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A three-stage scenario based operational performance test approaches for production capacity enhancement: Case study on the 5th refinery of South Pars Gas Complex in Iran

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ABSTRACT

In this work, the possibility of capacity enhancement in the South Pars Gas Complex of Iran has been studied. Mass balance is studied and data validation and reconciliation have been carried out in 5th refinery of South Pars Gas Complex in order to achieve the reliable data of the plant. Then the possibility of capacity increase has been studied, taking into account the important parameters such as alteration of the plant pressure profile. Calculation of the key parameters for different equipment at higher feed rate, specified the unit of operations which may have trouble during the capacity enhancement. The performance of export gas compressors, dehydration unit and High-Integrity Pressure Protection System (HIPPS) has been anticipated to be the obstacle of this project according to the results of design basis review. In order to increase the feed rate the operation at constant inlet pressure is considered while the final stage pressure decreases as it is safe procedure for the plant. Then performance test has been carried out to monitor the changes in the plant. Three methodologies were designed and evaluated for implementing the performance test, and the stepwise procedure has been carried out successfully. During the performance test, the feed rate has been increased in three consecutive steps by 4.5%, 3% and 2.5% respectively. The operation of key equipment such as turbo expanders, exports and refrigerant compressors, dehydration beds, columns and filters, have been examined by taking samples from inlet–outlet streams such as feed gas, acid gas, lean and rich amine, LPG product. Following the step wised feed rate increase, the performance test was operationally successful and the production capacity of sweet gas in South Pars has been increased about 10%.

1. Introduction

In today's world where energy consumption is rapidly increasing, due to population growth and living standards improvement, energy conservation projects have become more important than ever (Panjeshahi and Tahouni, 2008). Capacity enhancement in existing plants and removing the subsequent bottlenecks is an appropriate approach for exploring energy saving potentials and maximising the plants' profitability (Panjeshahi and Tahouni, 2008). Due to increasing demand for natural gas all over the world, production capacity enhancement has been the concern of different refineries and gas plants (Lynch and Fernandez, 1996; Amiri et al., 2006; Gomez Martinez, 2008).

In recent years, there has been great incentive to improve the efficiency of chemical processing plant with existing facilities (Liu and Jobson, 2004a). Retrofit projects propose changes in an existing plant in order to achieve more economical structure and/or more profitable process operation (Kralj et al., 2000). Generally, objectives of retrofit projects include increasing production capacity, reducing operating cost, adding new technologies and meeting new product specifications (Uerdingen et al., 2003). The retrofit of a chemical process can be performed by different methods such as thermodynamic (pinch analysis) and algorithmic.

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The thermodynamic method of process synthesis is very useful for the design of complex and energy intensive processes, but does not guarantee the global optimal solution because it cannot be used simultaneously with material balances (Kralj et al., 2000).

Another main research line is based on an extensive use of mathematical programming or evolutionary algorithms to solve the retrofit problem (Piacentino, 2011; Zhang et al., 2001). Ciric and Floudas proposed a two-stage approach based on Mixed Integer Linear Programming (MILP) (Piacentino, 2011). More recently, Rezaei and Shafiei have approached the same problem through a hybrid Non Linear Programming/Genetic Algorithm (NLP/GA) method (Rezaei and Shafiei, 2009). Methods, based on mathematical programming are difficult to solve for complex and energy intensive processes, because the number of variables increases with the number of combinations (Kralj et al., 2000).

Retrofit projects in heat exchanger networks and distillation columns have been studied by different researchers (Gadalla et al., 2013; Asante and Zhu, 1997; Chen, 2008). Considering distillation units, in order to reduce the huge energy consumption, existing equipment are revamped rather than building new units. Typically revamping projects are carried out to meet one or more of the following objectives such as: increasing the plant throughput, reducing the energy demands, more efficiently utilising the raw materials and reducing the environmental impact. All these objectives should be fulfilled without mechanical modifications on equipment, such as column actual diameter, pump-arounds and side-columns locations, exchanger areas and maximum heat loads in fired heaters. The interactions between the existing distillation process and heat recovery system have a critical impact on the revamping of the overall process (Gadalla et al., 2013; Gadalla et al., 2003). Most of researchers have worked on the idea of retrofit by sequential approaches *i.e*. column optimisation then HEN or vice versa, or simultaneous approach with targets of pinch analysis (Asante and Zhu, 1997; Chen, 2008; Smith et al., 2010). For distillation units, Xu et al. assumed that it is sufficient to analyse the hydraulic performance of only the key stages (i.e. the top and bottom stages, and those directly above and below the feed point) (Liu and Jobson, 2004a). There is currently no systematic and quantitative way of identifying which a modification will be effective for a particular process, therefore design engineer must resort to trial and error, rules of thumb, experience and intuition in order to identify effective solutions to the design problem (Liu and Jobson, 2004b).

