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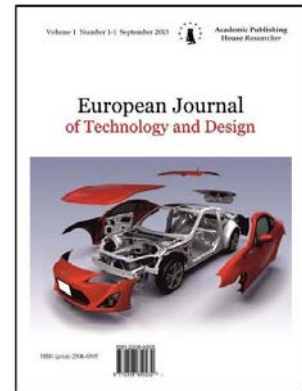
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Heat Integration of the Gas Condensate Stabilization Unit, a case study from the South Pars Gas Field in the Persian Gulf

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Abstract

Energy conservation in the design of a chemical plant is one of the most important considerations. In addition, to determine the minimum amount of hot and cold energy needed for a process is one of the main computations of determining the amount of stored energy. The heat integration (energy integrating) is an important factor in economic designs. In this paper, phases 9 and 10 of the gas condensate stabilization process of the South Pars gas are optimized using the integration design method. The results obtained showed the modified heat exchanger network, removal of existing both air fans, recovery of 2.5 MW of electricity and reduced operating costs.

Keywords: Heat Exchanger Network Modification, Heat Integration, Pinch technology, Gas Condensate Stabilization Unit.

Introduction

Pinch technology is a process integration technique (Integration) and is a powerful way to optimize the process design. The results of conventional optimization processes itself tends to optimize the system as a whole (a set of processes and unit operation). The application of Pinch Technology in Pulp and Paper Industry has provided new ways to reduce energy consumption in pulp and paper production processes [1]. The reducing energy consumption is one of the most advantageous aspects of Pinch Technology. Other advantages include the correct integration of steam turbines, energy consumption optimization and investment costs, identify the most suitable process changes and increase the flexibility of the plant [2]. This approach provides overall process designs that were basically compatible with the environment. Pinch analysis is a new thermodynamic concept where a proper analysis of the heat exchange process is done. Also, proper thermodynamic analysis leads to the identification of appropriate options in many other design goals; for example, to minimize the investment costs and operating expenses [2].

In the chemical process, the engineering design problems have been studied in two ways: (1) the unit operation level and (2) the overall system design level. Pinch analysis considers the system design problems to identify opportunities for energy saving and modification of existing plants or designing a new cost-saving plant. The implications of this approach are simple and easy and make it possible to deal with more complex problems. This approach focuses on simple values rather than complex mathematics. Hot and cold flows in a process are identified and shown in a

temperature-enthalpy diagram [3]. The analysis work starts from individual streams and is done by simple sum of the values of above heating temperature range and all streams hot and cold composite curves in a process. The results of the two streams of hot and cold composite curve and overlap between composite curves show the maximum amount of possible heat recovery in the process [4]. Excessive heat out of the hot composite curve represents the minimum required amount of external cooling. Similarly, out of the cold composite curve represents the minimum required amount of external heat. Both curves reach exactly at the same point which is called Pinch.

Pinch is a sub point where heat is source of the system, such as heat moves toward the cooling equipment, but do not enter. There is a heat sink on the top of the Pinch system. Heat enters the thermal heating equipment, but not out [5]. As a result, this system is separated into the process overall hot and cold equipment in a pinch point that indicates the degree of additional heating or cooling in the system. In the system with maintained required heating and cooling, throughout the pinch hot currents are zero. This system is a system in which the equipment goals are very close to the desirable condition [6]. The heat balance in a system with the external heating exceeds the minimum required in the process represents heat flow across pinch; therefore, additional external cooling is needed [6]. Recently, Heat Integration across plants is an extension of conventional Heat Integration in a single plant for further improving energy efficiency [7, 8, 9].

In this paper, phases 9 and 10 of the gas condensate stabilization unit of the South Pars Gas Field in the Persian Gulf are optimized using the heat integration design method and Pinch composite curves. Simulation tools have been used to achieve composite curves, and stabilizing process was designed and simulated in Aspen HYSYS specialized software.

Material and Methods

1. Process Description

In this refinery project, the gas condensate unit of Phases 9 and 10 of the South Pars gas field have been chosen for optimization and analysis.

The South Pars / North Dome field is a natural gas condensate field located in the Persian Gulf. It is the world's largest gas field, shared between Iran and Qatar. According to the International Energy Agency (IEA), the field holds an estimated 1,800 trillion cubic feet (51 trillion cubic metres) of in-situ natural gas and some 50 billion barrels (7.9 billion cubic metres) of natural gas condensates. Phases 9 and 10 produce 2 billion cubic feet (57 million cubic metres) per day of natural gas, 75 million cubic feet (2.1 million cubic metres) per day of ethane, 80,000 barrels per day (13,000 m³/d) of condensate, 3000 tons of LPG per day plus 400 tons of sulfur per day.

