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Multi-turbine wind-solar hybrid system

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ABSTRACT

In the paper, a new type of wind-solar hybrid system was proposed, in which multiple small wind turbines took the place of a bigger one. The electricity performance of the multi-turbine wind-solar hybrid system was studied in comparison with the traditional system. Two types of wind-solar hybrid system with the same capacity were set up in Tianjin, and the power output of the two systems were measured and simulated by the TRNSYS software. The results showed that, at low wind speed, the multi-turbine wind-solar hybrid system has more power production than the reference system. The simulated results agreed well with the experiment results. Then, the electricity performance of the multi-turbine wind-solar hybrid system was studied under various climates in China by the TRNSYS. The simulation results showed that the power output of the wind turbines in multi-turbine wind-solar hybrid system increases by 18.69%, 31.24% and 53.79%, when used in Shenyang, shanghai and Guangzhou, respectively, compared with the reference system.

1. Introduction

Wind energy has been widely used in many fields, such as street lighting, water pumping [1,2] and stand-alone or grid-connected generating power system [3] etc. However, a drawback of the wind energy is that the output power depends largely on the unpredictable weather or climatic changes. The power generated by the wind turbine does not meet the demand, and neither does the solar energy system.

There is the complementarity between the solar energy and the wind energy. For example, in China, high solar irradiation and poor wind energy emerge in summer, whilst a relatively abundant wind energy and poor solar irradiation occur in winter [4]. Meanwhile, there is high solar irradiation and relatively low wind energy in the daytime, while there is high wind energy but little solar irradiation at night. In the wind-solar hybrid system, one source of energy can offset the shortfall of the other, which can greatly meet the load demand. Besides, wind-solar hybrid system can improve the generating capacity factor which leads to fewer batteries to overcome the unpredictable electric demand.

A wind-solar hybrid system was usually comprised of wind turbine, photovoltaic (PV) modules, controller, inverter and batteries. The major advantage of the hybrid system is that its reliability is enhanced compared with the simple wind energy system or solar energy system [5,6]. The research on wind-solar hybrid system mainly focuses on the modeling for system configuration, optimal matching between wind turbine and PV modules [7–11], as well as simulation of power output [12–15]. Nema [16] analyzed the future development of renewable systems and the acceptance by users. Celik [5] presented the techno-economic analysis of wind-solar system using different sizing method.

In China, only 1% of areas are suitable for the large-scale wind turbine, 10% for turbines lower than 100 kW, and more than 40% for turbines lower than 10 kW [17]. So there is a large market potential for small wind turbines to be installed on the yard, farms and rural area. The multi-turbine wind power system [18–20], which consists of more than one small wind turbine on the same tower, has greater advantages compared with the big turbine at the same power. For example, when one of the turbines is damaged, it has little effect on the system. Peter Jamieson [21] compared the cost and O&M of 20 MW wind power system with a 20 MW conventional wind turbine, 4 × 5 MW wind turbines and 45 × 444 KW wind turbines. The result shown that the 45 × 444 KW system can reduce cost to ~89% of four 5 MW turbines or ~70% of a 20 MW single turbine system. The small wind turbine may start at lower wind speed than the big one, so the multi-turbine can harvest more wind energy, which makes the hybrid system more reliable.

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In this paper, a multi-turbine wind-solar system (namely the new hybrid system) is proposed to get more smoother power. The performance of the new system and the reference system was studied using the TRNSYS software, which will help to design the new hybrid system according to the actual demand and natural conditions.

2. Experiment

2.1. Components of the hybrid system

The new system and the reference system were set up in the rural areas in Tianjin. The components of the two systems are listed in Table 1. All the equipment of the two systems are the same, except for the wind turbines. The swept area of the 50 W wind turbine and the 400 W is 0.635 m^2 and 2.009 m^2, respectively.

The structure of the multi-turbine wind power system is shown in Fig. 1. The system is composed of eight 50 W wind turbines, tower, swivel bearing, tail vane and dragline. The eight 50 W wind turbines share a tower and a tail vane. The tower is consisted of two sections, the lower section and the upper section. The eight wind turbines and tail vane are installed on the upper section and the lower section is fixed by the dragline. Both sections are connected by swivel bearing, and the whole upper part can round freely against the wind.

A very important parameter for designing the hybrid system is the nominal voltage of the components, including the PV modules, batteries, wind turbines, controller and inverter. In the paper, the nominal voltage of the two systems is set as 24 V. The nominal voltage of the eight wind turbines is 12 V, so they are divided into four groups, each group consists of two turbines connected in series, and the four groups are connected in parallel.

