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Optimal Configuration of a Wind/PV/Battery Hybrid Energy System Using HOMER Software

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A hybrid energy system was put forward according to the renewable resources in a certain area and in order to obtain the optimal configuration of the system, HOMER software was employed to realize the optimization and to implement the economic analysis. The optimal system is consisted of 80 kW PV20 sets of 10 kW wind turbine, 300 kW batteries and 30 kW inventor, and the total investment is $ 709,471, when the capacity shortage is 0 %. The capacity shortage effect was considered and the results showed that the capacity of the battery changed most when the reality of the system declined, in addition the economic performance improved significantly with the Cost Over Electricity (COE) varying from 1.001 $/kWh in 0 % capacity shortage to 0.619 $/kWh in 5 % capacity shortage.

1. Introduction

As a new form of energy use，distributed energy can contribute to the utilization of renewable energy and clean energy, improve the efficiency of energy use, and also make up some defects of the large power grid, such as reducing the cost of long-distance transmission, realizing the divisional flexible power supply (Li, 2013). PV (Photovoltaic) system or wind power system has been studied widely to alleviate the crisis of the fossil energy (Xue, 2014), however, those systems were usually dependent (Sinha and Chandel, 2015), and heavily affected by weather condition. As a result, the capacity of the independent system can be oversized or undersized. Hybrid energy system can overcome the above defects and improve power supply reliability (Sen and Bhattacharyya, 2014).

In recent years, investigation of off-grid hybrid systems based on renewable sources has attracted significant attention. One of the most important aspects of the hybrid systems which leads to having a cost-effective system is optimal sizing. In order to achieve the optimal configuration of hybrid energy system, we need modelling, system design, analysis and optimization (Guo et al., 2014). Now we can use many kinds of software and technology to carry out economic and technical analysis of hybrid energy system (Wu et al., 2015), to make full use of renewable resources and minimize economic investment. Maleki and Askarzadeh (2014) optimized the configuration of a hybrid energy system including photovoltaic power, wind power, diesel engine and battery at a remote village in Iran using harmony search algorithm.

Zhou et al. (2014) carried out statistical analysis of the existing load of the power supply system and natural resources and proposed a wind/diesel/storage/biomass micro-grid system for a rural community. They optimized the system design using the improved non-dominated sorting genetic algorithm with the double optimal objectives: the minimum net present cost of the life cycle of 20 y and minimum environmental effect.

In order to efficiently and economically use the hybrid systems, an appropriate sizing methodology is necessary. If the hybrid systems are optimally designed, they can be cost-effective and reliable. Hybrid Optimization Model for Electric Renewables (HOMER) is a kind of user-friendly software developed by National Renewable Energy Laboratory (NREL). HOMER is currently the most widely used hybrid energy system planning software. There have been more than 80,000 people from 193 countries downloaded this software (HOMER, 2017). HOMER can optimize two forms of power system: independent energy system and the grid, and also can provide a powerful graphical display function which is convenient for users to compare various parameters (Sinha and

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Chandel, 2014). However, few research paper based on HOMER studied Chinese area and considered the electricity shortage effect.
According to the natural resources and power load of a certain community, this paper proposes a hybrid energy system, and then optimizes its configuration using HOMER, analyses its economy, with the effect of different electricity shortage rate on the system configuration being taken into consideration.

2. Location and resources

In this paper, the longitude and latitude of the community is 119.9E, 30.5N. This region belongs to the subtropical monsoon zone with four distinct seasons and abundant rainfall. The annual average temperature is 17.8 °C and the annual sunshine duration is 1,765 h. All those weather data were obtained from NASA website (NASA, 2017).

2.1 Solar resources

The output of the photovoltaic cells and the solar resources of this area are closely related. Figure 1 shows the solar radiation resources in the area. The solar radiation of this area reaching the strongest in June and July, and is the weakest in winter. The annual average irradiance is 0.2 kW/m^2 and the strongest radiation is 1.02 kW/ m^2.

