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Architecture and Energy Efficiency of Distributed Biomass based CCHP System based on FCF Method

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Abstract: China is a large agricultural country with a huge amount of biomass energy. However, due to the current energy structure, most of the biomass energy in China has not been fully utilized, which not only wastes energy, but also pollutes the environment. The CCHP system is a new type of distributed energy system, so the characteristics of biomass energy are suitable for the energy consumption mode of CCHP system; In this paper, the FCF method(FCFM) is proposed to study and analyze the architecture and energy efficiency(EE) of distributed biomass CCHP system. The working principle of distributed CCHP system and distributed biomass CCHP system are discussed; A FCF optimization objective function model is proposed, and the energy structure and characteristics of biomass cogeneration system are analyzed. A typical rural community is selected as the research object. According to the load data table of the object system, the utilization changes of cooling, heating and electricity loads of the object in a year are analyzed. Biomass cogeneration system converts biomass energy as efficiently as possible through biomass gasification. The whole process realizes the stepped utilization of energy, which has better environmental benefits than conventional cogeneration system.

1. Introduction

At present, most of the prime movers of CCHP systems in China are driven by the consumption of fossil energy. Biomass energy is used to replace coal, natural gas and other fuels, and the establishment of biomass CCHP system has alleviated the shortage of fossil energy on the one hand, eliminated the pollution of biomass waste to the environment on the other hand, increased the energy utilization rate of the region, and achieved regional self-sufficiency in energy, So as to form a complete regional energy circular economy operation mode, which has significant economic, environmental and social benefits. Therefore, based on the FCFM, this paper studies and analyzes the architecture and EE of distributed biomass CCHP system.

Many scholars at home and abroad have analyzed the architecture and EE of distributed biomass cogeneration system based on FCFM. Parihar a et al. Discussed a method to determine the optimal size of distributed generation system based on battery integrated biomass gasifier. Generally, the scale of biomass gasifier system takes into account the peak demand. Due to the partial load operation during the low demand period, the operation efficiency is reduced. The operation strategies of two gasifiers are discussed, and the energy cost is compared. Through a structured household survey of a small village without electricity, a real load curve is generated to illustrate the proposed method. For a given load curve, the power cost of the battery integrated gasifier engine system under intermittent operation mode is the lowest [1].

In this paper, the structure and composition of distributed biomass cogeneration system and FCFM are introduced as a whole, and the biomass gasification module is mainly analyzed, including biomass gasification equipment and biomass gasification process principle; Based on the analysis of the composition and working principle of the distributed CCHP system, this paper makes a multi-objective optimization and EE analysis of the distributed biomass CCHP system with the objectives of thermal efficiency, economy and environmental benefits. From the perspective of the development situation of energy utilization, or from the perspective of technology, biomass energy is used as the primary energy of the CCHP system, It is theoretically feasible to establish a distributed biomass energy cogeneration system [2-3].

2. Distributed Biomass Combined Cooling, Heating and Power System based on FCFM

2.1. Theoretical basis and Model Construction of FCFM

FCF is to consider the future cash flow of the company as a whole from all investors, including shareholders and creditors. The ideas of the two methods are the same, but they choose different routes [4]. Two principles must be strictly followed: the cash flow principle and the time value of money. It can be understood that regardless of the form of the asset, its final value is determined by the present value of the expected cash flow generated. The main basic points of FCFM are divided into two aspects. First, to a certain extent, the fluctuation of cash flow will cause a series of changes in enterprise value, which is impossible to realize profits; Secondly, only by fully and reasonably considering the factors of the time value of money, can the model become more complete [5-6].

2.1.1. Model of FCFM

Among all the methods for enterprise valuation at present, DCF method can be used as the basis of all valuation methods, which is the most widely used method, which means that DCF method is relatively more sound in theory and practice. DCF method can be simply understood as: the total of cash flow converted into present value in a certain period of time in the future is the value of the enterprise.

