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## *Selection of Gas Engine Capacity in Optimization of CCHP System Using Genetic Algorithm; A Case Study of Water Sports Complex*

F. Tavakoli Dastjerd<sup>1</sup>, M. M. Ghafoorian<sup>2</sup>, M.H. Shafiei Mayam<sup>\*3</sup>

1- Department of Mechanical Engineering, University of Sistan and Baluchestan, Zahedan

2- Department of Mechanical Engineering, Technical and Vocational University of Qaenat (Imam Khomeini), Qaen

3- Department of Mechanical Engineering, Bozorgmehr University of Qaenat, Qaen

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### **ABSTRACT**

Energy, economic and environmental analysis have been employed in order to optimize optimal (nominal) capacity of a combined cooling, heating and power system in a water sports complex. Design parameters are nominal capacity and number of gas engines and their partial load, heat capacity of boiler and cooling capacity of electricity and absorption chillers. These parameters are optimized either in the scenarios of possibility of selling electricity ( $S_s$ ) or impossibility of selling scenarios ( $S_{NS}$ ). Design parameters are optimized using genetic algorithm and a multi criteria objective function that is called relative annual profit (RAB). Next, how to select optimal capacity of gas engine has been investigated economically, saving fuel and controlling the pollutants ( $CO$ ,  $NO_x$ , and  $CO_2$ ). Optimization results illustrate that two gas engine with capacity of 130 kW and 150 kW have the maximum value of objective function in the scenarios of possibility of selling electricity, while in the impossibility of selling scenarios the maximum value of goal function is for on 120 kW gas engine. In addition, the results reveal that payback periods on investment are increased (decreased) when two similar capacity are chosen in the cases of  $S_s$  ( $S_{NS}$ ). Moreover, fuel consumption and  $CO_2$  emissions are decreased (increased) in the scenarios of  $S_s$  ( $S_{NS}$ ).

### **KEYWORDS:**

Combined cooling, Heating and power system, Maximum annual rate of return, Possibility of selling electricity

\* Corresponding Author, Email: shafiei@buqaen.ac.ir

## 1- INTRODUCTION

Decentralized power generation using combined cooling, heating and power system prevents losses of distribution and transmission in global network, decrease fuel consumption, increasing competition in power generation and reducing air pollution [1-4]. Although numerous studies have been done on CCHP that most of these researches are on optimization and determination of capacity of these systems according to energy command [5-7], no work has been done on selecting initial drive capacity (gas engine) in order to optimize CCHP. This is more serious for water sports complex that is one of the most important public areas in energy consumption. Providing thermal and cooling energies of swimming pool water, Jacuzzi, ventilation and purification needs huge systems that cause high energy consumption. Moreover, electricity usage of network regarding to provide electricity need of complex causes high energy losses. For this reason, in the present study optimization of heating, cooling and electricity sections is done for a water sports complex. Optimization is done in the scenarios of possibility of selling electricity ( $S_s$ ) or impossibility of selling scenarios ( $S_{NS}$ ) and determination of optimal capacity of gas engine has been investigated economically, saving fuel and environmentally ( $CO$ ,  $NO_x$ , and  $CO_2$ ).

## 2- Methodology

In this paper, annual benefit function is employed in order to equivalent all initial costs, salvage and performance. In fact, annual benefit is determined using difference of all costs of traditional power system ( $AC_{trad}$ ) and CCHP system ( $AC_{CCHP}$ ) via following equation:

$$RAB = AC_{trad} - AC_{CCHP} \quad (1)$$

In this method RAB function is determined based on annual benefit, require load of building during the year, driven capacity, number, element load, boiler and chiller capacity

$$Max\{RAB\} = (n_j \times E_{nom})^{optimum} \quad (2)$$

## 3- Results

One of the most important problems of achieving optimized CCHP system is choosing method of nominal capacity of prime mover; while these systems demanders determine optimized capacity of prime mover ( $E_{opt}$ ) after technical calculations of required loads. In most industrial centers, lower capacities ( $E_1$ ,  $E_2$ ) is used instead of optimized nominal capacity

( $E_{opt}$ ) while  $E_1 + E_2 = E_{opt}$ . The reason is permanent need and enhanced use from the system (when one system needs to repair). In this section, comparison of choosing method with selecting optimized capacities via RAB method is explained based on economical aspect (annual benefit and period of return investment), fuel consumption ( $FESR$ ) and air pollution of carbon dioxide ( $CO_2$ ).

Table 1 illustrates investigated parameters and annual benefit values for optimized capacities which are obtained via RAB method and choosing similar capacity of gas engine in both scenarios ( $S_s$  and  $S_{NS}$ ). The results of  $S_s$  scenarios reveal that the period of return on investment is increased by choosing two similar gas engines with capacities of 140 kW instead of gas engines with 150 and 130 kW, while annual benefit, air pollution of carbon dioxide and fuel consumption are decreased. This could be because of consuming more fuel and, providing unfit load curves.

The results of  $S_{NS}$  scenarios reveal that annual benefit is decreased by choosing two similar gas engines with capacities of 60 kW instead of gas engine with 120 kW, while the payback period on investment, air pollution of carbon dioxide and fuel consumption are increased. This variation could be because of increasing number of prime movers which leads to enhancement of recovery heat from gas engines, providing heating load, less fuel consumption, and less pollutants emission.

## 4- Conclusion

Energy, economic and environmental analysis have been employed in order to optimize (nominal) optimal capacity of a combined cooling, heating and power system in a water sports complex. Design parameters are number of gas engines and their nominal capacities, element load, boiler capacity, electrical and absorbing chillers capacity in both  $S_s$  and  $S_{NS}$  scenarios. These parameters are optimized using annual benefit ( $RAB$ ) and genetic algorithm. Finally choosing of nominal capacity of gas engine are investigated based on economic ( $RAB$ ,  $PB$ ), fuel consumption ( $FESR$ ) and environmentally ( $CO_2$ ). Results demonstrate that using CCHP system instead of traditional system not only efforts required energies but also causes appropriate annual benefit for the water sports complex, while annual benefit is positive in both scenarios. In fact, the periods of return on investment are 8.2 and 10.6 years when two gas engines (130 kW and 150kW) are chosen in the  $S_s$

**Table 1. Investigated parameters and annual benefit values for optimized capacities which obtained via RAB method and choosing similar**

$R_{CO_2}$ (%)	$FESR$ (%)	$PB$ (year)	$RAB \times 10^3$ (\$/year)	Nominal capacity (kW)	Scenario
35.2	22.1	8.2	249.818	$E_{opt2}=150$ & $E_{opt1}=130$	$S_{NS}$
29	19.6	8.3	243.817	$E_2=140$ & $E_1=140$	
44.1	36.8	10.6	180.657	$E_{opt1}=120$	
51	39.7	11.9	167.312	$E_2=60$ & $E_1=60$	$S_S$

scenario and one gas engine (120kW) is chosen in the  $S_{NS}$  scenario respectively. Additionally, investigation results of nominal capacity of gas engine as initial driver show that performance of initial drivers with no similar capacities are better than similar capacities in both scenarios. Actually, the annual benefit is decreased and the period of return on investment is increased by choosing two similar capacities. Fuel consumption and air pollution are increased in the  $S_{NS}$  scenario.

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