Here is the process occurred (Under winter conditions); in this unit, the feed which is a mixture of mainstream condensate (stream 10) and lateral condensate (stream 11) which is a raw gas condensate taken from the sludge is preheated with 231500 kg/h flow in the +5.683 °C operating conditions and 3000 kPa pressure in the E-101 heat exchanger to a temperature of +50 °C. Given that the feed is very diverse cutting oil including hydrocarbons from C6 Cut (less than C6 hydrocarbon) to C20+(more than C20), so according to phases 9 and 10 to archive access, the physical characteristics of the oil cut were obtained. Output current of the E-101 exchanger at T=+50 °C and a pressure of 2900 kPa with other sub-stream (stream 30) enters into D-101 three-phase separator at T=+19.62 °C and P = 2800 kPa operating conditions; In this three-phase separator under the operating conditions of T=+50 °C and a pressure of 2800 kPa, the vapor phase (stream 28), the heavy liquid phase (this phase consisted of water and glycol used to prevent hydration of the condensate in the injection well), and the organic phase (gas condensate) are separated from each other. The separated vapor phase is sent to off gas unit. The aqueous phase will be sent glycol restore unit to restore and reuse glycol. Condensate from the separator D-101 (stream 13) first enter the P-101 pump and reach to the pressure of 3720 kPa, the output of the pump is preheated to +72 °C in heat exchanger E-102 and enters Condensate Desalter for washing, fresh water is injected into the condensate flow for higher washing operation. The remaining water and glycol is sent to glycol restore unit. The condensate that is free of glycol enters into the stabilizer tower with condensate stream (stream 35) obtained from the compress unit at a temperature of +63.29 °C and pressure 1050 kPa. The C-101 stabilizer tower is originally the heart

of the process of stabilization unit, in this tower separating the light compounds from crude condensate operations (stream 15) by the fractionation occurs. C-101 towers consists of 19 sorting tray (regardless of reboiler and condenser) has a thermo-siphon reboiler and fully reversible condenser. Stream 15 enters from the upper tray, the overhead vapor enters the condenser at $T=+69\text{ }^{\circ}\text{C}$ (air cooler A-104) and will be condensed to $T=+60\text{ }^{\circ}\text{C}$. Due to the presence of water vapor in the overhead reflux drum (D-107) is a three-phase separator. In this vapor phase separator (stream 24), the aqueous phase (sour water) and the organic phase (stream 23) are separated from each other (according to the condensation temperature of the aqueous phase cannot be separated). The aqueous phase which is the tower reflux reaches to the 10 times absolute pressure in P-102 pump and returns to the upper tray (19th tray). At the bottom of the tower the heat required for the separation is supplied using Thermo siphon Reboiler (E-103). Heavy concentration in the liquid phase reaches its maximum value at the bottom of the Stabilization tower; however, at the disposal almost all light gases particularly hydrogen sulfide style will be close to zero, heat supply fluid is high pressure steam with intensity of 18020 kg/h. E-104 side reboiler is used in the process of heat output of E-103 reboiler. The lateral-flow from the 9th tray enters E-104 heat exchanger and again, after the exchange with the bottom of the tower C-101 products will be returned to the 8th tray, through this, E-103 reboiler energy consumption will be saved. The C-101 Tower bottom product after being exchanged with the stream flowing down from the 9th tray reaches at $+137\text{ }^{\circ}\text{C}$ and will be sent to E-102 exchanger under 1000 kPa pressure. The condensate product and the organic phase output of P-101 pumps are in heat exchange and enter into A-101 air cooler at temperature of $111\text{ }^{\circ}\text{C}$. The condensed stream is cooled down to $+92\text{ }^{\circ}\text{C}$ at A-101 air cooler spending totaling 2.5 MW energy and enters into E-101 heat exchanger by 880 kPa pressure. In this exchanger the raw condensate flow temperature rises to $+50\text{ }^{\circ}\text{C}$ using the established product stream (hot stream). The condensate output of the exchanger with a temperature of $+25\text{ }^{\circ}\text{C}$, enters into D-106 tank. The operating conditions of the tank D-106 are $T=+41\text{ }^{\circ}\text{C}$ and $P = 100\text{ kPa}$. The condensate input into the tank is with a good quality and has very favorable conditions for transport and storage requirements. The aim of compression is to increase the gas separated from the separators pressure and the C-101 tower to send them to a sweetening unit. On the other hand, given that after each compression stage the gas temperature increases so an air conditioner compressor is used for cooling compressor output after each compressor. Heavier compounds may condensate by reducing the temperature of the compressed gas, thus vertical two-phase separator are used after air coolers (general description of the compression). In refinery, phases 9 and 10 condensate steams from the gas condensate unit enter into D-102 two-phase separator as the off gas at a pressure of 970 kPa (outlet of the stabilizer tower condenser) to eliminate the possible fluids. Operating conditions of the separator are: $T = +58\text{ }^{\circ}\text{C}$ and $P = 860\text{ kPa}$. The outlet vapor of the separator enters into the K-101 compressor and reaches to the 2770 kPa pressure, immediately the K-101 compressor outlet gas is cooled down at the A-102 air conditioner at the temperature of $+132\text{ }^{\circ}\text{C}$ to $+60\text{ }^{\circ}\text{C}$, and enters into D-110 vertical separator, the operating conditions of the separator are: $T=+60\text{ }^{\circ}\text{C}$ and $P = 2770\text{ kPa}$. Output steam from D-110 and the steam separated from D-101 three-phase separator (stream 28) enter into the D-103 vertical separator, the operating conditions of the separator are: $T = +53\text{ }^{\circ}\text{C}$ and $P = 2770\text{ kPa}$. The purpose of this separation is the extraction of condensates that come from combining the two vapor streams (stream 29). The output vapor of the separator D-103 enters the K-101 compressor (second stage) and reaches to 7070 kPa pressure, quickly exhaust gas of air compressor which is cooled down in A-103 air fan to the temperature of $+81\text{ }^{\circ}\text{C}$ and is sent high to the pressure separator (stream 27) (Figure 1) [10].