The priority problem to be solved is the quantity and time distribution of enterprise cash flow. The first dividend discount model can be understood as discounting the dividends distributed to shareholders every year at a discount rate to obtain the stock value; When carrying out practical operation, we should make full use of all information, data and enterprise resources related to the target case enterprise as much as possible. We should not predict arbitrarily due to the subjective assumptions and choices of the appraisers. We should truthfully reflect the data that causes changes in cash flow in the predicted cash flow and its future growth. Based on this, we can make our operation meaningful and authentic, In order to truly evaluate the actual situation of the enterprise and make reasonable enterprise management decisions [7].

2.1.2. Steps of FCFM

When choosing the FCFM to operate, we should follow the following three steps: the net FCF in the forecast period; Determination of discount rate; The discounted value of the forecast period and the perpetuity period. When deciding to use FCF to evaluate the value of an enterprise, we should first calculate the relevant financial indicators and data of the enterprise in recent years based on historical financial data, analyze the basic financial situation through the historical information of the company, and at the same time, combine the background of the times, industry conditions and leaders′ planning for the future of the company. The process of FCF calculation is divided into each small project to estimate separately. At the same time, combined with the historical data in recent years as the basic information, we can objectively, scientifically and reasonably predict the future cash flow of the enterprise.

2.2. Problems Existing in Distributed Biomass CCHP System

Cogeneration system has been widely used in China. Through the development of recent years, the relevant technology has also been relatively mature. However, due to various reasons, there are still many problems in further promoting cogeneration technology in China, mainly focusing on industrial technology, application, policy and other aspects.

The development of the system itself is not perfect, there is a lack of new technology and process to improve the performance of the system power generation equipment, and the integration technology and experience of the system are relatively insufficient, which affects the overall architecture optimization design of the system;

There is a lag between the energy supply and demand of the cogeneration system, and the control system cannot adjust the system in time with the load, resulting in the unit often operating under low load, affecting the overall EE characteristics of the system [8-9]. At present, most of the evaluation indicators used in the cogeneration system directly borrow the traditional indicators, but the traditional performance evaluation indicators ignore the essential differences between the cogeneration system and the traditional unit yield system, and ignore the unequal value of cold, heat and electricity in grade.

The combined heat, power and cooling system is facing small scattered users. This type of user load changes greatly in different seasons and periods. However, at present, there are few studies on the EE characteristics of the system under variable load, and most of them are discussed and studied under fixed load. It is necessary to analyze the influence of relevant factors on cogeneration system in detail and clarify the mechanism of variable load characteristics of cogeneration system [10].

The capacity of the distributed CCHP system is relatively small, and the control mode is relatively simple. The system is not easy to resist the impact of other external factors. Grid connected operation is the most ideal way. However, due to the imperfect development of the cogeneration system, it is difficult to connect the cogeneration system to the grid. These have become factors that hinder the promotion and development of the cogeneration system [11-12].

2.3. Architecture Mode of Distributed Biomass based CCHP System based on FCF

2.3.1. Working Principle of Distributed CCHP System

The overall composition of the distributed cogeneration system is shown in Figure 1. According to the energy output of the distributed cogeneration system, the traditional cogeneration system is divided into three subsystems: power system, heating system and cooling system. First, the heat generated by fuel combustion is converted into electric energy by the power system. The waste heat of the power system is recovered by the waste heat of the heating system and supplied to the system. Finally, the low-grade heat energy is further absorbed and utilized by the refrigeration system and supplied to the system cooling capacity [13].

