ELECTRICITY PRICING PRODUCTION FROM COMBINED POWER PLANT

FALAH F. HATEM
University of technology - Mechanical Engineering Department

Abstract
The main goal of combination the power plant is to achieved high efficiency in addition to reduced the production cost of the unit power produced from the plant.
This work included the cost calculation of power unit which produced from a combined power plant and the comparison this cost with that power produced from gas turbine power plant, the results shows that the price of unit power which produced from combined plant is less when the annual operation hours is more than 600 hr. This work shows also the effect of different parameter such as thermal efficiency, fuel price, and the operation years on the power unit price.

1-Introduction

The combined cycle in the combined power plant consist of Topping cycle which produced power (gas turbine cycle) and the heat rejected from this cycle is used in a lower Bottoming cycle (steam turbine cycle) which also produced power the main goal of this combination is to achieved increasing in work which produced from the heat addition to the plant (fuel energy)(1) Always the Topping cycle is a gas turbine unit when the temperature reaches more than 1100^{o}C and the Bottoming cycle is a steam turbine unit. The plant will have high efficiency; the power produced will be more over fixbility , fast starting at the partial load and high efficiency for wide loads.(2)
The best method for evaluating the power plant economy is the cost calculation of power unit which produced from this plant and then compared with cost of power produced from a classic power plant(3)

2-The unit power produced cost calculation

The cost can be calculated from the equation (3):

$$P_E = \beta * IC + F + OM \quad \text{------------ (1)}$$

The power unit price can be calculated by dividing equation (1) by the total power produced annually:

$$C_e = \frac{\beta * IC}{WH} + \frac{F}{WH} + \frac{OM}{WH} \quad \text{-------------- (2)}$$

The capital cost calculated from:

$$IC = C_o * W \quad \text{------- (3)}$$

The β Interest ratio calculated from (1,4):

$$\beta = \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right] \quad \text{-------------- (4)}$$

The fuel cost calculated from (5):

$$F = \xi QH \quad \text{------------------ (5)}$$

OM Annual operation and maintenance cost is equal to the fixed cost (U) (staffs salaries, insurance…ect) and running cost (V) (maintenance, spare parts …ect.), then the power unit price is given by:

$$C_e = \frac{\beta C_o W}{WH} + \frac{QH}{WH} + \frac{U}{WH} + V \text{ ----- (6)}$$

$$C_e = \frac{\beta C_o}{H} + \frac{\xi}{\eta_o} + \frac{U}{WH} + V \text{ ----- (7)}$$

Where:

$\eta_o = W/Q$ Is the plant overall efficiency

3-The Combined Power Plant

Figure (1) show a flow diagram of a 125MW Brown-Bovary plant [6] ,the plant consist of a gas turbine unit, waste heat recovery boiler without extra fuel consumption and steam turbine unit, the description data of this plant is given in table (1) . Table (2) represents the economic data which are used to calculate the price of electric power unit which produced from the combined plant and from the gas turbine plant depending on the references (1-7).

4-Results and discussion

Depending on the table (2) and the equation (7) the power unit price can be calculated for both combined plant and gas unit plant,its equal to (0.03755$/kWh) for the combined plant and (0.0355$/kWh) for gas turbine plant, so the combined plant is more efficient because of low power unit price. the operation hours has an clear effect on the price of energy unit produced,figure (2) shows that the price come down by 45% in the combined plant and by 30% in the gas turbine plant when the operating hours increase from 1000hr to 8000hr ,its can also noted that the power unit price in the combined plant is more than in the gas turbine plant at operation hours less than 600hr. figure (3) shows the fuel price increasing effect on the power unit price for both combined plant and gas turbine plant for different operating period its clear that the combined plant dose not produced electricity at low price for low fuel price at low operation hours.

