

DES for Sustainable Development

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Abstract: Distributed energy system (DES) refers to an energy system that distributes on the user's side and can achieve energy multipurpose utilization. This paper first introduced the features such as safe, economic and environmentally friendly of distributed energy system, and concluded that DES is the necessary choice of energy sustainable development. Then introduced in detail the application of building cooling heating and power (BCHP) system, which is the main style of building distributed energy system. Several BCHP operating mode was introduced. The benefit, include energy saving and CO₂ emissions reduction, of BCHP of Maryland University of USA was analyzed. Also the application of fuel cell in BCHP system was introduced. And finally further improvements should be made to DES were discussed.

Keywords: distributed energy system sustainable development BCHP

1. INTRODUCTION

People were forced by environmental problem and energy crisis to redetermine their position in nature, and they gradually realized that resource was limited. After paying out heavy cost, people were forced to attach importance to environment, and think about reasonable utilization of limited resource, and eventually came out the global action—sustainable development. One result of the United Nations Conference on Environment and Development, held in 1992 in Rio de Janeiro, was the acceptance of a global action plan to achieve a sustainable development, socially, economically as well as ecologically. Sustainable development means to meet the needs of the present without sacrificing the ability of future generations to meet theirs [1].

To save energy, protect environment and achieve sustainable development, every country now are trying to construct the second energy system, making preparation for legislation, and quickening steps to develop related equipment. The second energy system has six major characters, includes the variety of fuel, the miniaturization of facility, the combination of cooling, heating and power (CCHP), the use of network, intelligent control and management, and high standard of environmental protection. These characters represent the direction of energy development: the use of renewable energy and extensive application of distributed energy system [2].

Distributed energy system (DES) refers to an energy system that distributes on the user's side and can achieve energy multipurpose utilization. The system generally uses gas fuel mainly as the primary energy, renewable energy as assist, and mainly adopts CCHP as the secondary energy, other central energy system (CES) as assist. DES is the best supplement of traditional large power station, and is the best way to improve environment, because it has the following features [3].

First, DES can meet the demand of special cases, for example, districts that have low grid coverage, distributed users, users that require high stability of power supply, such as hospital, bank etc, and users that have variety energy demand, need power, heating and cooling simultaneous.

Second DES can offset the insufficiency of security and stability of large grid. Distributed power supply system (DPSS) that is installed nearby the user directly, can cooperate with large grid and guarantee the reliability of power supply greatly. Even when large grid breakdown or unexpected disasters (such as earthquake, snowstorm, war etc) occur, it can maintain power supply for important user. Meanwhile, it helps to ease the electricity peak load.

Third DES makes integrated utilization of energy possible. DES has small scale and good flexibility, so it can meet user's different demands and achieve integrated energy utilization simultaneously by integration of different circulation, and avoid the problem of transportation of chilled or hot water for long distance. It also improves the efficiency of energy utilization greatly, up to 80 percentages, through recovery of waste heat and reduction of transmission and distribution loss.

DES can reduce the discharge of contaminant by use of advanced energy conversion technology, and decentralizes it to make it easier be absorbed by surrounding vegetation. And DES can achieve effective reclamation of major discharge, for example, fertilization of discharged gas. According to estimation, 66,000-ton carbon dioxide and 330-ton sulphur oxide discharge can be reduced each year if CCHP substitutes each 10 million watt grid power. So DES is in favour of environment and boosts sustainable development.

Also DES pioneers a new way for the utilization of renewable energy. Because of the limitation and pollution of fossil energy, the use and research of renewable energy (such as solar energy, geothermal energy etc) has aroused extensive attention.

Compared with fossil energy, renewable energy has low energy flow density and strong decentralization, so the actual renewable energy system has small scale and low efficiency that determines it is impractical to use renewable energy in CES. But DES supplies the best scale for the utilization of renewable energy. With the research on energy collection, translation storage and utilization of renewable energy develops, whether from the point of environment protection or social development, DES that uses renewable energy as basis certainly will be one of the best energy supply system in the near future.

According to the above discussion, we can see that DES is safe, economic and environmentally friendly. From the point of view of sustainability, DES is almost transcendent. The biggest carrier of DES is building. Together with intelligent control system, DES will be an important part of a building in the future. Next we mainly introduce the application of building cooling heating and power system, which is the main form of building DES.

2. BCHP SYSTEM

2.1 General description

BCHP is a multi-cogeneration system that supplies cooling, heating and power for building. In the BCHP, power is generated by equipments such as gas engine, gas turbine and fuel cell, whose waste heat is reclaimed by boiler, absorption chillers and desiccant to control temperature and humidity of building^[4]. Compared with systems that cooling by power and heating by thermal energy respectively, BCHP can reduce cost greatly.

