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Overall Optimization and Sustainable Development of Resources/Energy/Environment under Polygeneration Energy System

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Abstract: With the rapid development of the global economy, energy has become an important part of human life and international competition. A clean, reasonable and efficient energy system is an important guarantee for maintaining the normal operation and sustainable development of urban functions. The purpose of this paper is to study the overall optimization and sustainable development of resources/energy/environment in the context of polygeneration energy system, and to construct an energy system model. According to the constructed model, the urban complex M is selected as the case analysis object. Through the comparative analysis of different deflection ratios, it can be found that when the maximum deflection ratio is set to 0.7, the energy consumption of the system is significantly lower than before, while the NPV and carbon dioxide emissions are significantly lower. reduce. The biomass gasification index and other indicators did not increase but decreased, indicating that the biomass gasification gas has found the best balance between the energy output of biomass cogeneration and its chemical composition. Secondly, through the price sensitivity analysis of biomass fuel, it is found that although natural gas cogeneration has a high heat and power conversion efficiency, the current biomass price has a huge price advantage over natural gas, and only when the biomass price rises by more than 70% will it be Cogeneration using natural gas.

1. Introduction

The polygeneration energy system is an energy supply system based on the concept of cascade utilization of energy. , The development and utilization mode of this energy integrates energy saving, environmental protection, economy and energy supply safety and reliability, and has a very broad development prospect in my country. The sustainable development of my country's economy is of great significance [1-2].

At present, many researchers and institutions have developed a variety of energy models. Vialetto G proposed a new system based on RSOC. Each component of the system (existing and new) is defined using operational data, technical data sheets or models defined using thermodynamic tools. Then, study the interactions between them. Perform an energy analysis of the new system and evaluate the energy savings relative to the current configuration. Even with the increased complexity of the system, results show savings of 2% to 6%. Hydrogen production was evaluated comparing the RSOC integrated system with proton exchange membrane (PEM) electrolysis in terms of primary energy and economics [3]. Ferronato N analyzes the main strengths and weaknesses of implementing a sustainable MSWM. Research carried out shows that MSWM in La Paz is not efficient in terms of collection, recycling (8%), financial sustainability and equity of services. At the same time, local governments and stakeholders are interested in implementing new MSWM approaches to improve the current sanitation situation in cities, and many efforts have been made over the past decade. In general, La Paz can be seen as a good study area for developing waste value-added programs, becoming a model for developing low- and middle-income megacities in Latin America. The study provides some considerations about the affordability of the applied method and critically analyzes the presented case study [4]. Horlings L discusses a place-based approach to sustainable development, a place-based concept of relationships as a dynamic outcome of infinite relationships and networks. The argument is based on a literature review and illustrated with examples of nature and landscape governance. A framework is proposed for a more systematic understanding of site-specific linkages between sociocultural, political-economic, and ecological processes that enable or hinder the transition to sustainability [5]. These models can solve energy system planning and environmental problems, but the research on the complexity and uncertainty of energy system is still insufficient.

This paper will consider the complexity and uncertainty of the energy system optimization and management process under uncertain conditions, and build a model based on meeting the energy supply and demand balance and ecological environmental protection to minimize system costs and maximize economic benefits. Moreover, effective and reasonable energy planning can not only solve the problems of urban pollution, unreasonable energy structure, renewable energy utilization and energy security, but also lay the foundation for the sustainable development of the city.

2. Research on the Overall Optimization and Sustainable Development of Resources/Energy/Environment under the Polygeneration Energy System

2.1 Application Status of Energy Resources

Compared with the international energy consumption structure in my country, from the perspective of the overall international oil consumption level, the world accounts for 35% of the average energy structure level, while my country accounts for 18.9%; the overall average level of coal consumption in the international energy consumption structure Natural gas accounts for 29% of the energy, but my country has reached a high level of 70%; the international average level of natural gas accounts for 24% of the energy structure, but my country only accounts for 4.3%, the gap is very obvious [6-7]. The world average level of nuclear power installed capacity accounts for about 5.8% of the energy consumption structure, but my country accounts for only 0.8%. The levels of hydropower and various other renewable energy sources in the energy structure are generally comparable among countries in the world [8-9].