4-1The effects of different parameters on the power unit price can explain as follows:

a- thermal efficiency

Figure (4) shows the relation between the power unit price of the combined plant and the Investment cost at different thermal efficiencies, at certain efficiency we can note that the price increase by 50% when the Investment cost doubled also we can note that when the plant works at 50% efficiency and Investment cost of 300$/kW it will produced electricity by same cost with that of plant which works at 46% efficiency and Investment cost of 100$/kwh.

b- the fuel cost

The effect of fuel cost shows in figure (5), at fixed Investment cost the fuel cost increasing or decreasing by 25% will decrease or increase the price by 15%-25%.

c- Operating years

Figure (6) shows nonlinear relation for operating hours at different Investment cost when the operating years increase from 15 years to 30 years the power unit price decrease by 5% at Investment cost of 500$/kW, at Investment cost from 100$/kW to 300$/kW and when operating years reduced by 5years that will equal to 50$/kw reduction from Investment cost.

d- Operating and maintenance cost

From equation (7) we can note that the maintenance cost affected the power unit price and the increasing or decreasing the operating and maintenance cost will affected the power unit price by the same way.

5-conclutions

a. The power unit price of the combined plant is less than gas turbine plant at operating hours more than 600h.
b. The improvement of plant thermal efficiency reduced the power unit price.
c. The operating and maintenance cost and the operating years have a clear effect on the power unit price.

References

1- جون ه . هورلوك "محطات القوى المؤلفة" ترجمة د. خليل محمود جامعة الملك سعود، المملكة العربية السعودية، 1998.

2-Al.Wakil,M.M "Power plant technology",Mc Graw-hill Book company,Singapore,1984.

3-Spector,R.B."A method of evaluation life cycle costs of industrial gas turbine",ASME J.of G.T and power,vol.111,pp637-641,1989.

4-Hashem H.H. "Thermal-Economic analysis of industrial turbine cogeneration plant", Energy conves. Mgmt. Vol. 32,No.32,pp419-424,1991.

5-Ayyash, S. & Hammoudeh S."Economic analysis of energy management for cooling systems in Kuwait", Energy, vol.10, No.6, pp 721-725, 1985.

6- Czermak H. & Wansch A. "The 125 MW combined cycle plant Korneuburg ;Design features , plant performance and operation experience" , ASME paper 82GT-323, 1982.

7-Baujart V. "comparison of MED and MSF desalination processes for power and water combind plants", Int.conf.of energy and water desalination,Tripoli-Libya,20-21 June 2000.

Pt.	Mass (kg/s)	Pressure (bar)	Temperature (^oC)	Enthalpy (kJ/kg)	Entropy (kJ/kg K)
1	350	1.01	15	-	-
2	350	10.1	330	-	-
3	363	9.5	900	-	-
4	363	1.5	491	-	-
5	363	1.1	105	-	-
6	43.2	4.4	145	620	1.81
7	43.2	33.2	433	3300	7.02
8	7.9	4.4	210	2880	7.18
9	2.5	0.163	55	2490	7.24
10	48.6	0.07	40	2300	7.38
11	48.6	0.07	26	120	0.381
12	48.6	0.163	28	127.6	0.409
13	51.1	0.163	56	233	0.78

Table (1) the description data of the 125 MW combined power plant

No.	Items	units	Combined plant	Gas turbine plant
1	Investment cost	$ 1kW	350	250
2	Interest ratio	%	6	6
3	Operating hours	hr	8000	8000
4	Fuel cost	$/10Btu	4	4
5	Fixed cost	% of Investment cost	1	1
6	Running cost	$/kWh	0.005	0.005

