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Optimization of Steam Network through MINLP method: Application to Utility of KHARK Island NGL recovery Project

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The importance of energy crisis and global warming necessitates to present strategies in order to decrease the amount of emissions as well as fuel consumption in large and complex industries such as refining and petrochemical. Generally, steam networks are regarded as units, which consume fuel enormously.
KHARK Island is one of the world's largest deepwater oil ports; it is linked to the mainland by a 25-mi (40-km) pipeline. The oil terminal was a target of frequent attacks during the Iran-Iraq War in the 1980s, when it was partly destroyed. The NGL recovery facility is a grass roots development and will consist of the simultaneous development of two separate gas treatment and NGL recovery plants sharing common utilities and liquid export systems. Gas will be gathered from both onshore and offshore sources. In this paper, steam network of NGL KHARK in Iran is considered as industrial case study. Then, various scenarios are proposed to modify the network. In this regard, the network and suggested scenarios are simulated in STAR software environment. In next step, each scenario is separately optimized through Mixed Integer Non Linear Programming (MINLP) method and the best scenario is chosen from the viewpoint of Total Annualized Cost (TAC) and environmental impacts. The objective function of optimization is to minimize TAC.

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1. Introduction

A steam network is considered as a unit that consumes energy greatly. The main objective of the network is to produce the steam, which is required in different site processes. The amount of fuel consumption in steam networks is enormously high, because of boilers and other fuel-consuming components existence. Furthermore, water consumption and treatment costs as well as maintenance cost have caused the amount of total operating cost to increase. Hence, reduction of energy consumption saves total operating costs significantly. In addition, it is possible to reduce total annualized cost through introducing new scenarios, which improve the networks performance. Different approaches are proposed to optimize steam networks, which can be categorized as:
(1) Using renewable energy; (2) Promoting the network's components performance; (3) Selling or buying the power exported or imported that it depends on political and geographical strategies of countries; (4) Steam coupling between the networks and adjacent power plants; (5) Using heat recovery steam generating systems and gas turbines instead of old boilers and so on. Raissi *et al.* (1994) introduced total site integration. Their work provides analytical tools that help understand the interactions between site fuel heat recovery and co-generation [1]. Mavromatic *et al.* (1998) presented conceptual optimization of utility networks for operational variations [2]-[3]. Shang *et al.* (2000) suggested systematic methodologies for the analysis and optimization of total site utility systems under operational variations [4]. Varbanov *et al.* (2004) presented modeling and optimization of utility systems [5]. In this study,

2. Methodology

Mixed Integer Nonlinear Programming (MINLP) refers to mathematical programming with continuous and discrete variables and nonlinearities in the objective function and constraints [6]. 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 [7], [8].
In this research, MINLP method has been applied for finding optimum solution. The objective function is minimum total annualized cost (TAC).
In this paper, STAR software has been applied as simulation and optimization software that has been provided by Center of Process Integration (CPI) of the University of Manchester and licensed by K.N.Toosi University of technology. Also, new scenario has been proposed and has been optimized in view of TAC [9],[10],11].

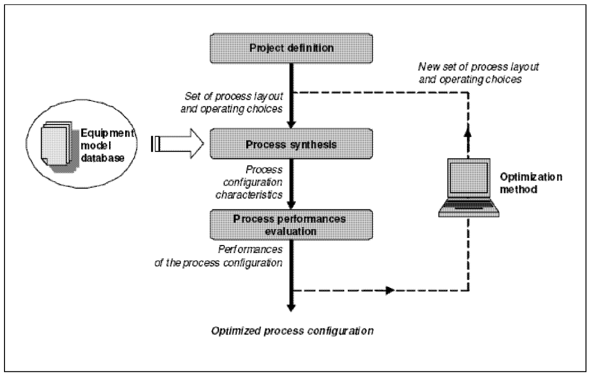

Fig.1. Process design methodology

The mathematical form of the optimization problem can be stated as follows:

$$Min_x \;\; \mathrm{J = f(x)}$$

$$\text{s.t.}\begin{Bmatrix} \mathrm{g(x)} \le 0 \\ \mathrm{h(x)} = 0 \\ x_{i,\min} \le x_i \le x_{i,\max} \end{Bmatrix} \text{ where } x_i \text{ is either an integer or a real number.}$$