As we all know, coal burning will cause a series of problems such as a large number of greenhouse gases, carbon emissions and serious environmental pollution, ecological damage, climate warming, etc. In the energy consumption structure of developed countries in the world today, natural gas, oil, coal, nuclear power The proportion of renewable energy sources such as hydropower and other renewable energy sources is close to 25%, each accounting for about a quarter of energy consumption. This energy structure is relatively reasonable in the current view, and is more conducive to the harmonious development of the environment, ecology, society and economy. Sustainability, according to the forecast of WEC (World Energy Council), in order to meet the requirements of environmental protection and the continuous demand for energy in the world [10-11]. By 2050, the global energy structure may be composed of at least 8 energy sources including coal, oil, gas, biomass, wind energy, hydro energy, nuclear energy and solar energy, and the proportion of each energy source in this energy system will not exceed 1% twenty. Therefore, in order to build a modern country, a country with harmonious development, a country with scientific development, and a country with sustainable energy development, the adjustment of energy structure is absolutely impossible to avoid? Seriously, for comparison, the average energy utilization efficiency of the world and my country, the former is 51.3%, while the utilization level of my country is only 36.8% [12-13].

2.2 Polygeneration System Modeling Method

(1) Gasification system

The molecular structure of coal is complex, and ASPEN software cannot handle such unconventional solid mixtures. It needs to be decomposed into simple substances such as C, H_2, N_2, O_2, S and ash according to the elemental analysis of coal. Completed in the RYield module; the above-mentioned simple substances undergo gasification reaction under the condition of high temperature and high pressure with the participation of oxidant. In the model, it is assumed that the gasification reaction is completely balanced, and the RGibbs reactor is used to simulate [14-15].

(2) Methanol synthesis system

The traditional gas-solid catalytic reactor is not easy to remove the reaction heat, resulting in poor heat transfer performance and difficult temperature control, thus limiting the single-pass conversion rate of synthesis gas; while in the slurry bed reactor, due to the inert thermal conductivity with good thermal conductivity. The liquid is used as the heat carrier, and the catalyst with fine particle size is uniformly dispersed in the liquid medium, which can effectively improve the heat transfer and reaction performance of the reactor. Therefore, the slurry bed methanol synthesis reactor was selected in this study [16-17].

2.3 Evaluation Indicators

Environmental indicators: one mainly uses the emission volume, the emission volume and the capture rate as the evaluation indicators. The economic performance evaluation one mainly takes the estimated construction investment, the cost of chemical fuel and electricity as the evaluation index. In addition, the income of by-products, internal rate of return, payback period, and net present value can also be considered as indicators [18].

Thermodynamic indicators: There are mainly evaluation indicators such as thermal efficiency or total energy utilization efficiency based on the first law of thermodynamics, equivalent heat-to-work efficiency, and relative energy saving rate equivalent to synthetic energy consumption. Exergy based on the second law of thermodynamics combines "quality" and "quantity" to evaluate the value of energy more scientifically.

3. Establishment of A Model for the Overall Optimization and Sustainable Development of Resources/Energy/Environment under the Polygeneration Energy System

3.1 Objective Function

According to the characteristics of the system, the goal of the system model is to minimize the total cost of the system. This paper takes coal as an example, including coal mining cost, coal transportation cost, coal washing cost, coal conversion cost, crop production cost, crop transportation cost and other system costs. The production cost of coal is the product of the production cost per ton of coal and the amount of coal produced. The transportation cost of coal is the product of the coal transportation cost per unit distance per ton, the coal transportation volume and the transportation distance. The conversion cost of coal is the product of the conversion cost per ton of coal and the amount of coal converted. The cost of crop production is the product of the production cost per unit of crop and the crop production. The transportation cost of crops is the product of the transportation cost per unit of distance and the unit of crops, the transportation volume of the crops and the transportation distance of the crops. To sum up, the objective function is shown in formula (1).

