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Optimization of Condensate Transfer Pump in the Hydrocarbon Condensate Stabilization Unit of Natural Gas Liquefaction Plant – An Industrial Case

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Abstract

PT. Badak NGL is a commercial LNG producer located in Bontang, Indonesia. In recent years, the decline in LNG production of PT. Badak NGL results in a lower hydrocarbon condensate flow rate. To prevent power losses since its pump operated at below rating, a new operation scheme was proposed. This new scheme adjusts the way of pump is operated without any alteration in terms of pump characteristics. Three pumps operated intermittently for 8 hours per day at a maximum flow rate. The pump power consumption was calculated based on electric current data monitored by relay panel. The results show that the pump energy saved by 60% with the absolute value of annual energy efficiency of 957.7 MWh. This study contributes to reducing the greenhouse effect by 412 tons eq CO and the annual production cost of around USD 130,000. The new scheme reliability examines by evaluating pump vibration, pump performance, hydrocarbon condensate quality, and condensate tank liquid level. The result shows that the pump's vibration in the range of 0.21 in/sec with a steady winding temperature.

Keywords: condensate transfer pump, intermittent pump operation, energy saving, CO2 emission reduction

1. Introduction

Natural gas plays an important role in fulfilling worldwide energy necessities in recent years. It was reported that the need for natural gas increased by 1.7% per year. To ease transportation, natural gas is converted into a liquid phase known as LNG through liquefaction (Kumar et al., 2011). It means that impurities such as carbon dioxide, water, mercury, and heavy hydrocarbon shall be removed from the gas. Generally, there are three bases of liquefaction processes used in the LNG industry: cascade, mixed refrigerant, and expander based (He, Karimi, & Ju, 2018). However, all the processes required huge energy. Therefore, any process optimization and improvement are conducted to reduce the energy consumption of the process.

The mixed refrigerant technology is widely used in large-scale LNG Plants. Most of the study on this process optimization is based on model development and simulation. The thermodynamic approach reported by (Vatani, Mehrpooya, & Palizdar, 2014) was constructed using ASPEN HYSYS to investigate the advanced energy analysis to identify the portion of exergy destruction. (Wang, Zhang, & Xu, 2012) developed the MNLP method (mixed-integer nonlinear programming) based on thermodynamic analysis, mathematical programming, and rigorous simulation to minimize the energy consumption of the process. The genetic algorithm (GA) uses MATLAB and ASPEN HYSYS to optimize the process in the sub-cooling unit reported by (Sun, He Ding, He, & Shoujun Sun, 2016). Other similar model simulations were also conducted by several investigators (Cao, Lu, Lin, & Gu, 2006; He & Ju, 2016; Khan & Lee, 2013).

A pump is a machine for conveying fluid from a lower-pressure state to a higher-pressure state by increasing the energy level of the fluid, typically driven by electrical energy. Pumping systems receive more attention since it was expected to use 20% of the electrical energy produced worldwide. In the industrial case, 20 – 25% of energy consumption comes from pump operation (Gopal, Mohanraj, Chandramohan, & Chandrasekar, 2013). Implementing the pump system efficiency concept will reduce huge energy consumption as well as environmental effect. It can be achieved by considering some factors including the design of the pump, the installation process, and the method of operation. It was stated that adopting centrifugal pumps with variable speed and working stages in place of conventional deep well pumps might increase pumping efficiency by 9 – 10% (Fiaschi, Graniglia, & Manfrida, 2005). (Odeh, Yohanis, & Norton, 2006) reported that discrepancies between head and pump ratings can cause significant efficiency losses. By modifying the hydraulic scheme, the fuel consumption of the pump can be reduced up to 3 - 4.1% (Qu et al., 2019).

PT Badak NGL is a commercial LNG plant in Indonesia that adopted mixed refrigerant liquefaction technology. This technology applies a mixture of hydrocarbon (methane, ethane, propane, butane, pentane, i-butane, i-pentane) and nitrogen as the natural gas cooling medium. In LNG production, a small amount of hydrocarbon condensate is produced. It still contains light hydrocarbon and needs to be stabilized at Condensate Stabilizer Plant before being stored in the Condensate Storage Tank and transferred to the Santan terminal by the condensate transfer pump. Due to the decline of LNG production over the last few years, the hydrocarbon condensate flow rate has also been reduced. To prevent the condensate transfer pump work below the minimum flow design, the operating intermittent pump was proposed. The main concept of intermittent operation is to operate the pump at its rate capacity in lower running hours. This study offers a novel intermittent transfer pump configuration to obtain the best pump energy consumption in terms of energy efficiency.