In this paper, the objective function of optimization is to minimize total annualized costs (TAC). Some parameters can be limited during the optimization such as gas turbine power, the amount of the steam produced in boilers as well as fuel ratio. The optimization approach is based upon fixed header conditions e.g. temperature and pressure.

3. Case Study

The detailed process flow sheets of the considered Utility plant in NGL of KHARK involving MP, LP and saturated LP steam as called AGR conditions has been shown in Fig.2. Steam distributed to several consumers (e.g. process steam, reboilers, fuel gas super heaters) from three main headers. These coupled Steam systems are linked with a condensate return line that can be visualized in Figure, in order to feed a de-aerator. A significant quantity of Make-up water is also produced in the NGL plant. This water, after treatment, is available in Utility plant to supply process water for boiler feed water after adding to condensates in the De-aerator.

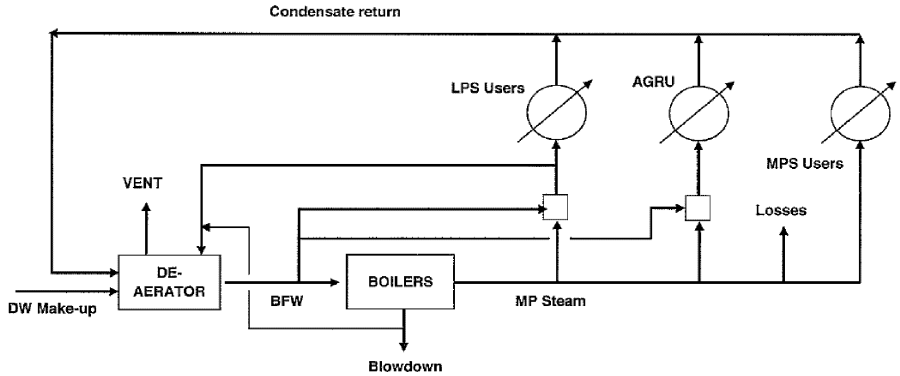

Fig.2. Schematic of NGL utility (KHARK Island)

The Utility plant uses a natural gas fired boiler with the maximum feed water temperature at the inlet of economizer being 110°C. Steam network involves MP steam at the condition of 11 bar / 205°C. The LP steam shown in Fig has steam parameters of 4.5 bar / 168°C that achieved by desuperheating of MP steam with feed water at the temperature of 110°C.Other levels of steam (Saturated LP) at 6.5 bar / 162°C are produced by desuperheating of MP steam with feed water. The utility data requirement in this project has been shown in Table.1.

Table 1. The utility data requirement

Parameter	°C	kg/hr
Total Medium Pressure (MP)	205	434,668
Low Pressure Steam (LP)	168	83,308
Saturated LP Steam (AGR)	162	292,963

4. Results

Most steam system optimization projects require an understanding of the steam balance. A steam balance is an excellent tool for understanding the steam system. The more accurate and detailed the steam balance, the more successful a plant will be in reducing its steam and operating costs. Once a steam balance has been developed, opportunities for steam savings become apparent, and project savings can be quantified. The schematic of NGL utility of KHARK in STAR software has been demonstrated in Fig.3. Table 1 shows base case and optimum case after optimization through MINLP method. As shown, about 85% of fuel cost and 39 % of TAC has been decreased only by optimization of process condition.