Table (2) the economic data

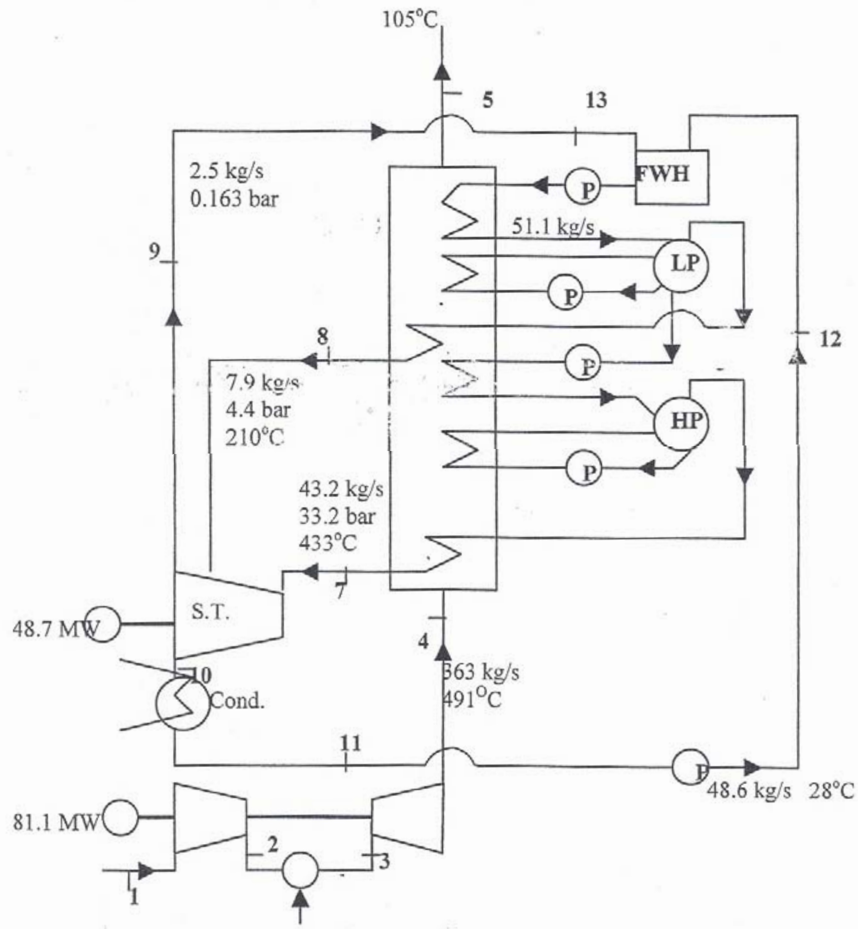

Figure (1) the flow diagram of the combined plant

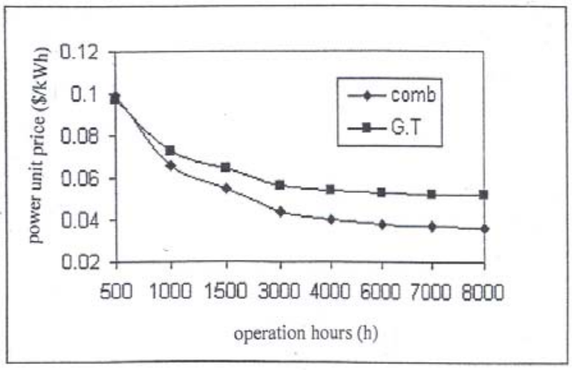

Figure (2) the price changing with operation hours

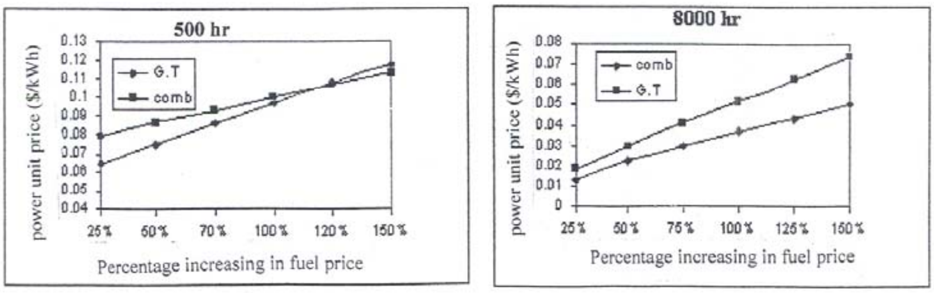

Figure (3) the fuel price increasing effect

Nomenclature

C_o Investment unit cost (\$/kWh)
F Fuel cost (\$/year)
H Actual annual working hour (h/year)
IC Investment cost (capital cost) (\$)
n Number of operation years
OM Annual operation and maintenance cost (\$/year)
P_E Power produced annual cost (\$/year)
Q The consumed fuel energy (kW)
W Installed capacity (kW)

Greek letters

β Interest ratio (%)
ξ The fuel unit price (\$/kWh)
η_o The plant overall efficiency