$$Min \sum_{i,j,k,m,t} [c_{ij}^{CP} x_{ijmt} + c_{ijm}^{CP} x_{ijmt} d_{jm} + c_{imt}^{CC} + c_{kj}^{AP} y_{kjm} + c_{kjl}^{AT} y_{kjm} d_{jm}] \quad (1)$$

c_{ij}^{CP} represents the cost per unit (such as ton, 10,000 tons, etc.) of the ith coal type, mining method and combination of washing technologies in the jth geographic unit;

c_{ijm}^{CT} represents the unit (such as ton, 10,000 tons, etc.) of the i-th coal type, the mining method and the combination of washing technologies that are transported from the j-th geographical unit to the m-th geographical unit (such as ton-kilometer, ton-hundred-kilometer, etc.)transportation cost.

3.2 Constraints

(1) Water resource constraints

The reverse distribution of coal water is an important constraint factor affecting the development of coal resources in the central and western regions, and it is also a necessary condition for the growth of crops, and will face problems such as water rights allocation in the future. Due to the scarcity of water resources, the competition between the coal industry and the agricultural sector for water resources will be increasingly intensified. The rational use and allocation of water resources must take a multi-sectoral strategy and a long-term perspective. The coal industry should fully enhance the ability to find water, tap the potential of agricultural water-saving, exchange water rights reasonably, and at the same time, it should improve the use of water-saving technology through constraints. The water consumption in the washing and selection process of coal mining, the water consumption in the conversion process and the water demand of crops should meet the local water resources constraints, so the water resources constraints in the model are shown in formula (2).

$$\sum_{i,m,t} w_{ij}^{P} x_{imlt} + \sum_{i,j,t} w_{imt}^{d} x_{ijmt} + \sum_{k,m} w_{kj}^{c} y_{kjm} \le w_j \quad (2)$$

In the formula, w_{ij}^{P} represents the water demand of the jth geographic unit per unit (such as ton, 10,000 tons, etc.) of the ith coal type, mining method and washing technology combination.

(2) Constraints on greenhouse gas emissions

Under the background of climate change, my country will inevitably put forward a strict absolute carbon dioxide emission limit in the future. Therefore, the coal industry must consider the constraints of greenhouse gas emissions in the process of layout, so as to avoid the project being rejected due to carbon dioxide emissions due to strategic mistakes. Forced elimination. Through the constraints of greenhouse gas emissions, on the one hand, it controls the expansion scale of coal conversion processes such as coal chemical industry and coal power station in a certain geographic unit, and on the other hand provides scientific decision support for the selection of CCS technology. The constraints on GHG emissions are shown in Equation (3):

$$\sum_{i,j,t} e_{imt}^{co2,d} x_{ijmt} \le E_m^{co2,c} \quad (3)$$

In the formula, CO2, dimte is the carbon dioxide emission per unit of the ith coal type, mining method and washing technology combination in the mth geographic unit converted into the dth coal conversion product using the t coal conversion technology; 2CO, CmE represents the carbon dioxide emission of the d coal conversion product The cap on carbon dioxide emissions in m geographic units.

3.3 BPIES Superstructure Modeling

The BPIES proposed in this paper follows the principle of "component counterpart, hierarchical transformation, and cascade utilization" for biomass utilization. The specific superstructure flow chart of the system is shown in Figure 1.

