CHEMICAL ENGINEERING TRANSACTIONS Volume 18, 2009
Editor Jiří Klemeš
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DOI: 10.3303/CET0918155

Evaluation of GE, Siemens and Alstom Gas Turbines in Power and Steam Production of Iran LNG Project

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In recent years, natural gas fired gas/steam combined cycle power plant has become popular due to its high efficiency and low emissions. However, the energy utilization is far from maximization in the conventional combined cycle power plant.
IRAN LNG Plant will consist in its initial phase of two LNG Trains. The sour wet gas is supplied to IRAN LNG by dedicated facilities, producing the raw gas from SOUTH PARS field. The main power generation facility in the plant is located in the utility area and consists of five gas turbine generators and HRSGs and two steam generators optimized to supply the required power for Liquefaction Units and other parts of two trains.
The aim of the present study is to investigate the different conditions of Combined Cycle Power Station in different scenarios. Regarding to steam and power requirements in this project, application of GE, Siemens and Alstom gas turbines have been considered. In this regard, different cases and conditions have been evaluated and compared. Simulation and economic analysis of each case has been performed in GT PRO 17 as one module in THERMOFLOW software. Also exergy and exergoeconomic analysis have been performed through Matlab code.

1. Description

The main power generation facility in the plant is located in the utility area and consists of five gas turbine generators and HRSGs and two steam generators optimized to supply the required power for Liquefaction Units and other parts of two trains [1], [2].
Due to unavailability on Iranian market of GE gas turbine as compressor drives, LNG Plant configuration need to be modified according to a new philosophy requiring all electric drives for refrigerant compressors.

Please cite this article as: Mazhari V., Khoshgoftar M.H. and Amidpour M., (2009), Evaluation of ge, siemens and alstom gas turbines in power and steam production of iran lng project, Chemical Engineering Transactions, 18, 947-952 DOI: 10.3303/CET0918155

The aim of this work is investigation of using different gas turbines for providing steam and power inn Iran LNG project. The scenarios considered in this evaluation have in common the gas generation side, consisting of n.5 Gas Turbines, each provided with a Heat Recovery Steam Generator (HRSG). However, it should be noted that in the case at n. 5 GT are barely sufficient to grant the required power (684MW) so that to comply with the (n+l) philosophy criteria, one additional GT should be accounted for, with relevant additional costs. The other scenarios differentiate on the steam side since Condensing Steam Turbines (ST) and Back Pressure Steam Turbines (BPST) have been considered [1], [2].
Due to the presence of gas turbines, which are highly affected by ambient condition, the plant design is conceived to match the power demand in the worst condition, when the temperature is particularly high. For this reason, the Gas turbines are design to operate at 48"C, and the plant is designed for a normal operation at 43°C producing 684 MW. Of course the plant is fit to operate at 48"C, accepting a lower efficiency and a reduced generation capacity. Steam and power maximum requirements in Iran LNG project has been shown in Table 1. Also, schematic of optimum power and steam generation unit in Iran LNG project has been demonstrated in Fig.1.

Table.1.Steam and power maximum requirements in Iran LNG project

Requirement	**Value**	**Remarks**
Electric Power	684 MW	2 Trains – Loading mode
HHHP steam	60.3 t/h	525°C, 100 bara
MP steam	400.0 t/h	270°C, 11 bara

