Research on the Utilization of Small Stand-alone Wind Power Generation in Yunnan Mountainous Areas

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ABSTRACT: In view of the problems that extending the traditional grid to supply power may be uneconomi-cal and it is unsuitable for building large-scale wind farm because of the less wind-rich region in Yunnan mountainous areas, a green energy supply scheme of applying small stand-alone wind power generation in Yunnan mountainous area is proposed. This paper introduces the typical structure, advantages and application of small stand-alone wind power generation system. By researching the spatial and temporal characteristics of mountain wind resource in Yunnan, the necessity and feasibility of small stand-alone wind power generation system applied in Yunnan mountainous area are demonstrated. Finally, an example describes the main steps of small stand-alone wind power system application design and evaluates benefits on the investment costs, energy saving and environmental protection. The results verifies the economic, environmental and social benefits of building small wind power system in Yunnan mountainous areas, which provides a basis and reference for the utilization of small stand-alone wind power generation system in the mountainous areas.

1 INSTRUCTION

The small wind turbine start wind speed is low and generally will generate electricity when the wind speed is more than 3m/s. The small wind power generation has the advantages of near the load center, realizing the power elimination on the spot, saving investment and reducing transmission loss and so on. Many countries have recognized and formulated relevant policies and plans for the development of small wind power [1-3], as well as our country that has brought "Twelfth Five Year Plan for the development of renewable energy industry"[4]. The plan points out that "to encourage building small wind power project on the local conditions and access to nearby grid, so that the local wind energy resources will be effective used". Along with the new energy "send electricity to the countryside", "bright project" and subsidies policy and international cooperation projects carried, Small wind power generation has been widely used in Xinjiang, Inner Mongolia pastoral and other remote rural areas.

Yunnan Province, with its more mountains, complex terrains, and rugged narrow roads, it is difficult to extend transmission lines to each household. However, the wind resource is abundant in this province, and it constitutes a complementary system with the local hydropower in the season. [5] So it is an effective solution to use the small wind power for the areas where is difficult to cover grid but with abundant wind resource.

This paper introduces the typical structure, advantages and application of small stand-alone wind power generation system. Based on researching the spatial and temporal characteristics of mountain wind resource in Yunnan, the necessity and feasibility of small stand-alone wind power generation system applied in Yunnan mountainous area is demonstrated. Finally, an example evaluates economic, environmental and social benefits of building small wind power system in Yunnan mountainous areas.

2 SMALL STAND-ALONE WINGD POWER GENERATION

Small wind turbine generally refers to a unit capacity of 10 kilowatts or less, its start wind speed is between 3~4 m/s. [6] The typical structure of small stand-alone wind power generation systems is shown in Figure 1. The principle is that the wind turbine rotates by the wind force and drives the generator to generate electricity. Then the alternating current that the wind generator sends out, charges the batteries after rectified by the controller, or supplies the AC load (single phase or three-phase) through the inverter. When wind power cannot meet the load because of its randomness and volatility, the batteries will charge or discharge to suppress system short-time energy fluctuations and smooth the instantaneous energy, ensuring the reliability of power supply. In addition, the battery can also directly supply DC load, meeting the electricity demand of varieties of loads.

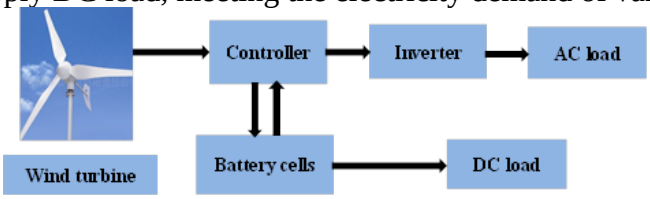

Figure1 typical structure of small stand-alone wind power generation systems

Small wind power generation is near the load center, implementing of local power and without the need for long distance transmission [7], which is an effective supplement for the large-scale wind farm. For the remote mountainous area where the rich of wind resource and short of power supply by the grid, it is suitable for application of small wind power generator. Many places in Yunnan belong to such areas.

3 WIND RESOURCES OF YUNNAN MOUNTAINOUS

3.1 *Distribution of Wind Resources*

Yunnan is a mountainous province where the mountainous area is accounted for 96% of the total area. In general, the province's wind resources is not as abundant as "Three North" and coastal areas in our country, but wind resources is also richer in some narrow tube area, tuyere or on the top of a high mountains. According to the "Yunnan Agricultural Climate Resources and Regionalization ", the map of Yunnan wind energy resources and regionalization is shown in Figure 2.