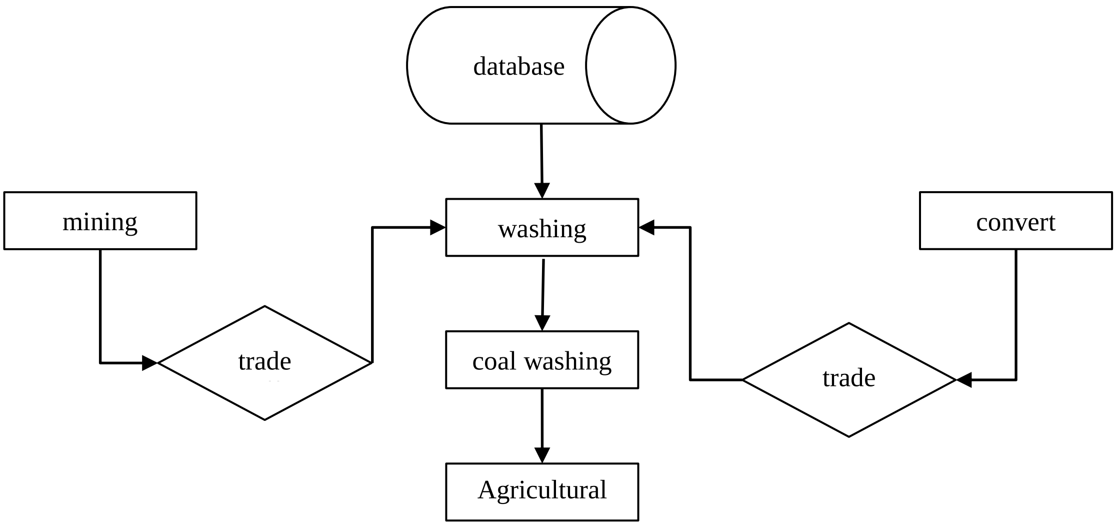

Figure 1. Optimized model structure

The BPIES studied in this paper is the coupling of the integrated energy system and the biomass gasification polygeneration technology. The system is based on the energy demand side response and is an energy system integrating refrigeration, heating, power generation and production of chemical products. A typical BPIES superstructure is shown in Figure 1. The optional technologies for the power generation equipment of the system mainly include thermoelectric conversion prime movers such as biomass gas turbines or steam turbines, photovoltaic power generation systems, and external power grids. The system can be connected to the grid or not according to needs. . The main function of the heating module is to meet the heat load and the heat consumption of the absorption chiller. The optional technologies include waste heat boilers, auxiliary backup boilers and ground source heat pumps. Electric refrigeration and air conditioners, lithium bromide absorption chillers and double-effect ground source heat pumps are the alternative technologies for cooling modules.

4. Overall Optimization of Resources/Energy/Environment and System Optimization of Sustainable Development under Polygeneration Energy System

4.1 Optimization Results of Different Split Ratios

As a regional integrated energy system, while ensuring the security of regional energy supply, it is necessary to consider the cascade utilization of energy, sequential utilization, and optimization of system economic benefits or other objectives. In this paper, the multi-generation mode under different split ratios is discussed in order to obtain the optimal equipment combination and operation strategy of the system in the target area. The effects of different split ratios on GT, NPV and CO2 emissions are shown in Table 1, and the results are shown in Table 1.

Table 1. Influence table of different split ratios on GT, NPV and CO2 emissions

split ratio	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
GT											
NPV											
CO2 emissions				10							

