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Optimization of Combined Cooling Heating and Power System (CCHP) by a Novel Hybrid Method

M.M. Ghafurian[1] H. Niazmand[2]

1- Introduction

Combined cooling, heating and power (CCHP) systems (also called trigeneration systems) are a combination of combined heating and power (CHP) systems with absorption or electrical chillers. Combined heating and power (CHP) systems are highly efficient and produce power and heat by utilizing a single source of energy. This system prevents losses of distribution and transmission in global network, decrease fuel consumption, increasing competition in power generation and reducing air pollution. The numerous studies have been done on CCHP showing no complete modeling and optimization by two methods of REUAC and MRM has been not performed so far. In the present study, a novel method that considers energy, economy and emission aspects of the project is presented for sizing and selection of the trigeneration system. The relative equivalent uniform annual benefit method (REUAB), MRM methods are used as for optimum sizing of the system. The results of sizing are presented for grid on mode. Finally, sensitivity analysis is performed to examine the effects of 10 % increase in electricity and fuel costs on the objective functions and optimum values of design parameters.

2- Methodology

The present case study is a hotel building in Tehran, Iran.

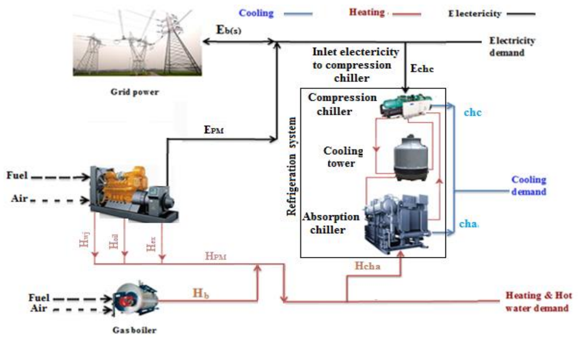

Fig. 1 The schematic of CCHP system with inter-connection to the grid.

The hotel contained 24 suits with the area of about 90 m^2. Figure1 shows the CCHP system with inter-connection to the grid.

In this research, the maximum rectangle method (heating $MRM_{,h}$ and electric $MRM_{,e}$) and relative equivalent uniform annual benefit method (REUAB), is introduced to determinate the capacity of prime mover and other equipment of CCHP system. In fact, REUAB of all costs of traditional power system ($EUAB_{trad}$) and CCHP system ($EUAB_{CCHP}$) are found by the following equation:

$$REUAC = EUAB_{trad} - EUAB_{CCHP} \quad (1)$$

In this method, REUAC function is determined based on annual benefit, required annual load of building, driven capacity, element load, boiler and chiller capacity. The MRM is determined the limitation of prime mover nominal capacity for optimization because the equipment's nominal capacity are not from the maximum range of energy demands.

$$\begin{cases} \mathrm{Max}\{REUAB\} = (n_j \times E_{nom})^{opt} \\ \mathrm{Min}\{E_{MRM_i}\} < n_j \times E_{nom} < \mathrm{Max}\{E_{MRM_i}\} \end{cases} \quad (2)$$

3- Results

Table 1 shows the optimum values of decision variables as well as the value of objective function (*REUAC*) at the optimum point for grid on modes and Table 2 shows the results of the optimization by applying the real conditions for prime mover on the objective functions and optimum values of design parameters. It was observed that REUAB for MRM_e &REUAB mode was higher than MRM_h & REUAB mode in the same constraint of selecting prime mover. Furthermore, if optimization procedure is not performed by applying real conditions for the prime mover, the optimum values of design parameters and objective function will be unreliable.

4-Conclusion

New approach was introduced for estimating capacity of combined cooling, heating and power system for grid on operating mode. The decision variables include cooling capacities of absorption and compression chillers, nominal capacity of prime mover, its part load and boiler heating capacity. single- objective optimization Genetic Algorithm are used for obtaining the final optimum point considering energy, economy and emission aspects with the help of REUAB and MRM methods. Results for our case study showed that by selecting one optimum selected gas engine

[1] Ph.D. student, Ferdowsi University of Mashhad.
[2] Corresponding Author: Professor, Ferdowsi University of Mashhad. niazmand@um.ac.ir

(E_{nom}=122kW), the maximum value of REUAB was327×10^2($/year). Finally the sensitivity analysis of the effect of apply real conditions for prime mover showed, REUAB decreased -0.79%. Furthermore the gas engine nominal power increased 10.7%.

Table 1. Optimum values of decision variables as well as the value of objective function (REUAC) and MRM methods at the optimum point for grid on mode

Optimization procedure enforcing	Without any a constraint of selecting prime mover					
Parameters	MRM_e and REUAB		MRM_h and REUAB		MRM_e and REUAB	MRM_h and REUAB
Nominal	$E_{nom,1}$	$E_{nom,2}$	$E_{nom,1}$	$E_{nom,2}$	E_{nom}	E_{nom}
Gas engine nominal power (kW)	34	87	22	303	122	323
Boiler heating capacity (kW)	463.3		199.2		462.8	203.5
Electrical chiller capacity (kW)	537.5		352/7		537.2	355.7
Absorption chiller capacity (kW)	113.5		298.3		113.8	295.3
REUAC ($/year)×$10^2$	94.9		88.1		327.5	318.5

Table 2, Results of sensitivity analysis for change in optimum values of design parameters and objective function (REUAB)

Design Parameters	Change in optimum values
Gas engine nominal power (%)	+10.7
Boiler heating capacity (%)	-11.73
Electrical chiller capacity (%)	-10
Absorption chiller capacity (%)	+9.6
REUAB (%)	-0.79