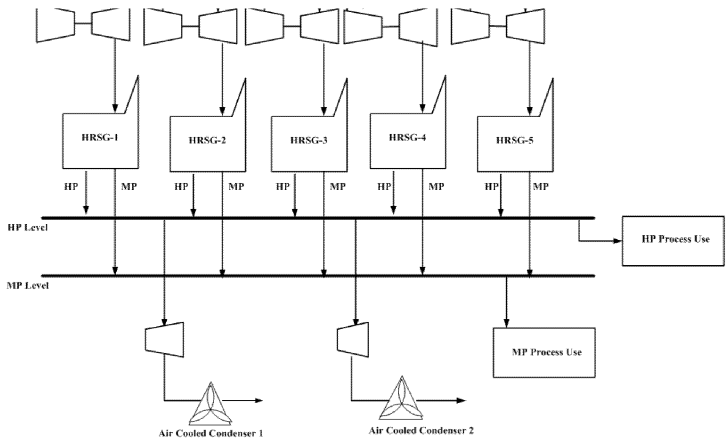

Fig.1. Schematic of optimum power and steam generation unit in Iran LNG project

2. Exergy Analysis

Exergy is the maximum theoretical useful work attainable from an energy carrier under the conditions imposed by an environment at given pressure p_0 and temperature T_0, and with given amounts of chemical elements [3], [4]. The purpose of an exergy analysis is generally to identify the location, the source, and the magnitude of true thermodynamic inefficiencies in thermal systems. Disregarding kinetic and potential energy changes the specific flow exergy of a fluid at any cycle state is given by [3], [4]:

$$e = h - h_o - T_0(s - s_o) \quad (1)$$

The reversible work as a fluid goes from an inlet state to an exit state is given by the exergy change between these two states [4]. That is:

$$e_2 - e_1 = h_2 - h_1 - T_0(s_2 - s_1) \quad (2)$$

where the subscripts 1 and 2 represent the inlet and the exit state for a flowing fluid. Now, we present the exergy destruction and exergy efficiency relations for various cycle components in plant [3].

3. Exergoeconomic

3.1 Cost Equation for Plant Component

All costs due to owning and operating a plant depend on the type of financing, the required capital, the expected life of a component, and so on. The annualized cost method of Moran was used to estimate the capital cost of system components in this study [5], [6], [7]. The amortization cost for a particular plant component may be written as:

$$PW = C_i - S_n PWF(i,n) \quad (3)$$

$$\dot{C}(\$/year) = PW \times CRF(i,n) \quad (4)$$

The present worth of the component is converted to annualized cost by using the capital recovery factor CRF (i,n), i.e [7]. Dividing the levelized cost by 8000 annual operating hours, we obtain the following capital cost for the kth component of the plant.

$$Z_k = \Phi_k \dot{C}_k / (3600 \times 8000) \quad (5)$$

The operating and maintenance costs are taken into consideration through the factor $\Phi_k = 1.06$ for each plant component whose expected life is assumed to be 30 years [7], [8].

3.2 Thermoeconomic Modeling

The results from an exergy analysis constitute a unique base for exergoeconomics, an exergy-aided cost reduction method. A general exergy-balance equation, applicable to any component of a thermal system may be formulated by utilizing the first and second law of thermodynamics. In a conventional economic analysis, a cost balance is usually formulated for the overall system operating at steady state [4]:

$$C_{P,tot} = C_{F,tot} + Z_{tot} \quad (6)$$

The cost balance expresses that the cost rate associated with the product of the system (C_P) and the cost rates equals the total rate of expenditure made to generate the product, namely the fuel cost rate (C_F) and the cost rates associated with capital investment (Z^{cl}) and operating and maintenance (Z^{OM}).

4. Results:

Thermodynamic simulation and economic analysis of GE, Siemens and Alstom gas turbines for providing steam and power requirements in Iran LNG has been performed in GT Pro. In this regard, computer code has been developed for exergoeconomic analysis that can be link to GT Pro. Evaluation of using GE, Siemens and Alstom gas turbines in power and steam production of Iran LNG Project has been demonstrated in Table1. As shown, Alstom is most and GE is lowest CHP efficiency. Also, plant net efficiency of Siemens is most and GE is lowest. In addition, Siemens is lowest and Alstom is most pay back and electricity price. Therefore, Siemens V.94.2 gas turbine is best choice for Iran LNG project.

In addition, exergy loss rates in Siemens, Alstom and GE cases at different ambient temperatures have been demonstrated in Fig 2, 3 and 4. The exergitic net electricity cost based on exergetic and economic analysis for each case has been calculated by Matlab code and has been illustrated in Fig.5. As shown, exergetic net electricity cost of Siemens gas turbines is lowest. It represents that Siemens case is best selection in view of exergetic and economic analysis simultaneously.