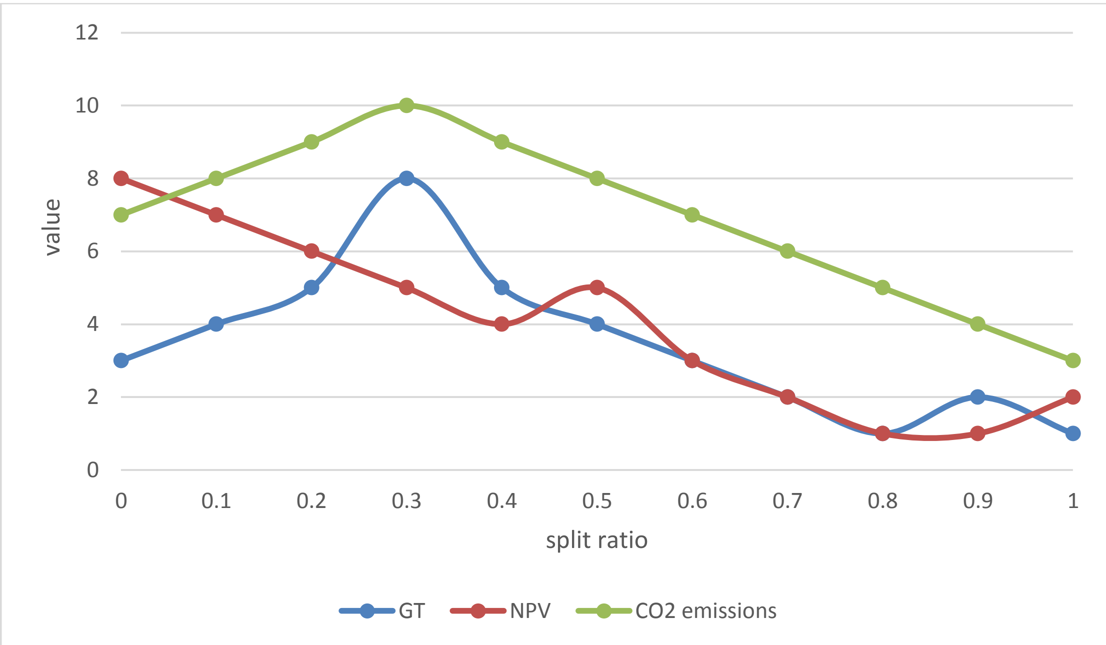

Figure 2. Effects of different split ratios on GT, NPV and CO2 emissions

As shown in Figure 2, when the split ratio increases from 0 to 0.4, the net present value NPV and carbon dioxide emissions of the system reach their maximum values respectively. This is due to the increase in the amount of synthesis gas entering the chemical synthesis module, which increases the investment in equipment and the use of biomass in the chemical module, and the increase in the amount of chemicals produced reduces the net present value of the system and the cost of system operation and maintenance. And when the split ratio increases to 0.7, the system has the shortest payback period and the smallest NPV, indicating that 0.6-0.7 is the optimal interval for the split ratio setting. It should be noted that when the split ratio is set to 0.6-0.7, the biomass consumption drops significantly, while the NPV, biomass fuel consumption, operating costs and carbon dioxide emissions do not increase but drop, and the installed capacity of GT and chemical synthesis The installed capacity and installed capacity of the equipment have not changed at all. This shows that when the maximum split ratio of the system is 0.7, the distribution of biomass fuel is the most reasonable, the operating conditions of GT and chemical synthesis modules are the best, and the energy sequence utilization and operating strategy of the system are optimal.

4.2 Biomass Price Sensitivity Analysis

With the maturity of biomass energy application technology, its marketization and planning price will be higher and higher. In this context, this paper takes M city as the target area, and analyzes its application prospects in terms of the future price growth of biomass raw materials. In addition, this paper supplements the natural gas CHP and natural gas boiler system as alternative equipment to compare and determine the biomass application boundary of the system. The impact of biomass price increase on the installed capacity of biomass GT, natural gas GT and chemical synthesis equipment is shown in Table 2.

