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Application of Solar CHP System in a University Campus for Reduction of CO_2 Emission

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Combined heat and power (CHP) or cogeneration systems have been received more attention during recent years however this concept had been known for a long time. Usually heat engines have efficiencies lower than 45 % so waste heat coming from a heat engine can be applied for heating or cooling purposes. This idea has been implemented in many industries successfully. During recent years this concept has been utilized for residential purposes while in conventional power plants this concept cannot be applied because of long distance between power plants and residential consumers. On the other hand, growing environmental awareness and the ratification of the Kyoto Protocol, has been caused combined heat and power receives more attention as a potential for reduction of energy usage and emissions (Tichi et al., 2010). In this work a university campus in south of Iran has been considered as a case study for doing feasibility study on application of a micro combined heat and power system (CHP) integrated with solar system. Usually a university campus contains different sinks of energy such as lightening, space heating or cooling and swimming pools. For this reason, there are more choices for application of extra heat. Since the ambient temperature in south of Iran is usually more than 30 °C, during 8 months of the year, a combination of absorption chiller, solar system and combined heat and power system has been considered for the simulation. In this work three scenarios have been studied. In the first scenario, CHP system has been coupled with compression chillers. In this scenario CHP system has been designed based on electricity demands. In the second scenario CHP system has been designed based on heat demands. In this case CHP system has been coupled with absorption chiller. In the third scenario combined heat and power system has been coupled with solar system. In all scenarios feasibility study has been done based on international as well as governmental energy price. Finally the amount of reduction in carbon dioxide during life cycle of system has been calculated. Approximately there are 160 university campuses like this case in Iran and application of CHP system can reduce CO2 generation up to 3.2×10^5 t/y.

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1. Introduction

Combined heat and power or cogeneration systems have become more popular because of their important role in reduction of fuel consumption as well as carbon dioxide emissions. Application of combined heat and power units improves the efficiency of energy production. Over the years, CHP system has received more attention in different countries. Wang et al. (2006) have reported that the United States of America have attempted to boost the installed capacity of CCHP systems from 46 GW in 1998 to 92 GW in 2010. This subject has been confirmed by Tichi et al. (2010). They have reported, energy department in the United States had planned by 2010; new constructed and existing commercial, institutional, and residential buildings must be met by CCHP systems. A lot of works have been done on modeling of CHP systems; for example Sontag and Lange (2003) modeled a regional plant for the power and heat supply of a residential complex with 40 flats. The plant consisted of a power-controlled CHP unit, a photovoltaic plant (PV), a field of solar thermal collectors and also power winds. The results showed a distinct decrease in fossil energy demand in comparison with conventional energy supply plants. Sugiartha et.al (2009) studied feasibility of a micro-gas turbine (MGT) based on tri generation system for a supermarket; results showed that the proposed system has a superiority over conventional systems. Pagliarini and Rainieri (2010) simulated a cogeneration unit coupled with a thermal energy storage system for University of Parma Campus in 2010. They suggested a simplified lumped capacity model for thermal energy storage system.

In this work, the potential of CO_2 reduction in a university campus in south of Iran has been studied. There are more than 160 private universities like this case in Iran and application of this system can be very effective in reduction energy consumption. A university campus usually requires considerable space heating and cooling demands because of administrative buildings such as departments, laboratories, workshops, dormitories. Therefore CHP system can be suitable and economic. Two different scenarios have been considered for application of an appropriate cogeneration system in Azad university campus of Mahshahr city. Usually the ambient temperature in this city is more than 30 °C, therefore it needs high cooling demand in most of the months. To cover cooling demands, the cogeneration system has been coupled with absorption chillers and a trigeneration or CCHP cycle should be design. In the first scenario, a combined cooling, heating and power generation system (CCHP) has been considered while in the second one, CCHP system has been coupled with a solar system. Both cases have been analyzed economically as well as environmentally.

2. Calculation Basis

Total constructed area in the campus of Azad University of Mahshahr is 100,000 m^2. The rate of heating loss and cooling demand, through the walls, windows, roofs, and floors areas have been determined equal to 98,328.58, 6,627.89, 100,000, 100,000 m^2 respectively.

The maximum heat loss during winter is about 5,129.04 kW while maximum chilling load during summer is around 10,685.54 kW. The peak of electricity consumption has been determined equal to 16.67 kW. The efficiency of power generation in Iran is around 35 % and the heat efficiency is equal to 55 %. Besides, it is assumed that the trigeneration system operates 18 h/d. The prices of electrical energy and natural gas without subsidies are 0.07 and 0.0085 $/kWh respectively.

3. Cycles and results

In a CCHP system, heat loss from gas turbine is the main source of waste heat recovery. It can be utilized for space heating and cooling. As mentioned above, in this work two scenarios have been studied for designing a trigeneration system for Azad University of Mahshahr. In the first scenario, the CCHP system has been designed on the basis of electricity demands and in the second scenario a trigeneration unit has been combined with a solar system. In both cases, 2 absorption chillers with capacities of 1400 t have been utilized for space cooling. Electrical consumption of each chiller has been evaluated equal to 11.6 kW.

3.1 CCHP unit based on electricity demands

The main parts of power generation unit in this scenario are gas turbine, generator, absorption chillers and supplementary boilers. Three supplementary boilers with capacities of 1900 kW have been utilized, as the recovered heat is not adequate for the absorption chillers. Since the CHP system has been designed in order to meet the peak of electrical demand, there is some electrical surplus per h. It can be sold to the near buildings or governmental network. Considering installation, operation costs and benefits of electricity surplus, it is found out that the initial investment will recover during 10 y with subsidized prices and 5 y without subsidy. On the other hand according to the combustion equation of the natural gas, annual CO_2 and NO_x emissions in this case have been calculated equal to 8403.66 and 7.18 t.