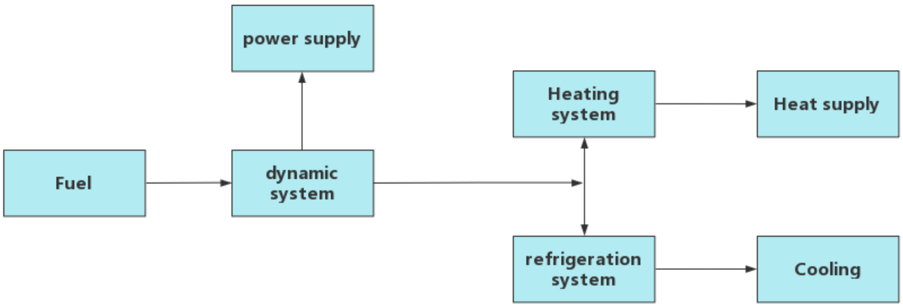

Figure 1. Energy supply process of CCHP system

2.3.2. Distributed Biomass CCHP System

According to the utilization type of fuel, distributed CCHP system can be divided into the following two types: using conventional fossil fuel technology: the main fuel types are fossil energy such as oil and natural gas. This type of cogeneration system mainly uses reciprocating internal combustion engine or industrial gas turbine as the power unit, and has basically realized commercialization; Using renewable energy technology: the main energy is solar energy, wind energy, biomass energy, hydropower and other renewable energy [14-15]. The main equipment is photovoltaic cells, wind turbines and small power plants using biomass as fuel.

Figure 2 shows the structural diagram of a typical biomass gas distributed energy supply system. The system can be roughly divided into five parts: biomass gasification system, power generation equipment, waste heat recovery system, refrigeration part and the control module of the system. The overall thermal energy utilization of the system is shown in Table 1 [16].

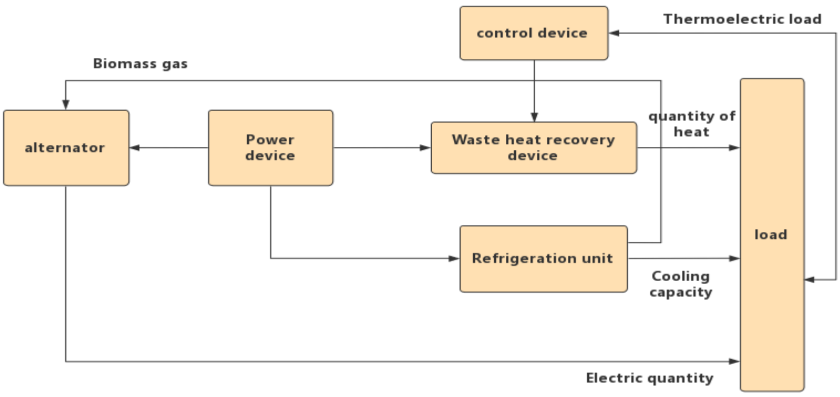

Figure 2. Schematic diagram of distributed biomass CCHP system

Table 1. System heat energy utilization

Biomass energy utilization temperature / ℃	Heat energy utilization equipment	Purpose
Greater than 800	Generator Set	Power supply
About 400	Lithium bromide cold and warm water unit	Heating or cooling
Less than 200	Secondary waste heat absorption device	Domestic hot water

China is rich in biomass resources, but the distribution is relatively scattered, which is not easy to collect and use, which is consistent with the characteristics of decentralized energy supply of distributed energy supply system. The integration of biomass energy and distributed combined cooling, heating and power generation system can realize the complementary advantages of the two, and has a good development potential. In recent years, new biomass utilization technologies have been continuously developed and applied. At the same time, China is constantly improving relevant preferential policies, which will promote the commercialization of biomass energy. In the long run, distributed biomass energy technology has better comprehensive social benefits [17-18].

3. FCF Optimization Objective Function Model

Cogeneration system is different from the previous unit production system. It is a complex energy output system that outputs cold, heat and electricity at the same time. Therefore, the evaluation of the system is more complex than the separate production system. It is unscientific to directly use the single system index commonly used in the previous unit production system to evaluate the cogeneration system. In this paper, a comprehensive evaluation index is adopted to evaluate the cogeneration system. The comprehensive evaluation includes three aspects: efficiency, economy and environmental benefits. The corresponding evaluation indexes are as follows:

(1) Utilization rate of biomass energy

The biomass energy utilization rate of the system is the fuel utilization efficiency of the system, which is the ratio of the total energy output of the system to the total energy input of the system fuel:

$$PES = \frac{U + G_k + G_c}{G_P} \tag{1}$$

In formula (1), GP is the primary energy consumption (kw) of the cogeneration system, u is the system power generation (kw), GK is the heating capacity (kw) of the CCHP system, and GC is the cooling capacity (kw) provided by the lithium bromide refrigerator.