BCHP can bring great economic and utilization value, and will be used widely in isolated district or house. The economic value is mainly that BCHP doesn't need spare power. It is estimated that up to 2020, the major form of building energy sources will be BCHP, and this is the direction of energy sources development of the 21st century^[5].

2.2 System scheme

Following we will introduce several normal schemes of BCHP. Gas turbine has become the main generator of BCHP, because it has the advantage of low pollutant discharge, high mechanical efficiency, high exhaust temperature and broad capacity range. Used in BCHP, it generate not only power but also steam, so have high both power and thermal efficiency^[6]. Generally high temperature in summer leads to inefficiency contribution of gas turbine greatly and consequently low efficiency. But this condition

can be improved if we use absorption chiller to recover waste heat of turbine to produce chilled water, and then chilled water can cool the gas entering the turbine.

Model1 adopts gas turbine and lithium bromide/water absorption chillers. After driving generator, the gas, which generated by gas turbine, still has abundant oxygen and very high temperature, which generally above 400 centigrade. It can be reclaimed directly or used as combustion - supporting air to carry out secondary combustion by absorption chillers to refrigerate. And secondary combustion has higher thermal recovery efficiency, which is up to 95 percent.

Model 2 is integrated BCHP system. This model adopts micro-turbine generator and lithium bromide/water absorption chillers, which can be single-effect chillers, exhaust re-combusting chillers and re-combusting/heat exchange parallel chillers. For the first one, the exhaust from turbine is directly discharged into the chiller to refrigerate or heat. For the second one, the exhaust that has high temperature and abundant oxygen supplied by turbine is discharged into the chiller and combusts directly to supply cooling, heating and hot water. For the third one, part of the exhaust is recovered by the weak solution, and part is used to carry out secondary combustion.

Model 3 integrates fuel cells and absorption chillers. Fuel cells are seen as a significant innovation for energy generation of the future since they are both environmentally friendly and can convert natural gas to electric current with comparatively high degrees of efficiency. Absorption chillers reclaim the high temperature steam generated by fuel cells.

2.3 Project examples

First we'd like to introduce the BCHP project of Maryland University. Table 1 shows the system specifications, and Figure 1 is the system flow diagram. Turbine, supercharger and generator were installed in a single shaft; combustion air was radial compressed into the regenerator by the supercharger and was heated by exhaust, then entered the firebox and mixed with fuel to combust. Then the combusted air drove the magneto to generate power. Inlet air of turbine is cooled to 15.6°C to keep turbine's constant capacity. The exhaust of the generator was discharged into the absorption chiller to generate steam to produce chilled water, whose rating temperature is 6.7°C, or to produce hot water, whose rating temperature is 93°C. Figure 2 shows the project system scheme.

Table 1: BCHP system specifications

Honeywell Turbine	Broad Absorption Chiller	Kathabar, Liquid Desiccant System
about 30 % efficiency in generating electricity; single moving shaft is about 65,000 RPM; about 1250 CFM 260 °C exhaust gases at design conditions.	double effect with COP up to 1.3; turbine's exhaust delivered to high stage absorber; turbine/chiller efficiency about 60% 93°C hot water available.	low grade heat desiccant, heat available from Broad unit; no supplemental gas; humidification of air for heating season.

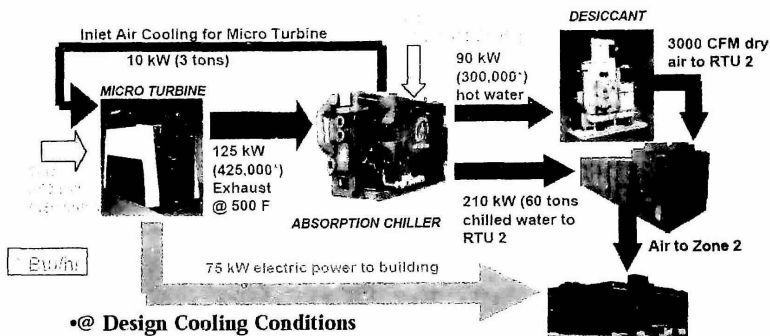


Figure 1: BCHP system flow diagram

The BCHP system began successful test operation in June, 2001. The centre of energy and environment engineering (CEEE) and the department of mechanical engineering of Maryland University tested the system thoroughly and detailed. The tested indexes included power capacity, cooling capacity, power efficiency, COP, heating efficiency, the inlet, outlet temperature and flow of chilled, hot or cooling water, the exhaust temperature and consumed power etc, and the test result reached the design target completely.

