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Power Plant Optimization Study in Iran LNG Project through MINLP Method

Mohammad Hasan.Khoshgoftar Manesh[1, 2], Vahid Mazhari[1], Majid Amidpour[2,*]
1. Iranian Power Projects Management Company (MAPNA), Oil and Gas Division Mechanical Department, Tehran, Iran
Email: Khoshgoftar_m@mapna.com; Mazhari_v@mapna.com
2. K. N. Toosi University of Technology, Mechanical Faculty, Tehran, Iran
*Associate Professor, Head of Energy System Department
Email: amidpour@kntu.ac.ir

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. Due to unavailability on Iranian market of gas turbine and rely on own Siemens V.94.2 gas turbine that manufactured by MAPNA company in Iran, LNG Plant configuration in Iran LNG project need to be modified according to a new philosophy.
The main purpose of the present study is to identify a technical solution able to satisfy the LNG Plant requirements from the point of view of electric power and steam and attention to reduction of environmental emissions. Also, economic impact has been considered. The optimization consists in finding the best technical solution allowing the Plant to target the availability and specified yearly production.
Since applications of this kind for a Power Station of this dimension in island operation are quite exceptional and unique, all the margins and cares shall be taken in order to avoid any bottlenecking in the future phase of detail engineering. In addition, different scenarios have been proposed and best configuration has been selected by MINLP method.

1. Introduction

This specification recapitulates the site conditions and defines the basis of the Engineering Work for the LNG Project at Tombak in Iran. The LNG plant site is located at Tombak [1],[2].
The aim of the present study is to investigate the find optimum configuration and process condition of combined cycle power station by MINLP method. Due to the presence of gas turbines, which are highly affected by ambient condition, the plant

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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.

Table.1 Steam and power maximum requirements [1]

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

On the contrary, during the cold season, the generation capacity increases of almost 25% and when the temperature goes down to 19°C the operation is close to a "n+2" configuration. This means that, planning the maintenance during the coldest months, a certain sparing capacity can be granted even is a generator is unavailable [3].

2. Optimization

Mixed Integer Nonlinear Programming (MINLP) refers to mathematical programming with continuous and discrete variables and nonlinearities in the objective function and constraints [3]. The use of MINLP is a natural approach of formulating problems where it is necessary to simultaneously optimize the system structure (discrete) and parameters (continuous). MINLPs have been used in various applications, including the process industry and the financial, engineering, management science and operations research sectors. It includes problems in process flow sheets, portfolio selection, batch processing in chemical engineering (consisting of mixing, reaction, and centrifuge separation), and optimal design of gas or water transmission networks [4], [5].
In this research, MINLP method has been applied for finding optimum solution. The objective function is minimum production cost that related to steam and power generation. However, in this optimization method is based on one objective function.

3. Methodology

In this study, GT PRO as one modules of THERMOFLOW has been applied for thermodynamic simulation, detail engineering and economic analysis of each case [6]. For optimisation study, LNGO software has been applied for finding optimum configuration and condition among superstructure that is shown in Fig.1. Integration of GT Pro, Excel and LINGO program help us to reach optimum results quickly.

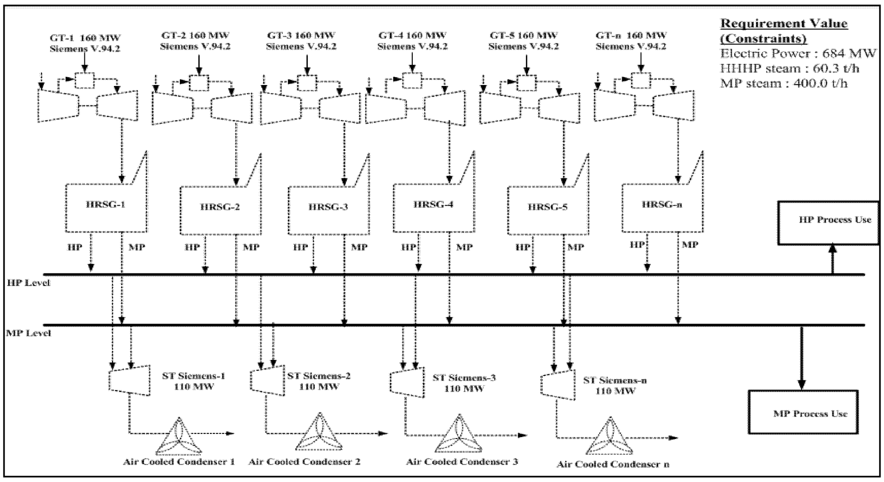

Fig.1. Superstructure of Iran LNG's steam and power generation unit

4. Results

The optimum case has been found by MINLP Methods through integration of professional power plant simulator and optimization. The optimum configuration has been shown in Fig.2.