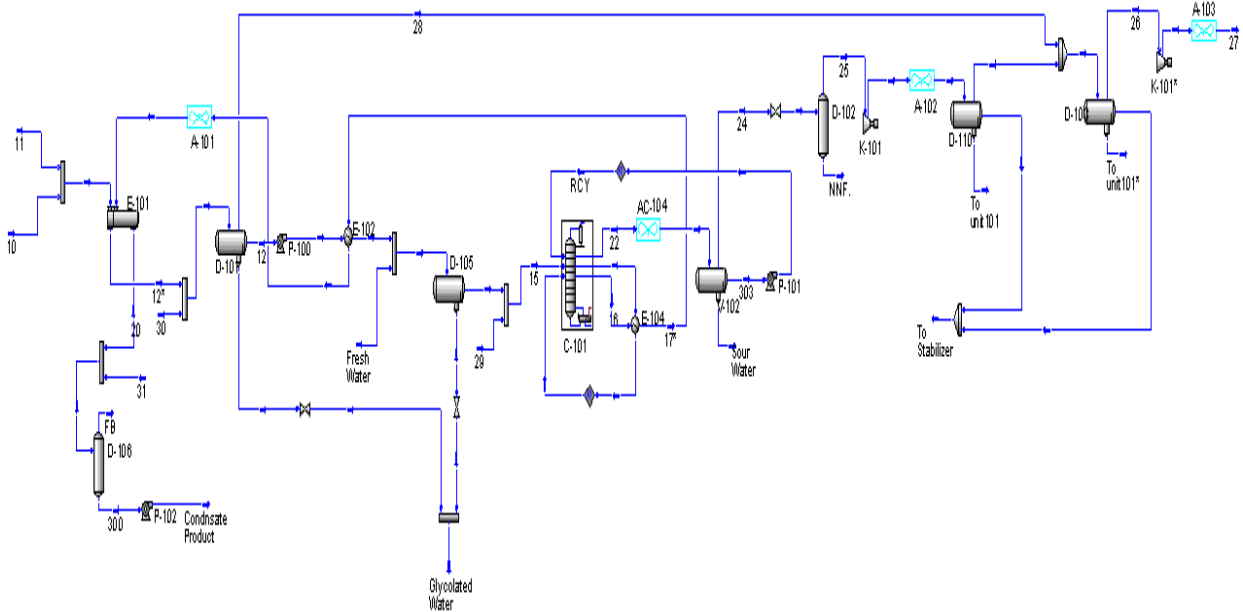


Figure 1: Simulation of the stabilization process (the distillation and compression) using Aspen HYSYS software

This process flow diagram (PFD) of the gas condensate unit was simulated in the Aspen HYSYS software. Table 1 presents the physical property of the raw gas condensate which is used in the simulation. The Peng Robinson (PR) equation state was used for simulation.