Table.1. Evaluation of using GE, Siemens and Alstom Gas Turbines in Power and Steam Production of Iran LNG Project

Parameter	CHP efficiency	Plant net efficiency	Pay back	Electricity Price	Fuel Price
Model/Unit	%	%	yr	USD/Kw.hr	$/GJ
Siemens V.94.2	61.61	41.12	3.548	0.0478	6.662
Alstom GT13E2	60.79	40.57	4.21	0.0493	5.38
GE 9231EC	60	40.04	3.997	0.0491	5.395

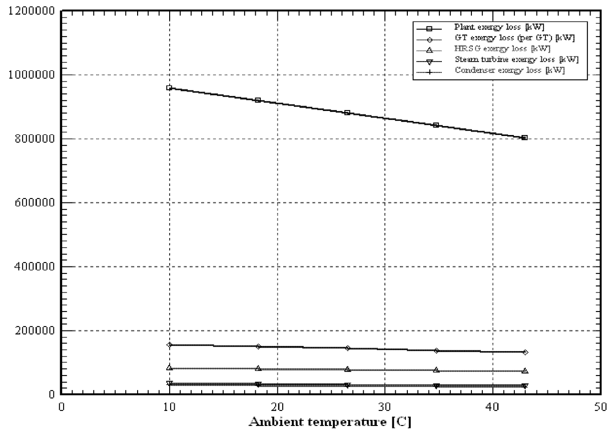

Fig.2 Exergy loss rates in Siemens case

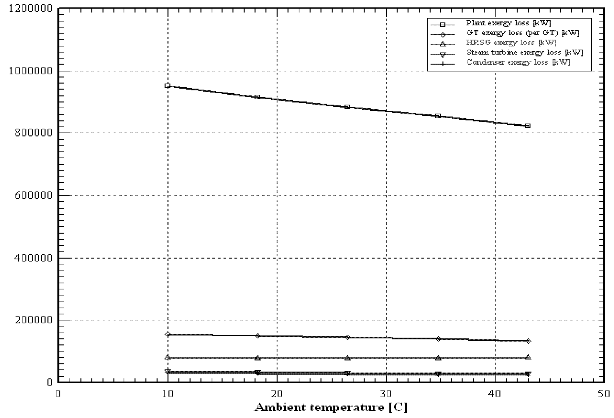

Fig.3. Exergy loss rates in Alstom case

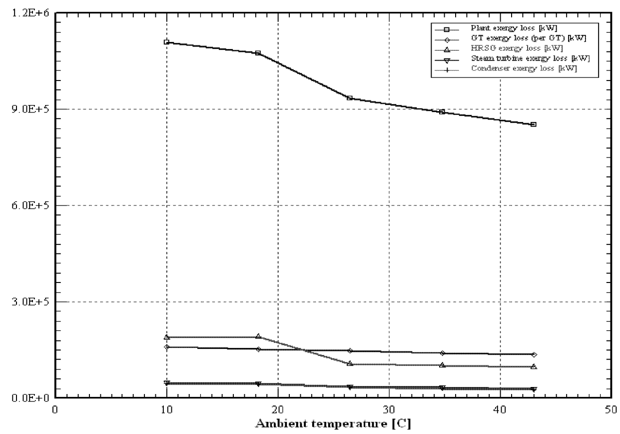

Fig.4. Exergy loss rates for GE case

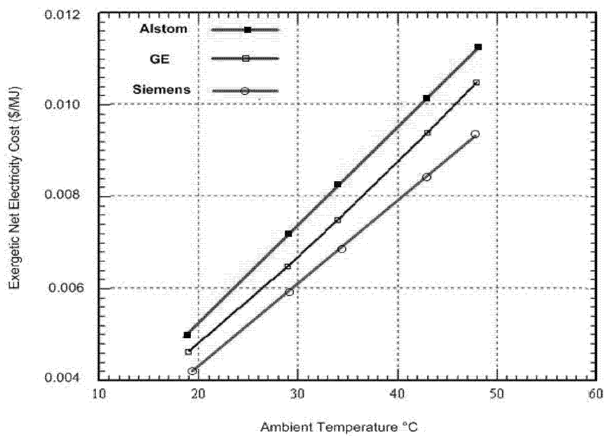

Fig.5. Exergitic net electricity cost for each case

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