The scenarios considered in this evaluation of optimum case 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 para 3.1 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.

- Normal operation cases: In A cases includes 5 GT(Load 76.15%) + 2 ST + 5 HRSG
- Upset case: As following, in upset case 4 GT(Load 95%) + 2 ST + 4 HRSG Case B – 2 LNG trains, loading mode, expander trip, 1 GT unavailable/maintenance, Guarantee case (43°C).

Figures 3 and 4 show plant output related to case A and B in optimum configuration and process condition. In addition, exergy loss rates for each equipment have been demonstrated in Fig.5 and Fig.6. As represented here, exergy losses of each component have been reduced with increasing ambient temperature in cases A and B. However, the exergy loss in gas turbine is more than other components.

As shown in Fig.7 and 8, the plant efficiency for cases A and B in optimum condition are decreased with increasing ambient temperature. Break-even electricity price for case A and B are demonstrated in Fig.9 and 10 respectively. As demonstrated, with increasing ambient temperature the price of electricity is increased. However, the price of electricity in Case A is more than Case B.

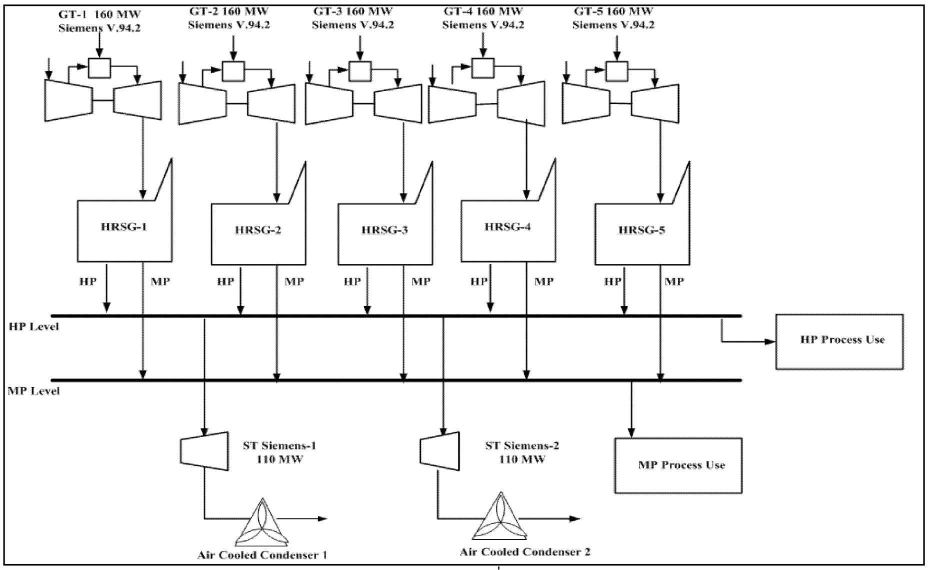

Fig.2 Optimum configuration of Iran LNG's steam and power generation plant

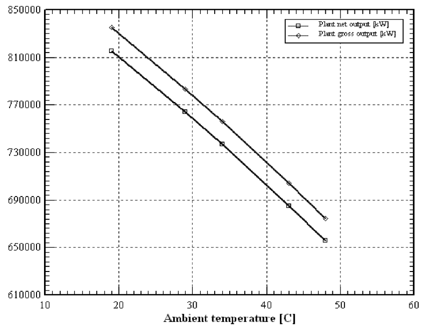

Fig.3. Plant output vs. T_0 (A)

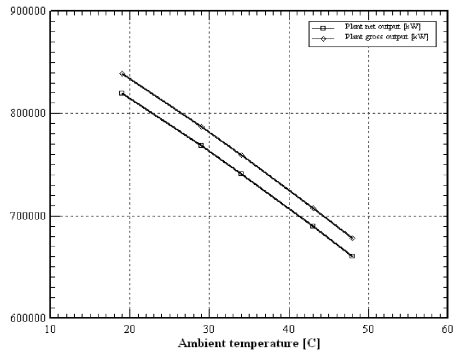

Fig.4. Plant output vs. T_0 (B)

