Biomass Gasifier Energy Cyber-Physical System Design with Coupling of the Wind and Solar Energy

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Abstract

The air pollution in China has been quite serious, and biomass is extremely rich in large agricultural country. In the view of current situation, highly efficient solar collectors, wind energy and solar energy coupled heating straw gasification system is studied. The stability of continuous gas production is analyzed in various weather conditions including windy, calm, sunny and cloudy. Highly efficient solar panels, wind energy and solar energy coupled heating straw gasification control system is raised. This system overcomes the time variability of the weather conditions to ensure the stability of the continuous gas production under a variety of weather conditions. It has high quality of gas production, strong anti-interference ability and robustness.

Keywords: *efficient solar panels, biomass gasification furnace, heating control system coupled solar and wind*

1. Introduction

At present, China's air pollution is very serious. For coal accounting for the highest proportion of fuel mix, China's air pollution is a typical coal-burning pollution.The total suspended particles, sulfur dioxide, nitrogen oxides are the main pollutants [1-3]. Before air pollution is mainly concentrated in the cities, but with the development of township enterprises, the area of air pollution spreading to suburban and rural areas, many township enterprises to establish the industries of chemical, textile printing and dyeing, chemical fiber, leather, ceramics, glass, refractories, metallurgy heating and so on, these industries extensive use of small boilers, furnaces, there is a low thermal efficiency, high concentrations of black smoke and dust, heating up a long time, there has a serious waste of energy, polluting the environment, and also increasing the air pollution in China.

The other hand, the crop residues and other biomass energy is continue to produced in china's vast rural areas. China is a large agricultural country, at least a few million tons of agricultural and forestry wastes are produced. Due to the lower of the original straw energy conversion means, the rich farmers do not want to use the the laborious straw energy, resulting in the use of rural biomass continuous drop every year and a large number of biomass resources are disposed as waste. It is not only a waste of resources, but also causes serious environmental pollution and ecological destruction.

In order to save coal resources, reduce pollution, using of rural straw as raw material gas instead of coal gas into the boiler or furnace combustion can solve the problem of clean energy supply of village and township enterprises, and because the township and village enterprises construction mostly next to farmland, the straw to collect very convenient, straw to collect cost is reduced, straw gas costs are greatly reduced compared with the cost of coal gas, can significantly improve the economic benefits [4-7].

In the isolated island, or in remote areas away from the power grid and poor transport facilities, or in villages the user is extremely scattered and the load light, if the local wind resources is rich, the establishment of a stand-alone wind power system to solve the local biomass pretreatment is a very effective and economical.

Stand-alone wind power generation system consists of the following components, wind turbine (including tower), rectifier, inverter, energy storage device and load regulator.

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The choice of stand-alone wind power system wind turbine capacity, not only to consider the needs of the users to the load power consumption, but also pay attention to the matching characteristics of wind resources and load in the local, and the number of hours for no wind of the wind energy [8-9] .

The use of wind power-sunlight combined power generation system is designed to more efficient use of renewable energy, achieving complementary of wind power and solar power generation. In the wind strong season or time, mainly takes wind power generation, supplemented by solar power to supply to the load. In winter and spring, wind is strong, in the summer and autumn, the wind is weak, but the solar radiation is strong, from the use of resources, they can complement each other exactly .Therefore , in remote areas or islands with less power network coverage,using wind - solar power generation system is a reasonable and reliable access to electricity supply approach [10-11].

Efficient wind and solar power coupled heating system is researched, so that the gas production rate has a substantial increase based on the original, maintain the stability of the continuous gas production throughout the year with a variety of weather conditions.

2. The Structure of the Power Generation System of Coupled Solar and Wind Energy

The structure of the wind-solar power generation joint supply system, is shown in Figure 1. The system can be run in three modes according to changes in wind speed and solar radiation.

(1) Wind turbines alone supply power to the load.

(2) Wind turbine and solar cell matrix to joint supply power to the load.

(3) Sunlight cell matrix individually supply power to the load.

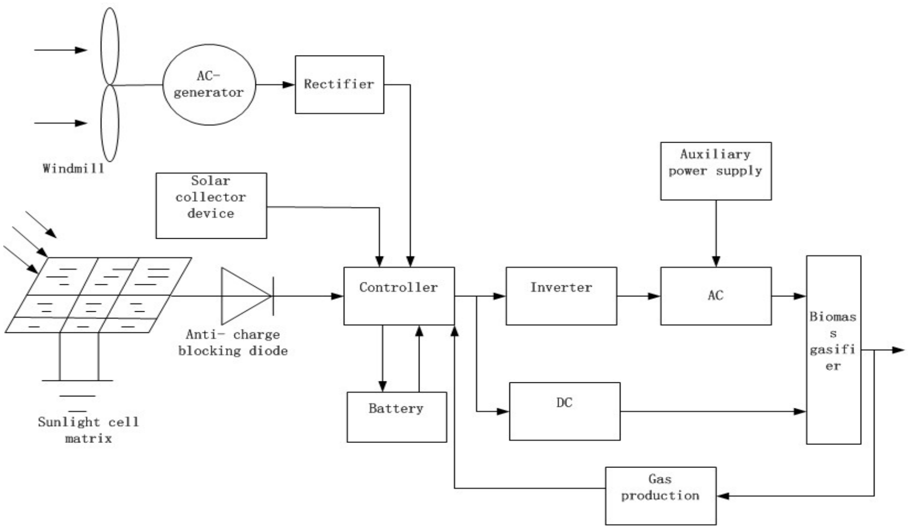

Figure 1. Solar and Wind Power Cogeneration Cyber-physical System

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2.1. Determine of Wind Turbine Capacity