(2) Carbon dioxide emission reduction rate

The CO2 emission reduction rate is an evaluation method involving the environmental benefits of the system. According to the energy conservation and the existing empirical formula in the literature, the CO2 emission reduction rate of CCHP compared with the split generation system can be obtained:

$$CDE = 1 - 1/[[\lambda_{el} + \gamma \times \frac{\lambda_{tf} - \lambda_{el}}{1+h}]\frac{X_{el}}{X_g} + \frac{1}{\lambda_b} \times \frac{\lambda_{tf} - \lambda_{el}}{1+1/h}] \tag{2}$$

In formula (2): is the share of power generation in fuel heating; Is the fuel utilization coefficient, that is, the primary energy utilization rate; Is the emission factor of conventional power generation (the emission rate of CO2 per 1kwh of electricity (kg/kw ·h)), and is the fuel emission factor (the emission rate of CO2 per 1kwh of fuel heat (kg/kw ·h)); γ It is defined as the ratio of the performance coefficient Copa of the absorption refrigeration unit to the performance coefficient COPC of the compression refrigeration unit.

(3) System economy index

The annual total cost is an evaluation of the power generation economy of the system. The equipment capacity of the system mainly determines the initial investment of the system, and the operation mode of the system mainly affects the operation cost of the system, including power purchase cost and fuel cost. This paper mainly considers the operation cost. The economic indicators of CCHP system are:

$$COST = \frac{P_e}{P_f} - \frac{1-\alpha+\alpha\lambda_e}{\lambda_e} \tag{3}$$

Wherein, UE is the power generated by the generator; GC is the cooling capacity supplied by the absorption refrigerator; Copab is the efficiency of absorption refrigerator; Is the waste heat utilization rate of cogeneration system; PF and PE are the local biomass gas and electricity prices respectively.: The economic index of the system is related to the waste heat utilization rate and power generation efficiency of the system. When the value of the above formula is greater than zero, the cost of the combined supply system is less than that of the sub supply system. When the value is less than zero, the cost of the combined supply system is greater than that of the sub supply system.

4. Optimization and EE Analysis of Distributed Biomass Cogeneration System based on FCFM

4.1. Annual Load Characteristics of the System

For an energy system, the load condition of the system is the basis for the configuration design and optimization of the system. This paper selects a domestic residential community as the research object. Figure 3 shows the annual load statistical data of the residential community.

