

# A Variety of Household Wind-Solar Hybrid Generation Mode in Inner Mongolia of China

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**Abstract:** Inner Mongolia is located in the Mongolian plateau where it has great wind and solar resources. Herdsmen in this region are living scattered and many places they living cannot be covered by power grid. BoYang has been committed to provide renewable energy service for local residential to raise them living quality through using renewable electricity for years and contribute to the national energy conservation and emissions reduction.

This paper introduces a variety of household wind-solar hybrid system model that are promoted in Inner Mongolia. They include independent wind-solar hybrid generation system, water pump systems and heating system used in zero-carbon buildings.

**Key words:** Inner Mongolia wind-solar hybrid generation system, water pump systems, heating system

## 1. Introduction

Inner Mongolia is located in the North of China where great wind and solar resources has. Four levels of wind resource are classified in China and Inner Mongolia is covered in the best level. According to the data of China Meteorological Administration, the technical available of wind resources can reach 1460GW in Inner Mongolia. Inner Mongolia also has good solar resource. Same with wind resource classification, there are also four levels of total solar radiation in China. The total solar radiation in the best area is over 1750 kWh/m<sup>2</sup> and the second-best places are between 1400 to 1750 Wh/m<sup>2</sup> [1]. The most areas of Inner Mongolia belong to the send-best level. Generally, herdsmen in there region are living scattered and the many places they living cannot be covered by power grid.

Since the good renewable energy resource and scattered life style, the application for renewable energy started quite early in here. It has experienced

three important stages. Initially, only small wind turbines were introduced. Then small wind and solar generation systems were developed. Now is the third stage to install big wind and solar systems.

The government, organizations, scholars, enterprises and individuals have made great efforts to solve the problem of electricity using in recent 40 years. The great majority of people in the area have enjoyed the electricity benefit from these efforts. Renewable energy is full of herdsmen's daily life. It can be used in many fields, such as lighting, water pump, heating cold room storage, and communication station.

## 2. Small Wind Turbines Were Developed and Used in the Early 1980s

Due to special geography environment and rich wind resources, people in Inner Mongolia began to develop wind turbines in the 70s. After that, small wind turbines technology has gradually matured. The representative wind turbine is 50 W and 100 W (blades diameter is 1.65 and 2 metrs respectively) which has widely used in Inner Mongolia. The power of the wind turbine appears to be small, but due to the low rated wind speed designed, it had been around for a long time.

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Two designed wind turbine rated wind speed is very low, only 6 m/s. Take Xilingol, one of the typical cities in Inner Mongolia, as an example, annual average wind speed is 3.4 m/s, wind speed more than 8 m/s is about 60-100 days in a year. The most of the days in a year the wind turbines can work. The daily output is about 0.3 kWh and 0.5 kWh respectively. They were enough for lighting to alternate kerosene lamp for illumination which was one of the most dominating choices for many homes. Some of herdsman even watch black and white television using the small wind turbine.

The price for the wind turbine system was about between US150-180. The governments provided about US 30 subsidies for herdsman. Finally, over 140 thousand wind turbine systems were promoted in Inner Mongolia. Even today these kind of small wind turbines are seen fairly often in this region. The surface of wind turbine is rusted, but it works well.

### **3. The Model of Small-Powered Wind-Solar Hybrid System in 90s**

With the development of living standards for local people in the 90 s, electricity consumption increased sharply. Except using lighting or TV, other electric appliances such as refrigerator and washing machine became popular among the herdsman. The original small wind turbines are hard to meet the demand of them. Especially in August and September, the monthly average wind speed is only 3.5 m/s and 3 m/s. Wind turbines are hard to produce enough power for users in such condition, which directly causes power shortage. The life of batteries becoming shorter is another problem produced with the condition of long-lasting power shortage.