The kinetic energy of wind is proportional to the square of wind speed. When an object made the flow of air slow down, the part of the kinetic energy of the flow of air transforms into the pressure energy on objects, the whole pressure on the object is the role of the force on the object.

The wind wheel of wind turbine absorbs energy from the air, so double the wind speed, wind turbine energy absorbed from the air has increased eightfold. This factor must be considered in determining the installation location of the wind turbine and selection of wind turbine model. The wind power absorbed by the wind wheel from the wind using the following formula, namely:

$$P = \frac{1}{2} C_P A \rho v^3 \quad (1)$$

$$A = \pi R^2$$

Where P is the output power of the wind turbine, C_P is the power coefficient of wind turbine, A is the wind turbine swept area, ρ is the air density, v is the wind speed, R is the radius of the wind turbine.

As we all know, if all the kinetic energy of the air close to the wind turbine is absorbed by the rotating wind turbine blade, then the air after the wind wheel will not move. However, air can not be completely stopped, so the wind turbine's power is always less than 1.

2.2. Determine the Capacity of Solar Cell Matrix

Design wind-solar power generation system,we should based on the user load to determine the capacity of the cell matrix of sunlight, generally it should be considered in accordance with the user load power required by the supply of photovoltaic cells, the calculation method and steps are as follows:

(1) To determine the series number of the cell matrix of the sunlight single battery

The sunlight battery-powered systems operate independently, always and battery supporting use, that form a floating circuit with the power system, to use part of the electrical energy for load, another part of the energy stored in batteries for use of the night or rainy days.Setting the sunlight battery on the battery float voltage value is U_f , then:

$$U_F = U_f + U_d + U_t \quad (2)$$

Where, U_f is the voltage that is required by battery in the float state determined according to the load voltage; U_d is the voltage drop for line loss and anti-charge diode, U_t is the voltage drop caused by the temperature rise when solar cells work.

Suppose sunlight single battery (or components) operating voltage is Um, the series number of sunlight single battery (or components) is:

$$N_S = \frac{U_f + U_d + U_t}{U_m} = \frac{U_F}{U_m} \quad (3)$$

(2) Determine the number of sunlight single battery cell matrix of the sunlight (or components) in parallel

For sunlight single battery (or components), the number of parallel N_P can be calculated as follows, namely(mm):

$$N_P = \frac{Q_L}{I_m H} \eta_C F_C \quad (4)$$

Where, Q_L is the load power consumption in every day, H is the average number of sunshine hours, I_m is the average operating current of the sunlight battery monomer (or components), η_C is the correction factor for the efficiency of the battery's charge and discharge, F_C is the correction factor for other factors.

(3) to determine the series number of the cell matrix of the sunlight single battery

The capacity of the sunlight cell matrix Pm can be determined as follows, namely, factor for other factors.

$$P_m = (N_S U_m).(N_P I_m) = N_S N_P U_m I_m \tag{5}$$

2.3. Determine the Capacity of Solar Cell Matrix

When sunlight cell matrix independent supplies power, the battery capacity is:

$$Q_B = 1.2 D Q_L K \tag{6}$$

Where, Q_B is the capacity of battery , D is the longest continuous rainy days, K is the correction factor for the battery to allow the release of capacity, 1.2 is the safety factor.

3. The Proposed Predictive Control System

Biomass gasifier can be used raw material, such as corn stalks, corn cobs, cotton stalks, rice straw, rice husk, straw, husk, millet straw, sawdust, bagasse, palm shell and so on. The moisture content is generally 15-20% in the main variety of crop straw. The circulating fluidized bed gasifier with a wide range of adaptability of raw materials, rice straw, wheat straw, corn stalks and wood shavings, sawdust, bark and other agricultural and forestry wastes can be used. According to the actual situation of the surrounding countryside, it can collect a variety of raw materials to ensure that the gasifier operation.