Figure2 Yunnan wind resources and regionalization

The development zone in Yunnan Wind, such as Lijiang, Tuahua mountain, Malone, Hong he and so on, The average effective wind power density is greater than 200 W/m2 and The annual utilizable hour of wind is more than 5000 hours at the10 meters high in the regional meteorological

station, which belongs to "wind energy rich region". The wind energy of many mountains in the East of Yunling Ailao Mountain has been close to the level of Chinese largest wind zone, where is not only suitable for medium wind turbine, but also for large wind turbine in some special position. Parts of Yunnan, such as Dayao, Xuanwei and Xiangyun, the annual average wind speed is more than 3.5 m/s. Areas in eastern of Ailao Mountain, such as Jinning, South Road, Fuyuan and Shuangbai, the wind speed reaches 3.5 to 4.4 m/s, is suitable for small scale wind turbines. Therefore, Yunnan mountainous area is considered as the wind-rich area in our country inland region, where has significant value of development and utilization.

3.2 *Characteristics of Wind Resource*

Different from "Three North" and coastal areas in China, wind resources in Yunnan showing different characteristics due to the particularity of its geographical environment. The main characteristics are the following points:

(1) The characteristic of regional distribution is obvious [8]. The wind resource of eastern Yunnan is richer than that of the west part. The wind speed of winter and spring in the eastern and northern Yunnan is larger, longer and relatively more stable.

(2)Seasonal characteristic is obvious. The wind resource distribution characteristic of Yunnan is that wind speed is larger in the dry-season and is smaller in the monsoon. The wind speed and effective wind energy density (more than 100 W/m2) are large in the dry-season from December to May next year. This feature of Yunnan wind power makes the wind power and the local hydropower constitute a complementary system on the season.

(3)The wind resource is scattered on space. The wind resource in Yunnan mountainous area is abundant, but is not focus on the spatial distribution. The widespread-rich wind resource region contiguous is too less to be suitable for the construction of large wind farm, but it is rather to develop small scale wind power.

(4)Yunnan has a moderate climate. As Yunnan is far away from the sea, it is not affected by the typhoon; and because Yunnan is located in low latitude plateau special geographical position, the temperature difference between winter and summer is small. These meteorological conditions are favorable for the installation and safety of the wind turbine.

According the above analysis about the wind energy resources of Yunnan, we know that the wind resources are mainly distributed in the mountains. The wind energy is abundant and has significant value of development especially in winter and spring. At the same time, because more than 80 percent of the Yunnan hydropower stations are runoff hydropower plants, which generate less power in the dry-season while generate more power in Winter and Spring. This is significant for meeting the demand of life and production of local residents.

4 CASE ANALYSIS

4.1 *Case Introduction*

Project profile

Take a mountainous village eastern Ailao mountain for example. The village has been supply power through the “send electricity to the countryside” project. However, as the village is at the end of the power grid, the power quality is poor, which couldn’t meet the electric load of residents. According to investigation, the climate of village is mild, and the characteristic of wind resource is obvious on season. The average monthly wind speed of the village is shown in Figure 3.

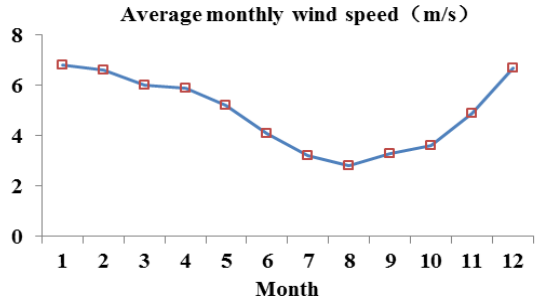

Figure3 Average monthly wind speed

It can be seen from the figure, the wind resource is mostly concentrated in winter and spring, and the average monthly wind speed is up to 6.2 m /s. While in summer and autumn, the average monthly wind speed is 3.6 m/s. Therefore the wind resource in this region is not satisfied with the requirements of building large wind farm, but it is suitable for developing small scale wind turbine. Moreover, the seasonal characteristic of the wind energy is complementary to the distribution of water resources on season.

Load Calculation

In the dry-season, which is in the two seasons of winter and spring, the village uses wind power to mainly meet the electricity of local life and production. In the monsoon, the village uses wind power to alleviate the pressure of grid power supply and small hydropower.

The power load of the village is mainly household appliances and irrigation. The home appliances including lamps, televisions, refrigerators and washing machines and its electricity situation [9] is shown in Table 1. There are 50 households in the village, with average 6 peoples and 10 acres of farmland per household.

Table 1 Electricity consumption of household appliances

Name	Power(W)	Number per household	Average working hours per day	Daily electricity consumption(kWh)
Light	10	5	6	0.3
TV	150	1	4	0.6
Refrigerator	110	1	8	0.88
Washing Machine	500	1	0.3	0.15
Total	770			1.93

Household consumption

Power load in two seasons of winter and spring:

$1.93 \times 30 \times 6 \times 50 = 17370$ kWh

Electricity for agricultural production

Assume that one acre per household is irrigated 8 times in winter and spring one year. The power consumption is 15 kWh each acre every time. Then the power load of agricultural production per household is:

$10 \times 8 \times 15 \times 50 = 60000$ kWh

The annual electricity consumption:

$17370 + 60000 = 773670$ kWh

It is can be learned according to the above calculation that the average power consumption of the village in two seasons is about 17.66kW.