At such a circumstance, the concept of solar and wind hybrid generation system was brought forward in inner Mongolian of China. As a typical grassland area of inner Mongolian, We still taking xilingol as an example. Throughout the statistics of 15 years solar total radiation at the area, the highest radiation is between 580 MJ/m<sup>2</sup> and 680 MJ/m<sup>2</sup> from April to

August. But the radiation is reduced to only 320 MJ/m<sup>2</sup> to 210 MJ/m<sup>2</sup> between November and February [2]. The average sunshine hour is about 300 hours in summer and it is less than 190 hours during the winter. This means that the weakest time for wind is the best time for solar. This radiation feature provides great condition for using solar energy.

The cooperation project of renewable energy between China and the United States was start-up during this period. The experts and scholars focus on the research of solar and wind hybrid generation. The wind turbines, controllers, inverters and batteries from different manufactures were choose and tested at the renewable energy laboratory in the United States. Base on the local household electricity consumption at that time and the development tendency of the future, the system configuration includes 300W wind turbine, 200 W solar panels, 600 W inverter-control system, 12 V 200 Ah battery 2 pieces. The daily average output can be 1.2 kWh for wind and 0.6 kWh for solar.

The system can meet the needs of basic household electric appliances, such as lighting, TV set and small freezer. The sale price was about \$1500 at that time, but the government supported 90% of the total price subsidies for this model. Only 10% was paid by herdsman. 40 thousands sets were promoted finally by government. Before the year of 2015, the installation of wind and solar hybrid system are mostly based on this rules, the volume of the systems for some projects may be bigger than this configuration, but basically they are in same level.

### **4. The Model of High-Powered Wind-Solar Hybrid System from 2015-2017**

The model of high-powered wind-solar hybrid system that can meet the needs of all living and part of production was started in 2015 and then it has been largely provided at a short time in Inner Mongolia. Not only small power electrical appliances, such as lighting, television, freezer, can be used, the bigger power equipment such as electric rice cooker, induction

cooker, pump system can also be applied by herdsmen. There are two different systems that are introduced. One system configuration includes 1.5 kW wind turbine, 1.5 kW photovoltaic, 4 kW inverter-control system, 12 V 200Ah battery 8 pieces. The daily output is to 9 kWh. Another system configuration includes 1kW wind turbine, 1kW photovoltaic, 2 kW inverter-control system, 12 V 200 Ah battery 4 pieces. The daily output is to 6 kWh.

The government supports 85% of the total price subsidies for this model that includes 60% from city government and 25% from county government. More than 5000 sets were promoted within a year in one city of Inner Mongolia that includes about 3000 sets installed by our company. And over 8000 sets have been installed at the end of June in 2017. The autonomous region government has great interests for the success of this model. It has considered promoting it to the whole autonomous region after widely surveyed.

There are some reasons for high-powered wind-solar hybrid system installed quickly at a short time. Firstly, living standard of the herdsmen arises significantly in recent years. All kinds of electric appliances are used, such as refrigerator, electric stove, heating apparatus, washing machine and water pump. The electricity produced by the small wind and solar systems are hard to supply so many electric appliances. They really need a higher powered generation system. Secondly, the cost of systems is reducing, especially for solar panels. At present the price for solar panel is only about 60 cents per watt in China, which was reduced at 80% compared with in 2010. Thirdly, the percentage of the subsidy is big from government, which account to 85%. The herdsmen only need to pay 15%, which is about USD 800 -1000. Most family can afford this expenditure.

## **5. Suggested Views of High-Power Household Wind and Solar Generation System Installation**

Based on the almost 40 years of developmental

process of renewable energy used at household in Inner Mongolia and the installation experience of high-powered wind-solar hybrid system with for years, some views are suggested when systems were installed in the area of inner Mongolia .

### *5.1 Wind Turbine*

Wind turbines with low rated wind speed should be considered firstly when choosing wind turbine in a hybrid system. For example, the rated wind speed could not exceed 9 m/s for wind turbines with rated power below 1 kw. The benefit of using wind turbines with lower rated wind speed could increase the total power generated of the whole year.

