use the electricity from state grid is more economical efficiency than DGPVPS. Thus the lower price placed barriers in the adoption of DGPVPS by residents.



	China	Japan	U.S.A	Germa n
Price Parities	0.912	1.517	1.656	2.413

Fig.5 The price parities between residential and commercial
Source: China Electric Power Research Institute , 2009

(6) Faultiness of authoritative standards

First of all, there is no authoritative standard on the concept and scope of DGPVPS or distributed PV by any government authorities. The only reference document at present is 'Recommendation for grid-connected work of distributed generation' issued by State Grid companies. What's more, the authoritative standard for the technology of DGPVPS grid-connect is insufficient. There are only two national standard documents about this work: 'Technical requirements for PV system's grid-connect (GB/T19939-2005)' and 'Characteristics of PV system's access to grid' (GB/T20046-2006).

(7) Weak policy executive ability

As early as 2006, according to 'Renewable Energy Law', the electricity generated by renewable energy (include DGPVPS) ought to be full acquired by Stat Grid, nevertheless, seven years past this rule has never be enforced.

(8) Legal and regulation constraints

Firstly of all, lake of a clear and fixed national FIT. At present, the purchasing price of DGPVPS is based on the local desulfurizing price, instead of a national FIT price or DGPVPS proprietary price. secondly, indeterminate identification of residential DGPVPS owner. It means that the behaviore of saling the electricity generated by DGPVPS is a individual's sale behavior or a commercial activity, and the tax will be different; thirdly, the problem of the real rights of roof: in most Chinese cities, residents live in high buildings and several households share the same roof. if a resident living in high building who wants to install a DGPVPS, he /she needs to get the permission by all the neighbors or it will be a tort.

(9) Lack of knowledge about DGPVPS

As a new product for Chinese, at present most of the owner of DGPVPS are PV relevant people instead of public. In order to popularize it, made the residents to fully aware of the DGPVPS is quite important.

(10) Conditioned by natural conditions

DGPVPS's energy production dependent upon the sun, as the common weaknesses of all the PV products. For instance, in summer season the generating capacity by DGPVPS occupies 30%-33% of the annual total generating capacity; in winter, the percentage declines to 10%. When weather conditions are fluctuating conditions under which PV efficiency is further decreased.

3. Recommendations

(1) Optimize the laws, regulations and detail the policies regard to DGPVPS

First of all, formulate the national uniform standards about DGPVPS, and learn from foreign experience to form a new mode for China' s DGPVPS in order to lay the foundation for DGPVPS play its reserves advantage (such as the basic concept, scope and technology standard etc.; Secondly, work out an explicit DGPVPS Feed-In Tariff (FIT) as soon as possible; thirdly, in terms of real right of public area used for DGPVPS , there should be a real explicit government regulation on it.

(2) Take advantage of manufacturing capacity, solar resource and market, deepen international cooperation.

China is mainly lack of development experience and advanced experience in PV. On the contrary, in these DGPVPS well developed countries, DGPVPS markets tend to saturation point. Chinese market and solar resource would be attractive for foreign com-

panies to cooperate on DGPVPS projects.

(3) Implement pilot programs of DGPVPS

At presrnt, the coverage of pilot program is limited to a few large-scale PV plants, instead of residential DGPVPS. In the future, DGPVPS pilot program can gradual extend from the small-size public facilities to residents.On the one hand, it can provide funds,on the other hand, it could made more public to recognize DGPVPS.

(4) Create an open competition environment

An open competition environment is conducive to promote the diversification of investors or investment style, encourage small and medium-sized companies or private capitals that are able to participate in the application of DGPVPS and to break the monopolistic situation in Chinese electricity.

(5) Raise DGPVPS awareness of public

At present, most of the DGPVPS owners are PV practitioners, common residents' awareness about it is at a relatively low level in China. DGPVPS as an environmental friendly product which can also bring the economic benefit should be accepted by public. To awaken the awareness of Chinese public: DGPVPS is not only an available way to environment protection, but also a lucrative investment.

3. Conclusions

With the rich resorce, huge potential market and booming PV industry,China's DGPVPS ought to well developed.The Chinese government's supporting efforts are increasingly greater and greater.However, as it is still in the initial stage of development,there are many weaknesses and threats internally or externally have hindered the development of DGPVPS.High initial and repair costs, long payback period, technical barriers, imbalance of resource, lack of financial support, lower residential electricity prices, faultiness of authoritative standards, weak policy executive ability, legal and regulation constraints, lack of knowledge about DGPVPS and conditioned by natural conditions,altogether limit extensive development of China's DGPVPS. This paper concluded series of strategies for DGPVPS development as well: optimize the laws, regulations and detail the policies regard to DGPVPS; take advantage of manufacturing capacity, solar resource and market, deepen international cooperation; implement pilot programs of DGPVPS; create an open competition environment; raise DGPVPS awareness of public. The further investigation of these barriersshould provide useful references to other regions that present similar situations.

Nevertheless, even though the DGPVPS is not cost-effective in short time, but it is helpful in reduce reliance on coal-power and do reduce the emissionof CO_2 and other pollutants. In the long run, thereis no choice but renewable energy, as fossil fuels are limited and will be eventually be exhausted. It is therefor enecessary for all the countries,including China,to pursue the transition from traditional energy to renewable energy as the main source of energy production.

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