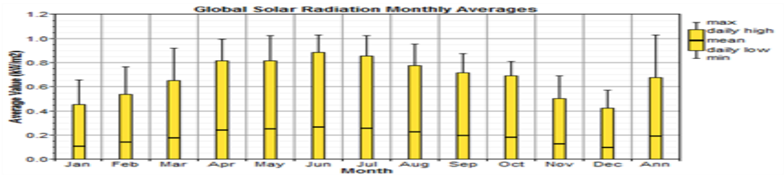

Figure 1: Monthly average solar radiation

The output of photovoltaic cells is not only related to the intensity of the radiation, but also depends on the weather condition at that time, mainly clear sky index. The red line in Figure 2 shows the region's clear sky index profile.

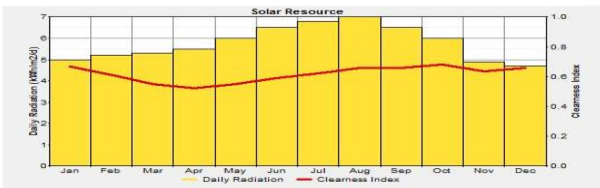

Figure 2: Monthly average clearness index

2.2 Wind resource

The output of the wind turbine is mainly dependent on the region's wind resources. Figure 3 shows the region's wind resources. The average annual wind speed of this region is 3 m/s, and the maximum wind speed is 10 m/s.
The solar resource is strong in spring and summer, and the wind resource is strong in autumn and winter, so forming a hybrid energy system of photovoltaic and wind power can fully utilize the resources characteristics of this region.

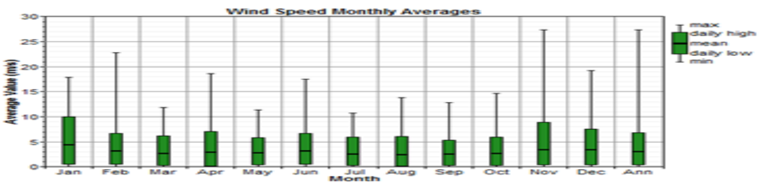

Figure 3: Monthly average wind speed

3. System description

3.1 System configuration

The system adopted in this paper is consists of photovoltaic cells, wind turbine generators, batteries, inverters and power load. The system structure is shown in Figure 4.

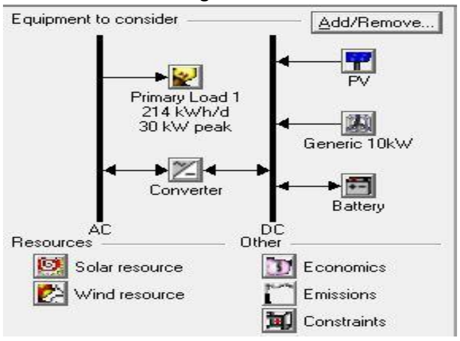

Figure 4: System configuration

3.2 Electricity load

The 8,760-hours electricity load data of this area are shown in Figure 5. The annual average load is 6 kW and the peak load is 29.5 kW.

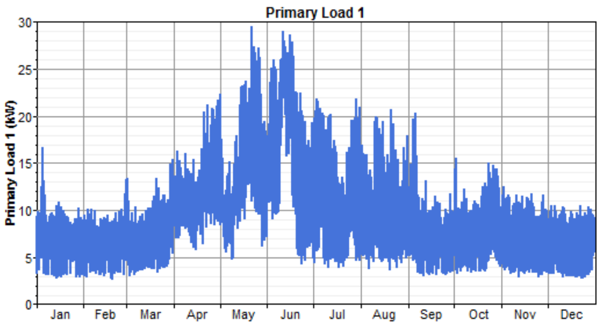

Figure 5: Electricity load

3.3 Input and output parameters

Table 1 shows the parameters of the devices.