Considering the overall plant performance, capacity enhancement procedure depends on the plant condition and equipment characteristics. As mentioned before, in some cases the plant has the capability to handle higher feed rate without addition of any equipment or extreme change in the operating condition. A thorough study of the plant design basis is necessary to define the safety margin of all equipment, controlling instruments and pipelines that affected by flow rate increase, considering the capacity increment. Usually in order to assess the constraint of equipment, simulation of the plant is used.

However, sometimes it is necessary to follow a revamping project, such as improving of column trays. In order to change the production objectives, limited heat recovery and hydraulics of heat exchanger network, overflow and foaling in distillation column and pressure drop alteration in the plant should be studied thoroughly to avoid serious damage (Tahouni et al., 2014). Following an optimization approach for existing refinery distillation process, Gadalla et al. achieved 25% reduction in energy consumption and operating costs (Gadalla et al., 2003).

In some plants, plant equipment cannot operate successfully at different condition and even revamping is not sufficient. In this case, addition of new equipment or even process is necessary. The common practice is either replacing the existing constrained process with a new unit or adding a process parallel to the constrained units (Harsh et al., 1989).

In this work, basic design review and theoretical calculations are done to study the feasibility of 10% capacity increase, without the need for addition of any equipment. Every single unit operation has impact on the overall performance of the plant, but some of them are more effective especially during the capacity increment and performance test. The equipment with high impact on overall performance which may encounter inefficient operation in terms of meeting specified design criteria (i.e. export gas compressors, dehydration beds and sulphur recovery unit), are determined. Different methods of the feed rate increase and capacity increment techniques are examined and the method with the lowest operational risk and appropriate pressure profile is selected. Considering the plant configuration, three different scenarios for performance test are designed and their advantages and disadvantages are studied. Consequently, the scenario with step-wise model, less operational risk and easy control and monitoring is implemented in the plant. The difference of this study with other practises is in application and procedure of the performance test and troubleshooting in the flow rate increment process.

2. Process description

The 5th refinery of the South Pars Gas Complex (SPGC) consists of two similar phases (9&10) to process the gas from South Pars field in Iran. As can be seen in Fig. 1, each phase is constructed in two parallel trains with the same equipment size. This refinery is designed to handle 56.5 million cubic meter per day (mcm/d) sour gas in normal operation condition to produce 50 mcm/d sweet gas, 80,000 barrel per day (bpd) gas condensate, 400 ton/d sulfur, 2600 ton/d ethane and 3200 ton/d LPG (Hassantash, 2011). The plant includes all processing units, utilities, off sites and infrastructure necessary to produce sale gas, gaseous ethane as cut of petrochemical feedstock, commercial grade propane and butane, granulate solid Sulphur and stabilized condensate.

According to the block flow diagram illustrated in Figs. 1 and 2, in each refinery phase, the separated liquid from the slug catcher (Unit 100), is sent to the condensate stabilizer unit (Unit 103). The sour gas separated from slug catcher along with recompressed off gas from Unit 103, is routed to the parallel gas sweetening units (Units 101 and 201), which use MDEA as solvent in the absorption process. The overhead of absorber (sweet gas) with maximum 3 ppm (vol.) of H_2S and 1% mole of CO_2, flows to the dehydration units (Units104 and 204) that applies molecular sieve beds for water removal. Each dehydration unit includes three molecular sieve bed dryers that 2 beds are in operation and 1 in standby, two dryers after filter and dryers' regeneration section (furnace, air cooler, separator and compressor). At normal condition, the dryers operate in 33 h cycle time that consists of 22 h in adsorption service and 11 h in regeneration service (heating/cooling/stand-by). The acid gas from the solvent regenerations of 4 gas sweetening units are gathered to the header and transferred to four identical and parallel Claus sulfur recovery units (Unit 108). The dry sweet gas is sent to the ethane recovery unit (Unit 105), where is fractionated to methane, ethane and heavier cut (C_3^+) through cooling, expansion and distillation.

After the heating, the produced sales gas in demethanizer column is compressed in Unit 106 to meet selling requirements. The lean gas from each ethane recovery unit 105 is combined in two steps. At the first, produced gases from train 1 and train 2 are combined in a sub-header and train 3 and train 4 are combined also in a second sub-header. Then these two sub-headers are fed to a common header that serves export compressors. The separated