We suggest that the capacity of the wind turbines should not be smaller than solar panel in a hybrid system in most inner Mongolia area. The system configuration we talk before is 1kw wind turbine and 1 kw solar panel or 1.5 kw wind turbine and 1.5 kw solar panel. This matching is good for system upgrade in the future, since it is only need to add the numbers of solar panel, the wind turbines and other components are unchanged. If the capacity of wind turbines is too small compare with solar panels in system, it is difficult to realize a good system using original wind turbine and other components because of the voltage problem. Then the wind turbine has to be changed.

### *5.2 Battery*

Lead-acid batteries were used in the early stages of household system. They are cheap but the life span is short and needs to add electrolyte frequently. So this kind of batteries is being phased out gradually. Currently, VRLA maintenance — free gel batteries are the mainstream product in Inner Mongolia energy storage market. The life span is over 5 years when depth of discharge is less than 25% and the price is competitive compared with other technical advanced batteries such as carbon battery or lithium battery.

As a kind of lithium battery, Lithium iron phosphate battery has small scale application in some

demonstration project in Inner Mongolia. One of the most important benefits for this battery is long cycle-life. According to data of lithium iron phosphate battery manufactory of China, its capacity retention rate is more than 80% after 5000 cycle times in 1C at room temperature. Its cycle life is ten times of lead-acid battery [3]. However the performance in low temperature for lithium iron phosphate battery has not yet to prove.

### 5.3 PV Panel

Almost all the PV panels installed in household in Inner Mongolia are using crystalline silicon PV modules because of the efficiency is quite high and longer life. The price of PV panel is reducing which makes increasing number of people using it. However the problem of efficiency of solar panel is reducing as time goes on has to be considering during the system design. The system designed should be making the panels paralleled easily in the future upgrade.

### 5.4 Controller and Inverter System

Reliability is the one of the most important factors for a controller and inverter system. According to the survey from project servicemen, over 95% fault in their maintenance work are from controller and inverter system in all record. Even some problems record forms other components such as batteries surface swell, but they were finally proved that caused by controller and inverter system problems through technical analyses. A reliable controller and inverter system can greatly reduce fault incidence rate for the system which means saving lot of maintenance cost.

When choosing the controller and inverter system, a high efficiency is also should be considered. This means a little electricity produced by wind turbines or solar could be self-consumed and more power could be used for a system. The noise of the controller and inverter system should be as small as possible since most of such equipment is installed indoor in household. It is regulated under 70 db in China but

generally under 60 db or lower is required by herdsmen in pastoral area otherwise lots of complaint would be received.

In many projects, dump load are both connect with wind turbines and solar panels. But we suggest that dump load used only for wind turbines. The intension of this is to reduce heat emitting of dump load. A switch is series in the circuit of solar panels to control on or off directly.

## 6. Wind-Solar Heating

Heating supply in pasturing area is always an intractable problem. Almost all the herdsmen are still using coal or cow dung as fuel to heat. This traditional way has been used hundreds years. With the change of life style and promotion of environmental awareness among herdsmen, heating supply with renewable energy are becoming more and more feasible. Some demonstration projects are built in pasturing area by BOYANG which caused great interest for local government and herdsmen.

One of the most significant features to realize wind-solar heating is to make great thermal insulation. In order to archive good insulation effect, the whole building includes walls, floor, roof is covered with the thickness of 250 mm to 300 mm (20 kg/m density) polystyrene as thermal insulation material. The local frozen layer is about 2.5 m deep underground in winter. So based on this circumstance, the floor insulation was made as deep as 3 meters.

Generally the doors and windows are the serious positions of heat loss in a building if without good thermal insulation. So we install a door and Windows with three layers of glass insulation, which can reduce heat loss as little as possible and save more energy.

The system includes 5 kW wind turbine and 2.2 kW solar panels as shown in Fig. 1. The average daily output power is about 26 kwh in heating season. Through heat pump drives the floor heating. We also installed a standby heat



**Fig. 1 BOYANG wind-Solar heating demonstration project in pasturing area.**

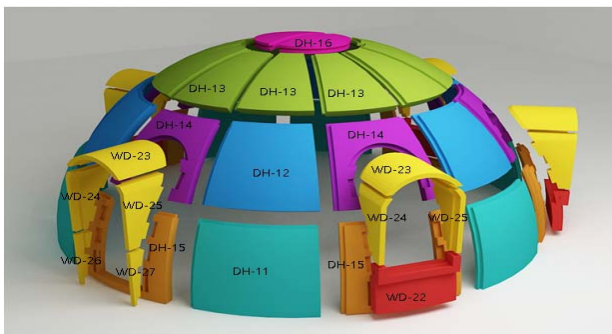
source, in case continuous no wind weather happened in winter.