2.2. Test

The data acquisition system is shown in Fig. 2. The solar irradiation was measured by a pyranometer (TBQ-DL\Jinzhou solar Meteorological Science and Technology Co., Ltd.). Wind speed was measured by an anemometer (FC-2B\Beijing FC Wind Control Co., Ltd.) installed on the tower. The voltage and current of the PV modules, turbines and batteries were all measured and recorded by the computer. The test was operated from April 3, 2013 to April 13, 2013.

3. TRNSYS simulation

TRNSYS is a transient system simulation program with modular structure. It recognizes system description language in which the user specifies the components that constitute the system and the manner in which they are connected. The TRNSYS library includes many components commonly found in thermal and electrical energy systems, as well as component routines to handle input of weather data or other time-dependent forcing functions and output of simulation results. The modular nature of TRNSYS gives the program tremendous flexibility, and facilitates the addition into the program of mathematical models not included in the standard TRNSYS library. TRNSYS is well suited to detailed analysis of any system whose behavior is dependent on the time. It is convenient for us to simulate the wind-solar hybrid system [22].

Table 1
Components of the two hybrid systems.

Component	New system	Referred system	Manufacturer
PV module	Top-140(12) × 2	Top-140(12) × 2	Tianjin Lingwei Photovoltaic Science and Technology Ltd.
Wind turbine	Z-50W × 8		Shenzhen Lvdiankang Technology Co., Ltd.
		EW-400 × 1	Yangzhou Shenzhou Wind Generator Co., Ltd.
Battery	NP100-12 × 4	NP100-12 × 4	Yangzhou Yongda Power Co.
Inverter	WI10-24	WI10-24	Hefei Weimin Power Co.
Controller	WWS06-24-N01	WWS06-24-N01	Hefei Weimin Power Co.

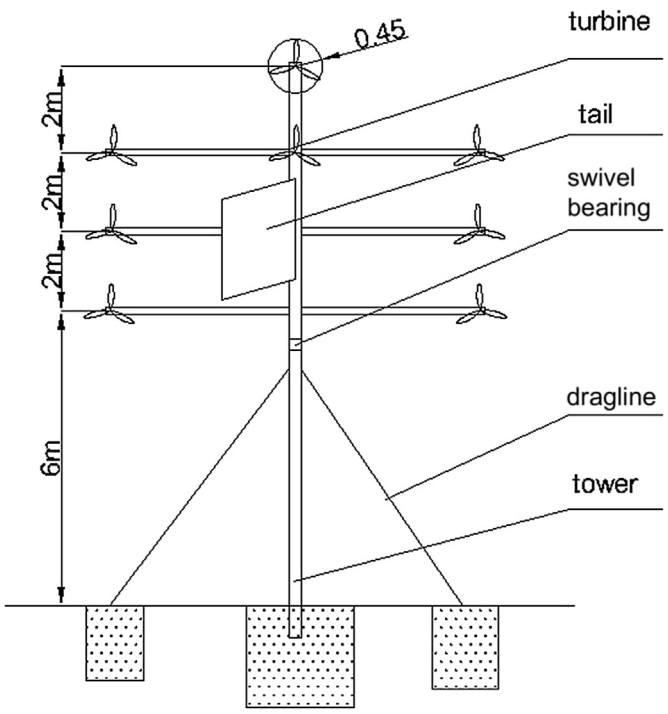

Fig. 1. Structure of the multi-turbine wind power system.

3.1. Model of the system

The simulation models of the two hybrid systems are shown in Fig. 3, which are used to forecast the electricity output. All the components of the systems are from the TRNSYS library. The meteorological parameters used in the simulation are measured on the experimental site. The anemometer in both systems is installed at the height of 10 m on the tower, and the irradiation data are from

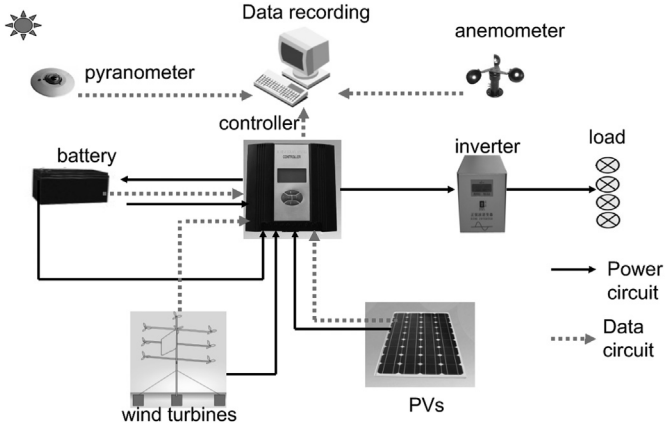

Fig. 2. Sketch map of the data acquisition system.