Table1: Parameters of the devices

Device	Type	Initial cost($/kW)	O&M cost ($/kW)	Replacement cost ($/kW)	Life cycle
PV	SPV	3,500	10	3,000	25a
Wind turbine	Generic 10 kW	4,000	20	3,200	25a
Battery	SHP	200	0	200	9,645 kWh
Inverter	Surrette 6CS25P	350	0	350	15a

4. Results and discussion

According to the weather data and load data given above, this paper optimizes the hybrid energy system by using HOMER software considering the effect of different electricity shortage rate on the system.

4.1 0 % electricity shortages

Table 2: Configuration of the hybrid energy system when the electricity shortage is 0 %

Composition	Capacity/kW
PV	80
Wind turbine	200
Battery	300
Inverter	30

When the electricity shortage is 0 %, the composition of hybrid energy system is 80 kW photovoltaic cells, 20 sets of 10 kW wind turbine, 300 kW batteries and 30 kW inverters (Table 2). System has a total investment of 709,471 \$. The unit capacity investment is 1.001 \$/kWh. Annual investment of the PV modules is 33,747 \$/y., accounting for 43 % of the total investment; the investment on wind turbine cost is 12,813 \$/y, accounting for 17 % of the total investment; the investment on the battery is 28,242 \$/y, accounting for 36 % of the total investment. Figure 6 shows the cost ratio.
Figure 7 shows the output of photovoltaic and wind power. It can be seen that the output power of PV in spring and summer is more and the output power of wind is more in autumn and winter wind, which is closely related to the weather conditions.

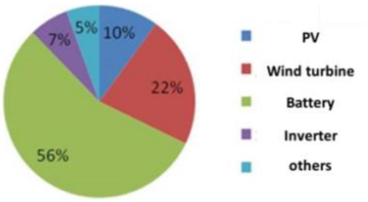

Figure 6: Cost ratio when the when the electricity shortage is 0 %

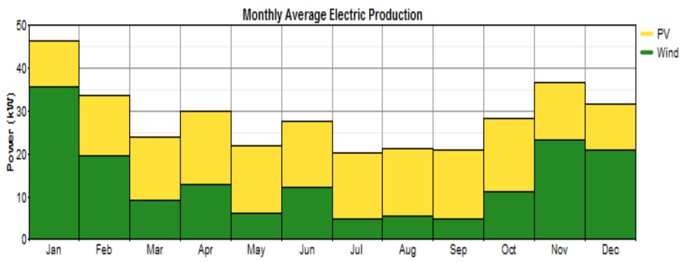

Figure 7: Output of PV and wind power when the electricity shortage is 0 %.

4.2 5% electricity shortages

When the electricity shortage is 5 % as shown in Table 3, the composition of hybrid energy system is 90 kW photovoltaic cells, 10 sets of 10 kW wind turbine, 100 kW batteries and 30 kW inverters. System has a total investment of \$ 518,704. The unit capacity investment is 0.757 \$/kWh. Annual investment of the PV modules is 37,965 \$/y, accounting for 66 % of the total investment; the investment on wind turbine cost is 6,407 \$/y, accounting for 11 % of the total investment; the investment on the battery is 9,414 \$/y, accounting for 16 % of the total investment. Figure 8 shows the cost ratio. Figure 9 shows the output of PV and wind power when the electricity shortage is 5 %.

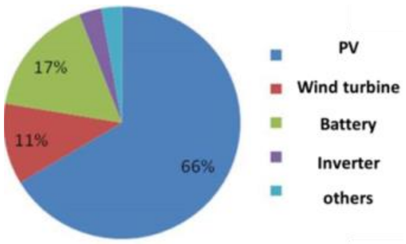

Figure 8: Cost ratio when the when the electricity shortage is 5 %

Table 3: Configuration of the hybrid energy system when the electricity shortage is 5 %