Table 1 shows the record of temperature at inside and outside room form November to December of local temperature at different time. The outside temperature change from -17°C to 1°C, but inside is keep stable in 17°C or 16°C. This means the thermal insulation of room is great.

Another type of wind-Solar heating is showed in Fig. 2. The room looks like with traditional Mongolia Yurt. The whole building is assembled to be an arched and frameless construction through different types of panel

**Table 1 The temperature of inside and outside of room [4].**

Date	Time	Inside (°C)	Outside (°C)
2016.11.20	8:30	15	-15
2016.11.20	14:30	16	-8
2016.11.21	9:00	16	-14
2016.11.21	14:30	17	-4
2016.11.21	17:30	15	-15
2016.11.22	8:30	16	-17
2016.11.22	14:30	17	1
2016.11.23	8:30	17	-12
2016.11.23	14:30	17	5
2016.11.23	17:30	17	-11
2016.11.24	8:30	17	-12
2016.11.24	14:30	17	13
2016.11.25	8:30	16	-11
2016.11.25	14:30	17	8
2016.11.26	8:30	16	-10
2016.11.27	8:30	16	-15
2016.11.27	14:30	17	8
2016.11.28	8:30	15	-9
2016.11.28	18:30	17	-5
2016.11.29	8:30	16	-7
2016.11.29	18:00	16	-6
2016.11.30	8:30	17	-9
2016.11.30	14:30	17	15
2016.12.1	8:00	17	-11
2016.12.1	18:00	17	-5
2016.12.2	18:00	17	-3
2016.12.3	8:30	17	-2
2016.12.4	8:30	17	-11
2016.12.4	19:00	16	-8
2016.12.5	8:30	16	-9
2016.12.5	14:30	17	-4
2016.12.5	17:30	16	-13
2016.12.6	8:30	16	-6
2016.12.6	17:30	16	-7
2016.12.7	8:30	16	-11
2016.12.7	18:00	16	-7
2016.12.8	9:00	17	-7
2016.12.8	14:30	17	-6
2016.12.8	18:00	16	-9
2016.12.9	8:30	16	-8
2016.12.9	14:30	17	-5
2016.12.9	17:30	17	-8
2016.12.10	8:30	17	-9
2016.12.10	12:30	17	-7
2016.12.11	8:30	17	-4
2016.12.11	14:30	16	2
2016.12.12	8:30	16	-8
2016.12.12	14:30	17	3
2016.12.12	17:00	17	-10
2016.12.13	14:30	17	2
2016.12.13	17:00	17	-8
2016.12.15	8:30	16	-10
2016.12.15	14:30	16	-9
2016.12.16	14:30	16	0



**Fig. 2** Mongolia Yurt type wind-Solar heating demonstration project.

with the thickness of 180 mm. The material of such panel is using the high density ( $40 \text{ kg/m}^3$ ) foam polystyrene. Generally, the normal thermal material could be only  $20 \text{ kg/m}^3$  or  $30 \text{ kg/m}^3$ . The benefits of using such material are improving the building strength and having higher insulation efficiency. In addition, the arched structure has advantages of wind resistance and shock-proof.

The room is about  $50 \text{ m}^2$ . The system includes 1.5 kW wind turbines and 7.5 kW solar panels 200 Ah battery 16 pieces. Nine pieces of electric heating floors are in parallel as heating source in room which is made up of nature flax. Each electric heating floor is 135 W with  $120 \text{ cm} \times 60 \text{ cm} \times 10 \text{ T}$ . The average daily electricity consumption is about 24 kWh. The surface temperature of the floor can be controlled between  $20\text{--}50^\circ\text{C}$ . This type of building and the way of heating has been growing attention among the herdsmen. In addition it was also greatly prompted into the tourism in grassland area especially in winter.