Table 1. Physical property of the raw gas condensate

Components	MW	SPGR	TC (°C)	PC (bar)	Acentric factor
C6CUT	84	0.690	234.65	32.82	0.271
C7CUT	96	0.727	269.05	31.51	0.310
C8CUT	107	0.749	297.45	29.51	0.349
C9CUT	121	0.768	325.15	27.37	0.392
C10CUT	134	0.782	349.05	25.30	0.437
C11CUT	147	0.793	370.15	23.51	0.479
C12CUT	161	0.804	390.75	21.93	0.523
C13CUT	175	0.815	409.05	20.75	0.561
C14CUT	190	0.826	427.45	19.58	0.601
C15CUT	206	0.836	445.75	18.48	0.644
C16CUT	222	0.843	460.75	17.44	0.684
C17CUT	237	0.851	476.25	16.55	0.723
C18CUT	251	0.856	487.45	15.86	0.754
C19CUT	263	0.861	497.95	15.24	0.784
C20+	385	0.850	530.00	11.18	0.790

The heart of the gas condensate unit is distillation tower (Figure 2). Therefore, the detailed design of the equipment provides a significant contribution to the results of real consequences. The Reboiled absorber option in the Aspen HYSYS was chosen for the distillation Tower (C-101). Operating condition for the tower simulation was shown in Table 2.

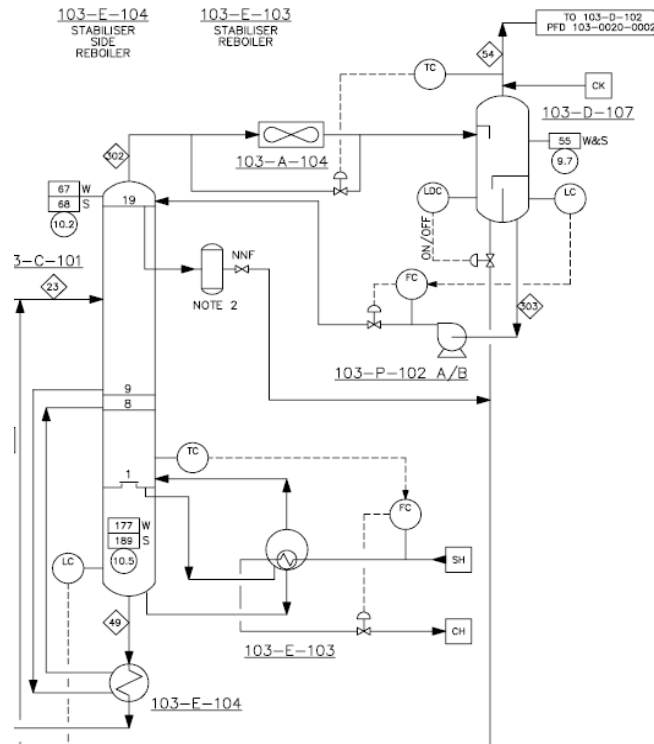


Figure 2: PFD of the C-101 distillation tower

Table. 2 operating condition of C-101 column

	Top Tower	Bottom tower
Pressure (bar (abs))	10.4	10.7
Temperature (°C)	69 to 71	178 to 190
Condenser Pressure drop	50	-

Results and discussion

The integration design method generally includes the following steps:

1 – Simulation and process design using commercial Aspen HYSYS software:

This stage involves careful review of process maps and data mining required for software entry (Figure 1);

2 – Check to process from Integration perspective: at this stage, the process needs and resources will be identified; the process of stabilizer unit include cooling outlet hot gas of the K-101 and A-102 and A-103 air fan compressors; given the low temperature of the gas stream entering the stabilizing unit, the flow is considered the heat possibility (cooling) of the process;

3 – Thermal optimization scenario: this section seeks to identify the need and process features of process-process heat exchanger to exchange energy and the elimination of direct energy (the air fan is recommended);

4 – Call the feasibility of optimization scenarios using Energy Analysis:

In this section using the energy analysis conventions defined for the hot and cold streams, we will study the feasibility of scenarios. Given the unit 103 energy analysis, raw stream of incoming condensate is a good option because it has the necessary and sufficient condition for cooling:

1 – The temperature of the crude condensate is much lower than the temperature of the air fan exhaust;

2 – The flow rate of the crude condensate is multiple than that of the output current of air cooling;