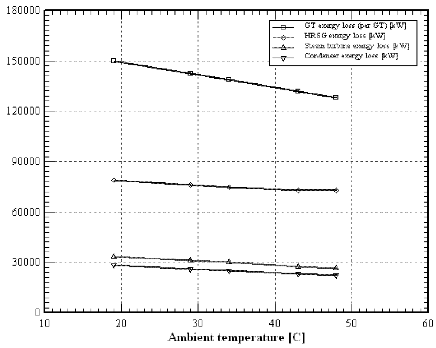

Fig.5. Exergy loss of each Equipment (A)

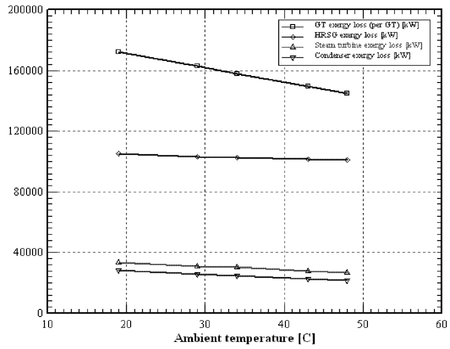

Fig.6. Exergy loss of each Equipment (B)

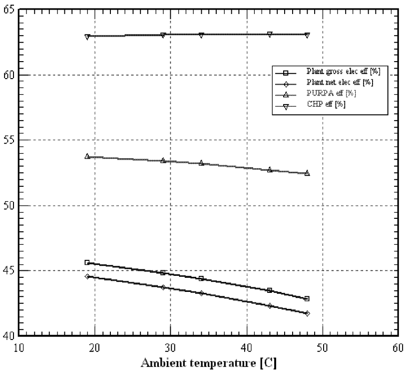

Fig.7. Plant efficiency (A)

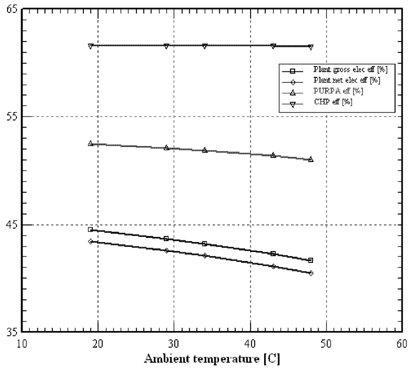

Fig.8. Plant efficiency (B)

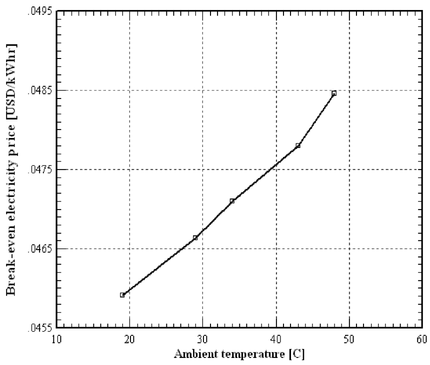

Fig.9. Break-even electricity price (A)

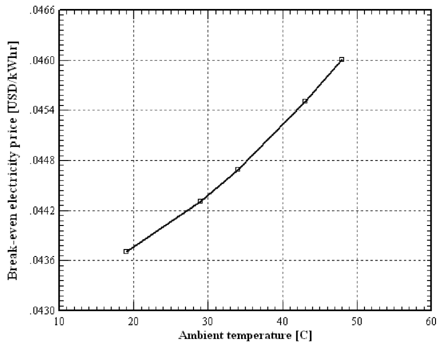

Fig.10. Break-even electricity price (B)

5. Conclusion

Progress in the MINLP arena has been significant in recent years, and we are now able to solve large-scale problems efficiently using a wide variety of approaches. However, MINLP has yet to reach the level of maturity that MIP has achieved. While the MIP community has benefited greatly from preprocessing to reduce model sizes and to detect special structure, MINLP technology is still lagging behind. In this regard, integration of optimization software with power plants simulator can be very suitable and simple for complex systems**.**

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