## 7. Solar-Wind Water Pump System

The main purpose of using solar-wind water pump system is to solve the problem of water drinking for livestock such as cattle and sheep. Generally, there are hundreds of sheep and cattle for one herdsmen family. Water drinking is one of the biggest problem in pastoral areas due to the climate featuring of dry summers and cold winters. Before using renewable energy, the diesel generator is the only chose for herdsmen. But the higher cost for diesel makes increasing number of herdsmen to change to use renewable energy. Solar-wind water pump system can be basically to realize water supply for the whole year, especially when wind and snow weather for days cause bad lighting in winter or no wind reason in summery.

Fig. 3 shows a 96 V DC water pump system. The configuration includes 1.5 kW wind turbine (blades diameter 3.3 m, rated speed 10 m/s) and 2.5 kW solar panel and 12 V 200 Ah battery 8 pieces. The average daily power is over 15 kWh.

Generally the deep of well in pastoral area is between 20 to 100 meters. In order to satisfy the herdsmen's water using demands, the system designed that can pump 10 tons of water per day and 2.5 tons per hour. The controller system and batteries are installed in a small room, the whole system are designed working between  $-30\text{--}+40^\circ\text{C}$ . Water level monitoring function was set in the water pump controller that can realize automatic water pump. When water level lower the value set up, pump protective device will start to prevent water pump overload and burn out. At the same time, there is monitor device in the water tank. When water if full in the tank, the pump will stop work automatically.



**Fig. 3** Typical solar-wind water pump system in pastoral area.

There are hundreds of thousands families in pastoral area of Inner Mongolia, almost each family in pastoral has a well, some have installed wind solar pump system, most are still using diesel generator to pump water, so the potential for this market is quiet big.

## 8. Solar-wind Cold Storage Room

Cold storage room are more widely used in many fields such as medical health, blood banks, poultry slaughter and processing of aquaculture, agriculture products, dairy, beverage storage. Currently cold storage room are mostly used in the city where has utility grid in Inner Mongolia. Freezer is the only choice for the herdsmen in the area where the grid cannot be covered, but it cannot meet the daily needs for some big families to store dairy or meet. We introduced the wind-solar powered cold storage room in Inner Mongolia in this year as a demonstration project.

It was about 16 m<sup>3</sup>. Generally the storage temperature is set at -18°C, the compressor is shut down. When the temperature increased to -14°C, the compressor is start and work. The daily electricity consumption is 12 kwh. The system configuration includes 1.5 kW wind turbine, 4 kW solar panel, 12 V 200 Ah battery 8 pieces and 15 horsepower diesel generator as a backup.

Currently, our government is effort to develop grid construction of pastoral areas. If user's area is covered by grid someday, the power to this wind-solar cold storage room can also from grid when renewable energy is not enough. The costs of the exchange battery are saved. That means the application for the cold storage room is much more flexible.

## 9. Conclusion

As one of the best renewable resource area of China, the application of renewable energy in Inner Mongolia

is quite widely and early, especially for small wind turbines and solar energy. The local government has been supporting renewable energy application. Due to without grid cover in many pasturing areas, the way of supporting from the inner Mongolian local government is different with other areas of China. It is mainly through initial investment subsidies which was also a majority supporting way in the last 15 years in China. But with the continuous expansion of the scale of renewable energy, the way of initial investment subsidies is generally changed into Feed-in Tariff in most places of China, especially for large on-grid PV power station and wind farm and many distrusted solar power projects.

Through the great efforts from government, enterprises and related research institutions, almost all the residents in pasturing areas where has not covered by grid can use enough electricity in daily life through wind and solar hybrid system. The water pump system, solar-wind Cold storage room and Wind-Solar heating are promoting in these areas. Other wind-solar power applications include communication station and electric monitoring on roads. Even they are not used for household, but they are also have widely application in Inner Mongolia area.

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