Composition	Capacity/kW
PV	90
Wind turbine	100
Battery	100
Inverter	30

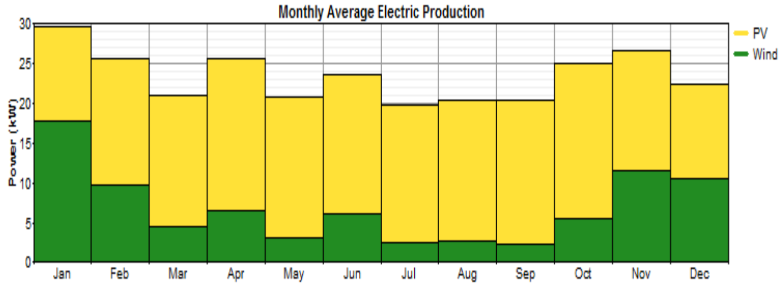

Figure 9: Output of PV and wind power when the electricity shortage is 5 %.

4.3 10 % electricity shortages

When the electricity shortage is 10 % as shown in Table 4, the composition of hybrid energy system is 60 kW photovoltaic cells, 10 sets of 10 kW wind turbine, 100 kW batteries and 30 kW inverters. System has a total investment of 403,833 $. The unit capacity investment is 0.619 $/kWh. Annual investment of the PV modules is 25,310 $/y, accounting for 57 % of the total investment; the investment on wind turbine cost is 6,407 $/y, accounting for 14 % of the total investment; the investment on the battery is 9,414 $/y, accounting for 21 % of the total investment. Figure 10 shows the cost ratio. Figure 11 shows the output of PV and wind power when the electricity shortage is 5 %.

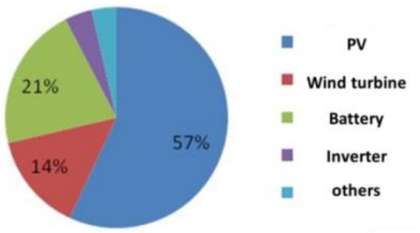

Figure 10: Cost ratio when the when the electricity shortage is 10 %

Table 4: Configuration of the hybrid energy system when the electricity shortage is 10 %

Composition	Capacity/kW
PV	60
Wind turbine	100
Battery	100
Inverter	30

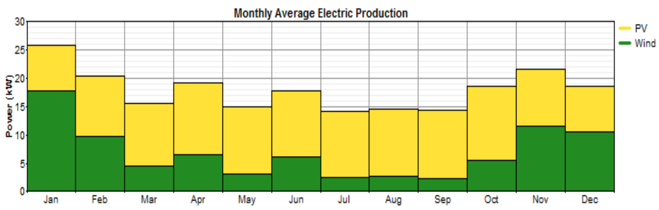

Figure 11: Output of PV and wind power when the electricity shortage is 10 %

5. Conclusions

A hybrid energy system was put forward according to the renewable resources in a certain area. HOMER software was used for the optimization and to implement the economic analysis. Also this paper considered the capacity shortage effect of this system.

1）According to the weather conditions and the electricity load of a specific area, this paper puts forward a hybrid energy system to meet the requirement of power supply, and optimizes the system configuration and analyses economy using HOMER software. When the electricity shortage is 0 %, the hybrid energy system is consisted of 80 kW PV, 20 sets of 10 kW wind turbine, 30 kW inverter and 300 kW batteries. The total investment is 709,471 $.

2）It can be seen that the hybrid energy system has a good complementary characteristic with more power output of PV in spring and summer and more power output of wind power in autumn and winter.

3）When the reliability of power supply system decreases (the electricity shortage ratio increases), the economy of the system is greatly improved. The cost of unit capacity is 1.001 $/kWh when the electricity shortage rate is 0 % and drop to 0.619 $/kWh when the electricity shortage rate is 10 %. The effect of the electricity shortage rate on the system structure is mainly reflected in the capacity of the battery. The composition of battery is 300 kW when the electricity shortage rate is 0 % and drop to 100 when the electricity shortage rate is 5 %.

Acknowledgments

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