3 – According to the dual terms, the ability of crude condensate stream for cooling the compression unit exhaust gas condensate form the unit 103 can be expressed as: based on the

simulation results the energy consumption in both air coolers is 2.5 MW, thus to reduce the energy consumption the used stream first must be greater than 2.5 MW, and second its temperature be less than the output air energy fan. Whatever the flow temperature is the lower a smaller heat exchanger is required with the less investment costs. Based on simulation results, the crude condensate stream energy equal to 782400000 kJ-hour that given its low temperature, it can be said that the stream has great potential to meet the cooling needs of compression, this is also proven by the simulation results. Crude condensate stream at +5.68 °C and a flow rate of 231500 kg/h with energy rate of 782400000 kJ-hour, first exchanges heat in the E-100 heat exchanger and K-101 compressor output and hot stream is cooled down to the desired temperature without using the A-102 air cooler to designed optimal temperature (+60 °C); during the exchange of heat cold stream temperature reaches to +15.21 °C;

4 – Cold stream leaves E-100 exchanger at +15.21 °C temperature and enters into E-101 heat exchanger that has been used to replace the A-103 air fan to cool down K-101 compressor exhaust gas. In the E-101 heat exchanger the transmitted heat rate between the hot and cold streams is 1471 kW (the result of the HYSYS). The cold flow temperature after the heat exchange in the E-101 heat exchanger is equal to +24.34 °C (Figure 2). Finally, the crude condensate stream leaves the E-101 heat exchanger at the temperature of +24.34 °C and will be sent to the beginning of the process where it enters the E-101 heat exchanger;

5 – The study process re-simulation scenarios based on the defined scenarios in step 3, and the results analysis:

At this stage, the scenario defined in step 3 will be applied in the process using Aspen HYSYS software (Figure 3);

6 – A comparison of the current process and the optimized process:

In this section, the current process will be compared with the optimized process.

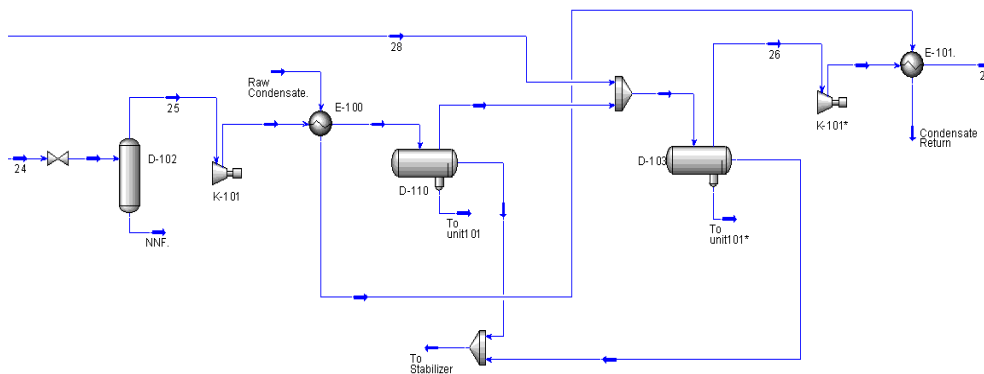


Figure 3: The optimized design and heat exchanger network modification of the compression unit 103 (removal of air cooler and replacement of heat exchangers)

After simulation of the current process and its resultant composite curve (Fig. 4), it was determined that in the whole operating unit 103 site, before the node or the Pinch (black squares in Figure 4), the amount of 5000 kW external cooling system is required. Composite curves have bottleneck called Pinch point that is a limit to heat recovery.