Now we can see the benefit of BCHP through comparison. BCHP power generating equipment works 12 hours on working days, and the

determination of cooling system's operating hours and cooling load is based on BIN data. Comparison is based on existing utility prices for building, and comparison of CO₂ emissions was based on national average for power generation, which is 0.65 kg of CO₂ per kWh. Gas price was 53¢/Btu in 2001 and table 2 shows the Comparison of savings in operating charges and reduction in CO₂ emissions. We should know that peak time refers to 12 pm to 8 pm, and intermediate time refers to 8am to 12 pm and 8 pm to 12 am. The peak demand charges were 15 \$/kW in summer and 4 \$/kW in winter respectively.

Table 2: Comparison of savings in operating charges and reduction in CO₂ emissions

Comparison of operating charge									
time	Summer: June- October				Winter: November- May				Total
Item	Peak	Inter	Demand	Total	Peak	Inter	Demand	total	1 year
Electric price(c/kWh)	5.76	5.09	15		4.90	4.34	4		
Cost of 75kW form grid(\$)	3,666	1,619	5,323	10,610	4,058	1,873	2,179	8,110	
Nat. Gas cost to generate 75 kW(\$)	4,000	2,000		6,000	5,434	2,717		8,151	
Total saving in generating electricity(\$)				4,610				-41	4,569
Savings in cogeneration with Absorption chiller (\$)	2,780	1,064	4,940	8,784	200	30	305	535	
Total saving in Micro Turbine/Absorption Chiller system(\$)				13,394				494	13,888
Total Turbine operating hours	848	424		1272	1152	576		1728	3000
CO ₂ emissions in tons									
75kW electricity form grid(tons)	41.3	20.7		62.0	56.2	28.1		84.3	146.3
Micro Turbine emissions(tons)	38.5	19.3		57.8	52.3	26.2		78.5	136.3
RTU instead of Absorption system(tons)	31.4	13.6		45.0	2.8	0.4		3.2	48.2
Reduction in generating electricity				7%				7%	7%
Combined with Absorption Chiller				46%				10%	30%

For its high-energy utilization efficiency, low pollution and noise, fuel cell is considered as one of the most attractive power generation equipment in

21st century. Already many DES systems have adopted fuel cells, for example, "building as power plant (BAPP)" project of Carnegie Mellon University

energy consumption and environmental impact. Also the reconstruction of energy system of CNG edifice was based on fuel cells. The edifice has 32 storeys, with 57,900 m² total area. And it former used 2 centrifrifugal chillers of 2640 kW and 2 gas-fired burners of 2450 kW to cooling and heating. Considering reconstruct the former system into fuel cells BCHP system. Figure 3 shows the system diagram, and the broken lines represent equipments that have already exist formerly. The new system adopted phosphate fuel cells (PAFC), which is a natural gas-fed beta-test co-generative unit able to produce, at nominal conditions, 2700 kW of electric power and 4590kW of thermal power. The former can satisfy the peak load of the edifice, while the latter is reclaimed by absorption chillers. According to detailed calculation, the BCHP system can save at least 20% primary energy compared with former system.



3.CONCLUSION

To conclude compared with traditional energy supplying system, DES has its superiority. DES is an effective measure to save energy, protect environment and realize sustainable development. But we also should note that development of DES confronts many obstacles and a lot of technique problems should be solved. First establish reasonable price relations between natural gas and electricity. A reasonable price that can encourage utilization of clean energy is the final determinant to achieve energy saving^[7]. Second develop equipment for BCHP. Also should investigate the technique measure and economy measure to merge BCHP into grid, and to formulate policy and code that in favours of the development of BCHP. Then establish DES Service Company to design, construct, operate and maintain DES, for equipments of CCHP are more complex than air-conditioner and boiler that consume electricity. At last develop software technology [8,9]. One is DES integration design software. Develop a system integrated model that includes all modules and a computer platform to develop software to optimize design. With the software can design optimal and flexible DES according to different requirements to achieve maximal energy efficiency and economy efficiency under different conditions. What should be paid attention to is that the integration optimization design software of DES should combine well with the energy saving optimization software of building. Without such system integration technology, the DES cannot achieve very good economy effect even constructed with advanced equipment. Another is operation management and control technique of DES. The software is required to ensure the system work in high efficiency when cooling or heating load change for climate reason, or when the price of power, natural gas or other energy change. With such software can control the system well even when the condition

change suddenly, and meet the comfort or other requirements by paying for the minimum cost. Such software should be exploited and improved during the development of DES as quickly as possible.

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