Wind turbine selection

According to the local average wind speed and the average power consumption, we choose the small scale wind turbine of 2 kW. The parameters of the 2kW wind generator provided by Qingdao are shown in Table 2. In order to meet the electricity demand of local residents in the dry season (in

winter and spring season), and maintain a certain margin, we choose 32 wind turbines. Each wind turbine is equipped with 6 batteries at 200AH, 12V and one inverter at 3000W.

Wind turbine siting

The small stand-alone wind power system is located on the top of the mountain with an altitude of 1300 m, where is not far away from the village. The wind speed over there is stable and large. And the noise of the wind turbines will not affect the normal life of the residents.

Table2 the Parameters of wind generator

Models	FZY-2KW	Generator Type	Brushless 3-phase
Rated Power(kW）	2	Blade Material	Nylon Reinforced
Rated Speed (r/min)	320	Rotor Diameter (m)	3.7
Start-up Wind Speed(m/s)	3	Number of Blades	3
Rated Wind Speed (m/s)	9	Height of tower(m)	6
Working Wind Speed(m/s)	3-25	Tower-top Weight (kg)	80
Survival Max. wind (m/s)	40	Product Life	15
Battery Capacity Recommended：1200AH 6 blocks			

4.2 *Analysis of Result*

Evaluation of economic benefit

The costs of main equipment used in a small stand-alone wind power generation system are shown in table 3. Other investment costs including installation, transportation, artificial and maintenance accounted for 30% of total investment. The price of local electricity (including taxes) is 0.792 Yuan /kWh before the system construction. Calculated under the assumption of product Life about wind turbine is 15 years, economic benefits comparison before and after the completion of the small stand-alone wind power system are shown in table 4.

Table 3 Cost of main equipment in small wind power system

Equipment	Wind turbines	Battery	Inverter
Model	FZY-2KW	UD-200-12	I-P-TPI 3000W
Unit cost (RMB)	8200	1083	3450
Number	32	192	32
Total cost(RMB)	262400	207936	110400

Table 4 Economic benefits comparison before and after constructing the small stand-alone wind power system

Cost types	Before	After
Total investment cost (ten thousand RMB)	91.92	82.96
Investment cost /household /year (RMB)	1226	1106

From table 4, we can see that after installation of small wind power generation system, both total cost and household's cost every year are less than the cost of purchasing electricity from the power grid. It embodies that the construction of small stand-alone wind power generation systems has a good economic benefit in Yunnan mountainous area.

Evaluation of environmental benefit

Wind energy is a kind of clean and renewable energy. Wind power generation firstly turns wind energy into mechanical energy, and then turns the mechanical energy into electricity. Therefore, there is no mineral consumption or any harmful gas emissions in the process of wind power generation. However, traditional power generation using fossil fuel will discharge CO2, SO2 and various nitrides during the power generation process. In this paper, we mainly compare emissions (CO2, SO2 and NOx) before and after the building of small wind power generation system. Emissions and fine standard of CO2, SO2 and NOx in traditional coal-fired power generation is shown in table 5. Table 6 shows the comparison of environmental benefit before and after building the small stand-alone wind power system.

Table5 the Emissions and fine standard of CO_2, SO_2 and NO_x in traditional coal-fired power

Emission types	CO_2	SO_2	NO_x
Emissions(g/kWh)	852.79	0.197	0.4963
Fine standard （￥/kg）	0.00775	0.775	3.0771

Table6 the environmental benefit before and after building small stand-alone wind power system.

Emission types	**Total emissions(kg)**		**Environmental punishment cost(￥)**	
	Coal-fired power	Small wind power	Coal-fired power	Small wind power
CO_2	9896670.6	0	76699.2	0
SO_2	2286.2	0	1771.8	0
NO_x	5759.6	0	17722.8	0

It can be seen from the table 6, after the completion of small stand-alone wind power system, there is a substantial reduce of pollution emissions and less environment pressure; Saving gas pollution treatment costs can reduce the cost of residential electricity. Obviously, the development of small wind power has a great deal of environmental value.

Evaluation of social benefits

The construction of small wind power generation system in this region can not only satisfy local residents' electricity demand during dry seasons that hydropower output is insufficient, but also ease the pressure of power supply. Building small wind power generation system can solve the problem of power supply for residents and also bring modernization to the farmers in the remote mountain.

5 CONCLUSION

Small stand-alone wind power system with its unique advantages has become a powerful supplement to the power grid in China; small wind power will play an important and positive role to promote and encourage the dispersed and distributed renewable energy projects. By researching the spatial and temporal characteristics of mountain wind resource in Yunnan, the necessity and feasibility of small stand-alone wind power generation system applied in Yunnan mountainous area are demonstrated. Finally, an example evaluates the economic, environmental and social benefits of the small wind power through the comparative analysis of the investment costs, gas emissions and environmental costs with the grid. Applying small wind power in the remote mountainous areas where has abundant wind resources, can not only get farmers richer, but also ease the trend of conventional energy depletion and contain the rapidly deterioration of environment, which has important economic, environmental and social value.

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