Table 2. The impact of rising biomass prices on the installed capacity of biomass GT, natural gas GT and chemical synthesis equipment

price increase percentage	0%	20%	40%	60%	80%	100%
Biomass GT	3	4	3	4	2	1
Natural Gas GT	0.1	0.2	0.1	0.2	2	3
chemical equipment	3	3	2	2	1	0.1

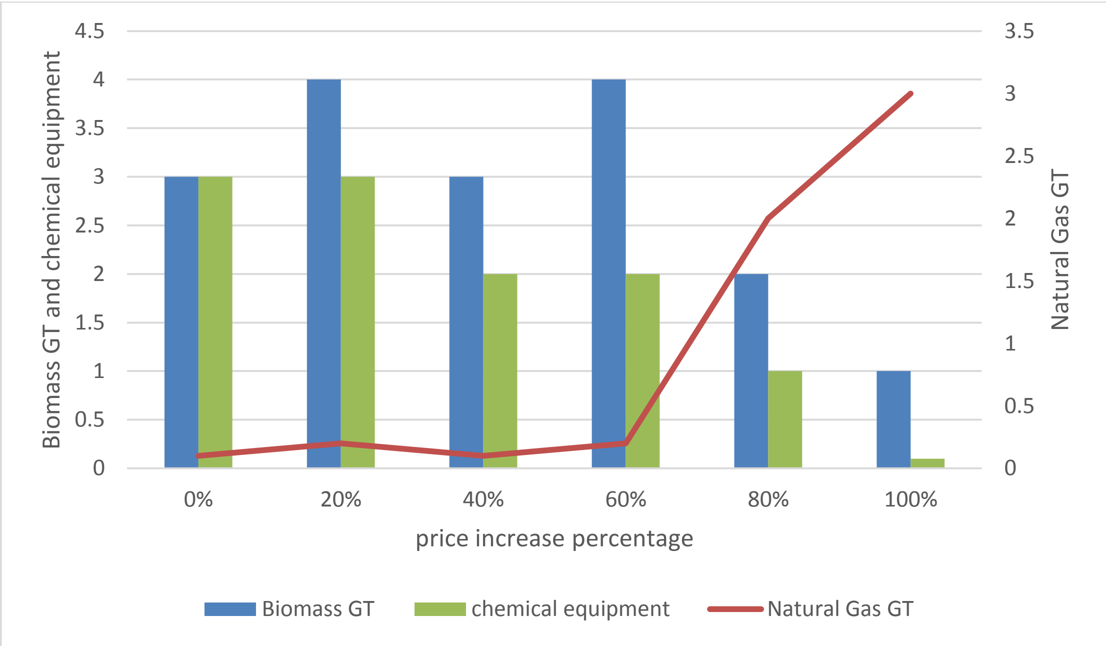

Figure 3. The impact of rising biomass prices on biomass GT and natural gas GT

As shown in Figure 3, when the price of biomass raw materials gradually rises, the installed capacity of biomass CHP and chemical synthesis equipment gradually decreases, from not buying electricity from the grid to buying electricity from the grid gradually increases, and the income from the sales of chemical products increases year by year. Slightly reduced. When the biomass price increased by 70% compared with the current one, the combined 2MW biomass CHP and 3MW natural gas CHP system was used for energy supply. At the same time, the electricity purchased by the system increased significantly, and the sales of chemical products decreased significantly. When the biomass price increases to 90%, the biomass fuel will no longer be used, and the combined energy supply method of the grid and natural gas CHP will be adopted.

5.Conclusions

Based on the constructed unit models, combined with the three decision-making indicators of environment, economy and energy efficiency, this paper establishes a system-level optimal configuration method to solve the BPIES optimal configuration problem based on hourly load. Compared with the conventional CCHP system, BPIES has the functions of capacity optimization, equipment selection and combination, operation optimization, etc., and has more practical applicability in the diversion optimization of chemical products and secondary energy production. For the complexity and uncertainty in energy planning, carrying out regional energy supply and demand adjustment, sustainable development model exploration and energy system optimization management is conducive to alleviating regional energy supply and demand balance, optimizing regional energy consumption structure, and ensuring regional energy supply security. As well as improving the quality of the regional ecological environment, it is of great significance for urban optimization of energy structure, promotion of economic development and environmental protection, as well as ensuring the sustainable development of regional energy in my country.

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