The efficient solar collectors, wind and solar power coupled heating straw gasifier control system shown in Figure 2, which consists of high efficiency solar collector device, wind, solar co-generation heating, controller based on a variety of weather conditions, the gas production to adjust heating mode, so as to achieve the purpose of continuous gas production, that is, to achieve the stability of the gas production, even if in the same process and it will result in different discrete models. Figure 2 shows the model obtained by equations (1), (3) and (5); and we get:

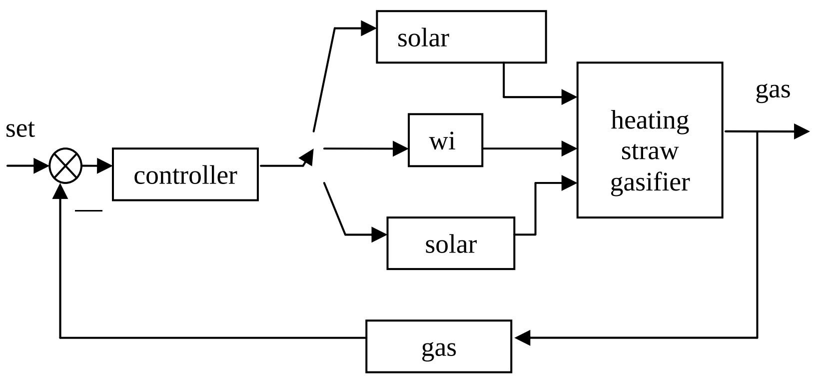

Figure 2. The Efficient Solar Collectors, Wind and Solar Power Coupled Heating Straw Gasifier Control System

In a variety of weather conditions, the stability of the continuous gas production is analysed. Assumptions selected a 100W wind turbine, rotor diameter is 2m, rated wind speed is

6.3m/s, the running wind speed is 3 to 15m/s. According to the basic formula of wind (1) to calculate the annual generation capacity of the wind turbine.

$$P = \frac{1}{2} C_P A \rho v^3 \eta \quad (7)$$

Where, P is the power output of wind turbine, kW. ρ is the air density kg/m^3. v is the wind speed m/s. C_P is the wind energy utilization factor of wind turbine. η is the power output efficiency of the wind turbine. A is the swept area of wind wheel.

To 100W class wind turbine, usually simplify equation (1) to $P = kv^3$. When wind speed changes between 3m/s and the rated wind speed, we should view that k is a constant, the wind turbine output power is proportional to the cube of wind speed. When the wind speed interval running above the rated wind speed, wind turbine output power is equal to its rated power.

Assuming that the load power is 250W, the annual total electricity consumption is the 190KW·h, average daily power consumption is 0.5KW·h.

Assumptions, the local annual average wind speed is 3.69m/s. Wind speed frequency distribution in Table 1.

Table 1. Household-type Wind Speed Frequency Distribution

Speed (m/s)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15~17
hour（h）	842	1031	1488	1328	1153	876	723	515	383	171	85	72	38	28	15	12

In accordance with two assumptions mentioned before, calculating of the 100W wind turbine generating capacity according to Equation (8).

$$\begin{aligned} &E = E_1 + E_2 && (3m/s \le v_i < 6.3m/s) \\ &E_1 = \sum[P_N h_i (v_i / v_H)^3] && (v_i = 3 \sim 6.3m/s) \\ &E_2 = P_N \sum h_i && (v_i = 6.3 \sim 15m/s) \end{aligned} \quad (8)$$

Where, E is the wind turbine generating capacity, kW·h. E_1 and E_2 are the generating capacity of wind turbine at different wind speeds, kW·h. v_j is the wind speed, m/s. v_H is the rated wind speed of wind turbine, when the wind turbine is 100W class, $v_H = 6.3$ m/s. h_i is the number of hours corresponds to wind speed in years. P_N is the rated power of wind turbine, where $P_N = 100W$.

According to Table 1 providing the wind speed frequency distribution, The generating capacity of 100W wind turbine group is 268kW·h in the local greater than 50% of the power consumption of load years. The remaining 50% is provided by the efficient solar collector installations and solar. The capacity of the solar cell matrix is determined by 2.2 sections.

According to the view that systems power generating and power supply are static equilibrium, the stand-alone wind power generation system selecting a 100W wind turbine is able to meet the annual electricity needs of the user.

It can be seen, take advantage of the complement each other and more straw gasifier producing gas to supply has obvious economic benefits, not only that, the use of straw also has significant environmental benefits, the SO_2 and NO_X emissions during biomass utilization process is less, causing air pollution and acid rain phenomenon will be significantly reduced. China is a big agricultural country and biomass is extremely rich, the straw in the rural areas is about 850 million tons each year, extensive use of biomass has an important significance for China's environmental protection.

4. Conclusion

This paper studies the efficient solar collectors, wind and solar power coupled heating straw gasifier control system, the following conclusions are.

(1) For the impact of a variety of weather conditions, such as wind, no wind, light, no light, the stability of the continuous gas production for a variety of weather conditions was analyzed.
(2) For a variety of weather conditions, a highly efficient solar collectors, wind and solar power coupled heating straw gasifier control system is presented.
(3) The system overcomes the time variability of the weather conditions to ensure the continuous gas production stability of a variety of weather conditions, can significantly improve gas production, anti-interference ability and good robustness.

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