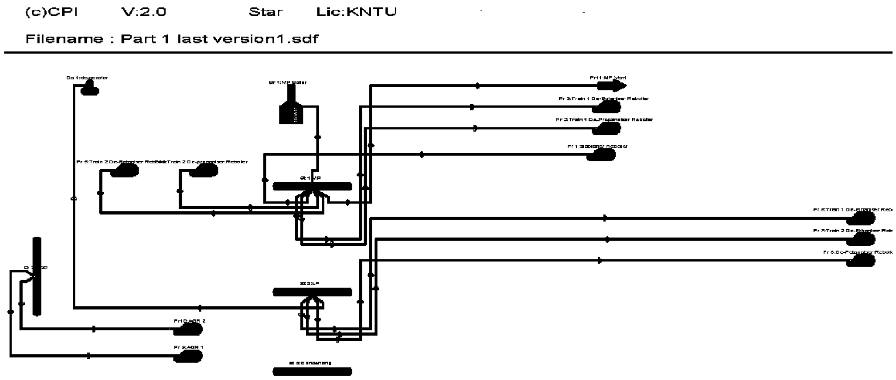

Fig.3.The schematic of NGL utility of KHARK in STAR environment

Table2.Simulation and optimization results

Parameter	Unit	Simulation	Optimization
Demin Water Cost	[$/yr]	17930.5	2686.76
Total Operating Cost	[$/yr]	0.122036E+07	0.182862E+06
Total Fuel Cost	[$/yr]	0.120243E+07	0.180176. E+06
Total Capital	[$]	0.254029E+07	0.208096E+07
Total Annualized Cost	[$/yr]	0.376065E+07	0.226382E+07

Reference

1. Raissi, K. (1994). Total Site Integration. PhD Thesis, UMIST, UK.
2. Mavromatic, S. P., Kokossis, A. C. (1998). Conceptual Optimization of Utility Networks for Operational Variations- 1: Targets and Level Optimization. Chem. Eng. Sci., 53, 1585-1608.
3. Mavromatic, S. P., Kokossis, A. C. (1998). Conceptual Optimization of Utility Networks for Operational Variations- 2: Network Development and Optimization. Chem. Eng. Sci., 53, 1609-1630.
4. Shang, Z. (2000). Analysis and Optimization of Total Site Utility Systems. PhD Thesis, UMIST,UK.
5. Varbanov, P. S., Doyle, S., Smith, R. (2004). Modeling and Optimization of Utility Systems. Trans IChemE, 82A:56.
6. T. Tveit, T. Savola_and C. J. Fogelholm, Modelling of steam turbines for mixed integer nonlinear programming (MINLP) in design and off-design conditions of CHP plants, SIMS'05 46th Conference on Simulation and Modeling.
7. A. Alle, J.M.Pinto, A general frame work for simultaneous cyclic scheduling and operational optimization of multiproduct continous plant, Brazilian Journal of chemical Engineering, Vol. 19, No. 04, pp. 457 - 466, October - December 2002

8. Pablo E. Martinez, Ana Maria Eliceche, Minimization of Life Cycle Greenhouse Emissions and Cost in the Operation of Steam and Power Plants, 18^{th} European Symposium on Computer Aided Process Engineering – ESCAPE. Lyon – France, June 1-4 2008.
9. STAR Software, Version 2, Center for Process Integration, School of Chemical Engineering & Analytical Science, University of Manchester, UK, Under license of K.N.Toosi University of Technology, Energy and Process Integration Laboratory.
10. Khodaei J. A., H. (August 2008). Simulation and Optimization of Steam Network in Tehran Oil Refinery. MSc Dissertation, K. N. Toosi University of Technology and the University of Manchester.
11. Khoshgoftar Manesh, M. H., Khodaei J. A., H., Amidpour, M. (2008) Optimization of Steam Network in Tehran Oil Refinery (New Scenarios). 30th International Conference of Industrial Energy Engineering (IETC), Texas, USA.
12. Utility summary and conditions Data Sheet, KHARK Island Gas Gathering and NGL Recovery Project, Iranian Offshore Oil Co.