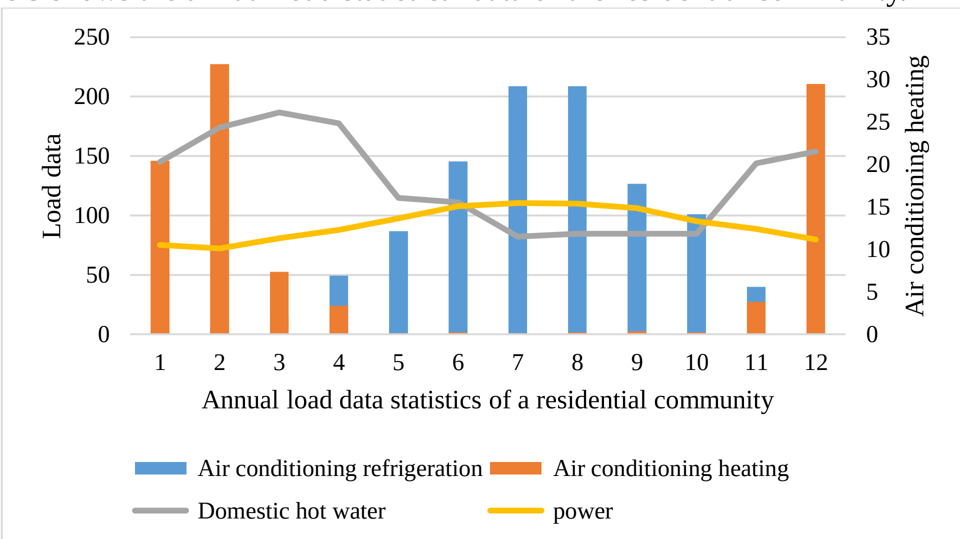

Figure 3. Annual load data statistics of a residential community

Through the analysis of the literature data, the load condition of the system is obtained. It can be seen from the figure that the annual power load of the system fluctuates slightly month by month; the refrigeration load of the system changes greatly. The utilization of the system cooling capacity is very small in January to March and November to December, and the cooling capacity of the system is relatively large in 4 to 10 parts, reaching the peak of cooling capacity in July to August; Similarly, the heat utilization of the system also changes greatly with the seasonal period. It can be seen from the figure that the heating peak period of the system is from January to March and from November to December, and the heat consumption of the system is small from April to October.

4.2. Typical Daily Load Characteristics

The typical daily load conditions in summer, winter and transition seasons are selected in this paper, as shown in Table 2.

Table 2. Typical daily load of a rural community in each season

	Electric load /kw		Heat load /kw		Cooling load /kw	
Period	Maximum value	Minimum value	Maximum value	Minimum value	Maximum value	Minimum value
Typical summer day	4587.31	1942.84	190.62	28.59	11485.88	2484.15
Typical day of transition season	4486.45	1882.79	388.89	47.43	1882.79	1548.01
Typical day in winter	3586.66	1602.79	889.64	126.89	5189.09	801.99

Combined with the above data table, the cooling, heating and power load characteristics of the rural community are analyzed as follows: the power load of the system is basically the same in the three typical diurnal variation trends, which can be roughly divided into two periods, gradually increasing from 8 a.m. to 21 p.m., reaching the peak of power consumption of the system, during which the power load is roughly between 3000~4000kw; The other stage is from 24 o′ clock at night to 7 o′ clock in the morning the next day. The electrical load is relatively low, basically about 1400kW, which is basically half of the peak period in the daytime. The change trend of the cooling load of the system is similar to that of the electric load, but the cooling load is greatly affected by the season. The cooling load of the system is the largest in summer. With the increase of temperature, the cooling load of the system gradually increases. The peak period of the cooling load of the system is from 11 a.m. to 21 p.m. The typical daily variation of the heat load of the system is not very large, and the demand is smaller than the electric load and cooling load. Due to the low ambient temperature in winter, the heat demand increases significantly, and the peak period of the heat load is about 19:00 to 22:00 in the evening.

5. Conclusion

The biomass CCHP system architecture given in this paper is based on the existing models. Due to the limitations of conditions, the scheme design of the system in this paper is limited to theoretical analysis and lacks more rigorous experimental data verification; The multi-objective function optimization model established in this paper ignores many actual factors that affect the operation of the cogeneration system. Although the simplification of these parameters has little effect on the optimization of system operation, these simplified factors should be taken into account in the simulation of CCHP system or the actual operation of the system; CCHP system is a complex energy multi output system, and there are many factors that affect the system characteristics. The analysis of the system is a complex process. This paper only discusses the architecture and EE characteristics of the CCHP system from a shallow level.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

References

[1] Parihar A , Sethi V , Banerjee R . Sizing of biomass based distributed hybrid power generation systems in India. Renewable energy, 2019, 134(APR.):1400-1422.