3.2 Solar CCHP unit

The principle elements of the trigeneration cycle in this scenario are thermal solar collectors, gas turbine, a generator and absorption chillers. Solar collectors supply heat demands for space heating and also for absorption chillers. Photovoltaic (PV) cells were not used instead of generator because of high installation costs. Meteorology data of Mahshahr (average radiation energy per day and sunshine hours in a day) have been extracted from related graphs (Arabi and Dehghani, 2010). Based on extracted data from Figure 1, the number of required collectors has been calculated equal to 17490.

Results showed that the total initial investment will be recovered in 15 y considering unsubsidized prices for energy. In this scenario annually just 135.97 t CO_2 and 0.12 tons NO_x will emitted.

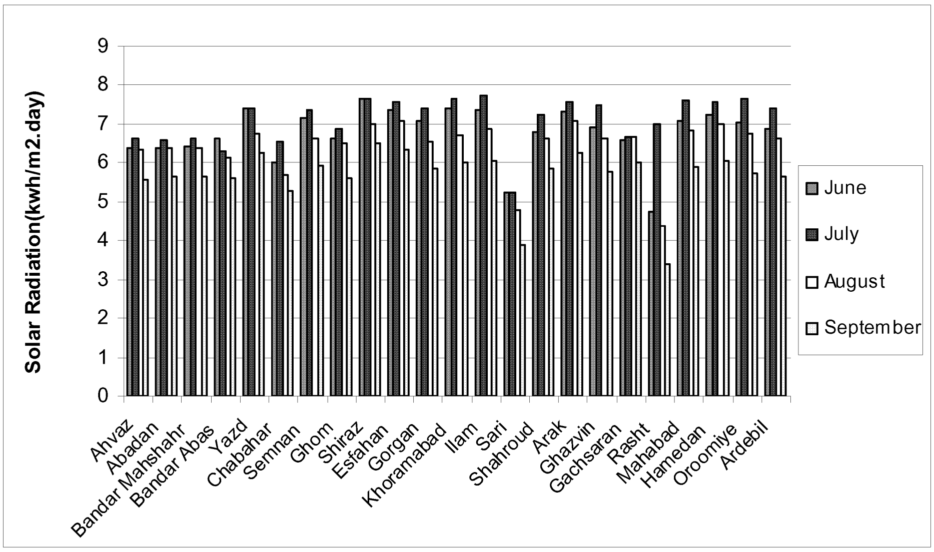

Figure 1: Solar radiation in different cities of Iran (Arabi and Dehghani, 2010)

4. Economic analysis

At the current state of Azad university of Mahshahr, heating and cooling requirement have been supplied through electricity from governmental network. Present average annual demand of electricity in the campus is equal to 3,577,723 kWh.

Table 1 summarizes the electricity and fuel costs of the present condition and future condition if both scenarios implemented.

Table 1: Electricity and fuel costs in three cases

Systems	Electricity cost($)	Fuel cost ($)	Total cost ($)
Present	280,000	-	280,000
CHP	-	165,000	165,000
Solar CHP	-	6,382	6,382

Table 1 shows that using a CHP system, coupled with a solar unit, can distinctly reduces the power demand costs in comparison with other scenarios. In Table 2 initial costs, commercial costs have been reported. Using this data it is possible to make decision regarding feasibility of both scenarios.

Table 2: Different economic parameters in scenarios 1 & 2

systems	Installed cost (1,000$)	Annual operating cost (1,000$)	Initial investment recovery period
CHP	896.2	330.6	5
Solar CHP	8,224.3	12.4	15

The table shows that the initial investment needed for the first scenario is much less than the second case. Therefore in the case of having a limited budget, the first CHP cycle is preferred. On the other hand the operating cost in the second case is much less than the first scenario and this can compensate the disadvantage of the solar CHP system as an expensive unit. The results show that while solar collectors are expensive, a combination of CHP and solar system is not applicable.

5. Environmental analysis

As mentioned in the previous parts, one of the main advantages of combined cooling, heating and power generation systems is their role in reduction of environmental disasters caused by fossil fuel emissions. In this work, the amount of CO_2 and NO_x emissions produced in the current system as well as both CCHP and solar CCHP systems have been calculated. (Table 3)

Table 3: Environmental emissions

Emissions	CO_2 (t)	NOx (t)
Present	2,159.3	1.8
1^{st} scenario	1,511.5	1.2
2^{nd} scenario	1,35.97	0.12

Our calculations showed that application of CHP system is really effective in reduction of CO_2 emissions. Because there are more than 160 university units in Iran, the first scenario of CHP systems can reduces more than 104,943.6 t/y. While in the second scenario the amount of CO_2 reduction can increases by 327,779.5 t/y. If the price of carbon credit based on Kyoto protocol consider, the economics of CHP system will improve.

6. Conclusions

In this work different scenario for CO_2 reduction in a sample university campus of Iran has been considered. It has been showed that application of CHP systems as well as solar CHP system can reduces the energy consumption as well as environmental emissions, significantly. Considering all private universities in Iran, it is shown that application of CHP system can reduces carbon dioxide emissions more than 3.2×10^5 t/y. Meanwhile it is shown that while the cost of solar collectors is relatively high, this technology cannot be applicable.

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