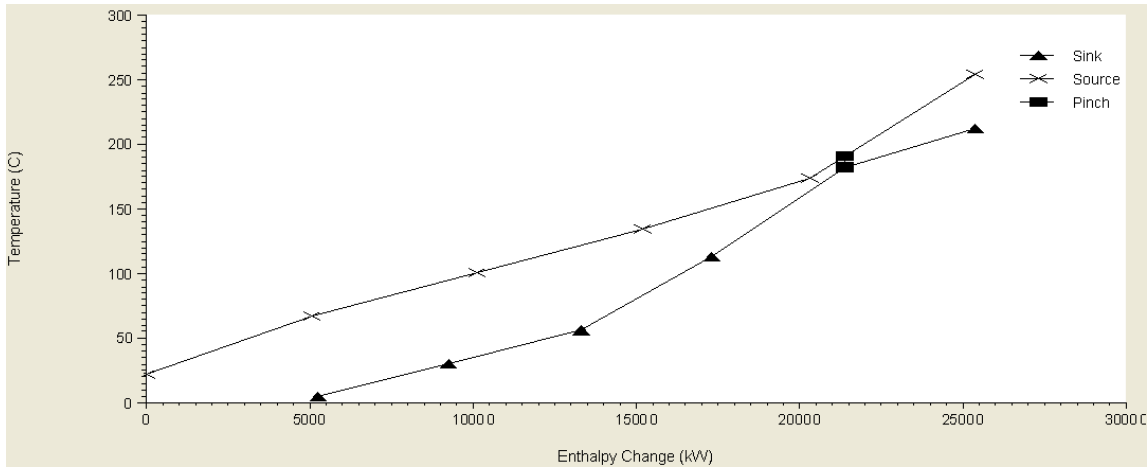


Figure 4: Pinch composite curves diagram for the unit 103 current process (stabilizing unit)

One way to make the composite curves parallel is to move some of the nodes to other temperatures and or complete elimination of some nodes with the main focus on the area near the process Pinch. In addition, the basic feature of having an area of low temperature on the Pinch and a region with excess heat under the process pinch provides an instruction on how to modify the process to increase the potential for heat recovery. The use of heat exchangers instead of air coolers in compressing section as the optimization scenario based on 6 stages was presented to move Pinch point with no limits in the heat recovery on total site (Figure 3). As a result of this scenario application, A-102 and A-103 air coolers will be eliminated from the process using crude condensate feed stream of (cooling fluid) and their energy consumption will be recovered (Figure 5).

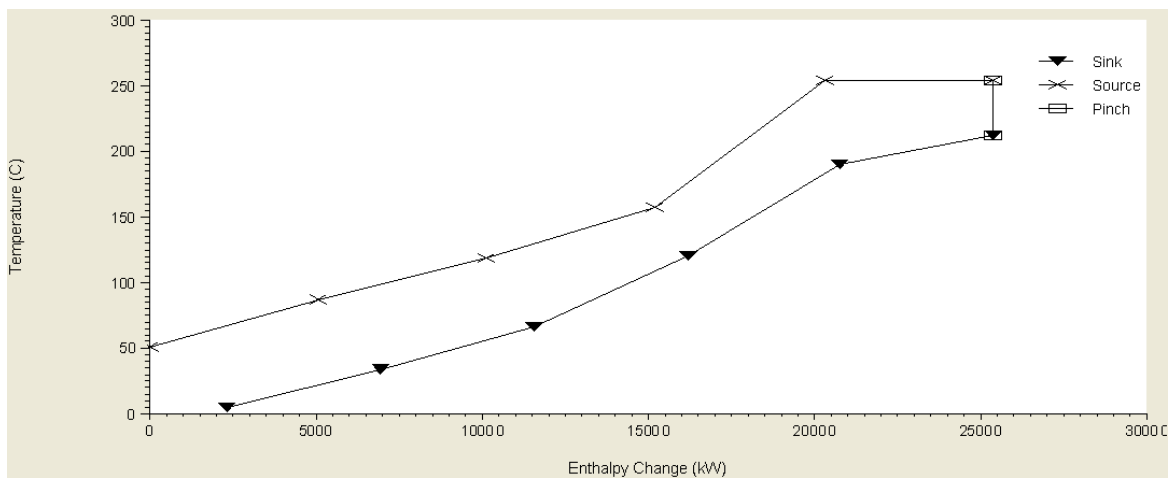


Figure 5: Pinch composite curves diagram for the integrated process (Pinch point movement and cooling energy reduction throughout the whole site)

Given the composite curves diagram for the integrated state (Figure 5), it is clear that heat exchanger network modification will lead to Pinch point (node) movement and a reduction in total energy recovery limitation in the whole site. Finally we can say that the stabilizing process thermal integration will also reduce operating costs (unit 103) in addition to the recovery of 2.5 MW of electric power and heat exchanger network modification of the entire site

Conclusion

The gas condensate stabilization unit of the South Pars Gas filed was simulated and optimized using the integration design method and Pinch composite curves have been used for this purpose. The process was simulated with Aspen HYSYS software with Ping Robinson equation state. Simulation tools have been used to achieve composite curves. Simulation results reveal that using the feed flow as the energy integration factor (for cooling) and using heat exchanger

(Integration Exchanger) instead of the current air coolers, 2.5 MW electric power will be saved in addition to deleting the air coolers (A-102 and A-103) and reducing operating costs amounted to 90190 \$ per year.

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