[2] Abo B O , Gao M , Wang Y , et al. Lignocellulosic biomass for bioethanol: an overview on pretreatment, hydrolysis and fermentation processes. Reviews on environmental health, 2019, 34(1):57-68. https://doi.org/10.1515/reveh-2018-0054

[3] Hovenden M J , Leuzinger S , Newton P , et al. Globally consistent influences of seasonal precipitation limit grassland biomass response to elevated CO2. Nature Plants, 2019, 5(2):167-173.

[4] Fourati Y M , Ghorbel R C , Jarboui A , et al. Sticky cost behavior and its implication on accounting conservatism: a cross-country study. Journal of Financial Reporting and Accounting, 2020, 18(1):169-197. https://doi.org/10.1108/JFRA-08-2018-0071

[5] Schmidt K . Mexico unveils finance revamp in Pemex push. Upstream: The International Oil & Gas Newspaper, 2019, 24(8):22-22.

[6] Delong U , Dhaene J , Barigou K . Fair Valuation Of Insurance Liability Cash-Flow Streams In Continuous Time: Applications. Astin Bulletin, 2019, 49(2):299-333. https://doi.org/10.1017/asb.2019.8

[7] Galles M , Matus F . Pensando Distributed Services Architecture. IEEE Micro, 2020, PP(99):1-1.

[8] Bai T , Li S , Zou Y . Distributed Mpc For Reconfigurable Architecture Systems Via Admm. IEEE/CAA Journal of, Automatica Sinica, 2020, 8(7):1336-1344.

[9] Kaya E , Iwata H , Miyazaki S , et al. Successful coronary flow restoration by stent-free strategy using the pull-back method of cutting balloon in spontaneous coronary artery dissection. CJC

Open, 2019, 1(4):213-215.

[10] Kornev N , Samarbakhsh S . Large eddy simulation with direct resolution of subgrid motion using a grid free vortex particle method. International Journal of Heat and Fluid Flow, 2019, 75(FEB.):86-102.

[11] Mari C , Marra M . Valuing firm′s financial flexibility under default risk and bankruptcy costs: a WACC based approach. International Journal of Managerial Finance, 2019, 15(5):688-699. https://doi.org/10.1108/IJMF-05-2018-0151

[12] Lara C L , Bernal D E , Li C , et al. Global optimization algorithm for multi-period design and planning of centralized and distributed manufacturing networks. Computers & Chemical Engineering, 2019, 127(AUG.4):295-310.

[13] Gsk A , Skc B , Jhs C . Does biomass energy consumption reduce total energy CO2 emissions in the US? - ScienceDirect. Journal of Policy Modeling, 2020, 42(5):953-967.

[14] Ozsin G , Putun A E . TGA/MS/FT-IR study for kinetic evaluation and evolved gas analysis of a biomass/PVC co-pyrolysis process. Energy Conversion and Management, 2019, 182(FEB.):143-153.

[15] Goethel C L , Grebmeier J M , Cooper L W . Changes in abundance and biomass of the bivalve Macoma calcarea in the northern Bering Sea and the southeastern Chukchi Sea from 1998 to 2014, tracked through dynamic factor analysis models. Deep-Sea Research, 2019, 162(APR.):127-136. https://doi.org/10.1016/j.dsr2.2018.10.007

[16] Lenis Y A , Maag G , Eduardo L , et al. Effect of Heat Flux Distribution Profile on Hydrogen Concentration in an Allothermal Downdraft Biomass Gasification Process: Modeling Study. Journal of Energy Resources Technology, 2019, 141(3):031801.1-031801.10. https://doi.org/10.1115/1.4041723

[17] Mullen C A , Strahan G D , Boateng A A . Characterization of Biomass Pyrolysis Oils by Diffusion Ordered NMR Spectroscopy. ACS Sustainable Chemistry And Engineering, 2019, 7(24):19951-19960. https://doi.org/10.1021/acssuschemeng.9b05520

[18] Avcioglu A O , Dayioglu M A , Turker U . Assessment of the Energy Potential of Agricultural Biomass Residues in Turkey. Renewable Energy, 2019, 138(AUG.):610-619. https://doi.org/10.1016/j.renene.2019.01.053