2. Method

2.1 Research Procedure

In an LNG plant, condensate stabilization refers to the separating of light hydrocarbons (C1 and C2) from hydrocarbon condensate. It means that this process aims to increase the number of heavier fractions (C5 and C6+) in the hydrocarbon condensate (Rahmanian, Ilias, & Nasrifar, 2015). Besides, the stabilization of hydrocarbon condensate is also important to reduce hydrocarbon losses from the storage tank. In the PT Badak NGL plant, the light hydrocarbons are used as the boiler's fuel while the heavier hydrocarbons are treated into condensate with Reid Vapor Pressure (RVP) at 9 psi to 11 psi. After meeting the specification, hydrocarbon condensate is pumped to the Santan terminal for further processing as shown in figure 1.

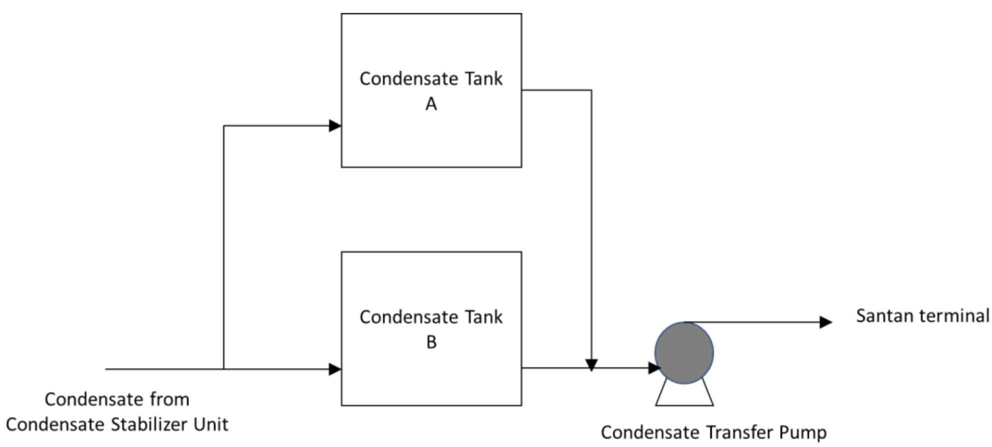

Figure 1. Condensate Transfer Facilities Block Diagram

In the last several years, the production rate of hydrocarbon condensate in PT Badak NGL declined from around 200 m^3/h to 35 m^3/h. To deliver the condensate, there are three transfer pumps available in the plant. Two pumps have a rated flow of 105 m^3/h respectively and one pump has a rated flow of 137.5 m^3/h with an identical minimum flow of 45 m^3/h. In normal operation, only one pump operated with a flow rate adjusted equal to condensate coming from Condensate Stabilizer. As shown in figure 2, the pump operated all day with a flow rate of 60 m^3/h to prevent working at its minimum flow. It means that 25 m^3/h of condensate returned to the condensate tank. It indicated that the pump was utilized far below its capacity.

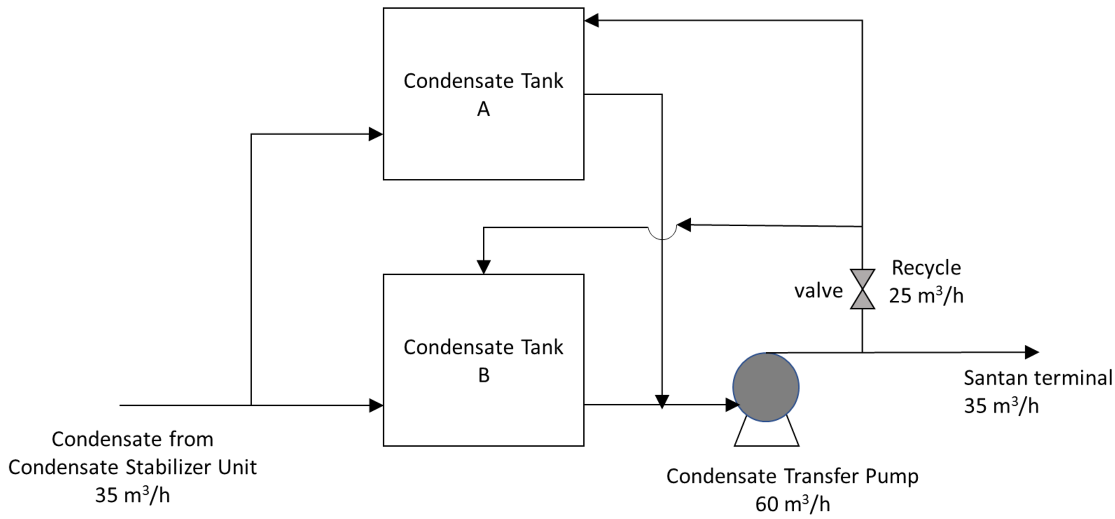

Figure 2. Continuous Condensate Transfer Block Diagram

To handle this issue, the study of intermittent operation was investigated. As opposed to continuous operation with a single pump for 24 hours of operation, all three pumps operated for 8 hours/day respectively with the discharge flow set at 105 m^3/h as shown in figure 3. Before operating, free-water draining is performed to minimize condensate water content.

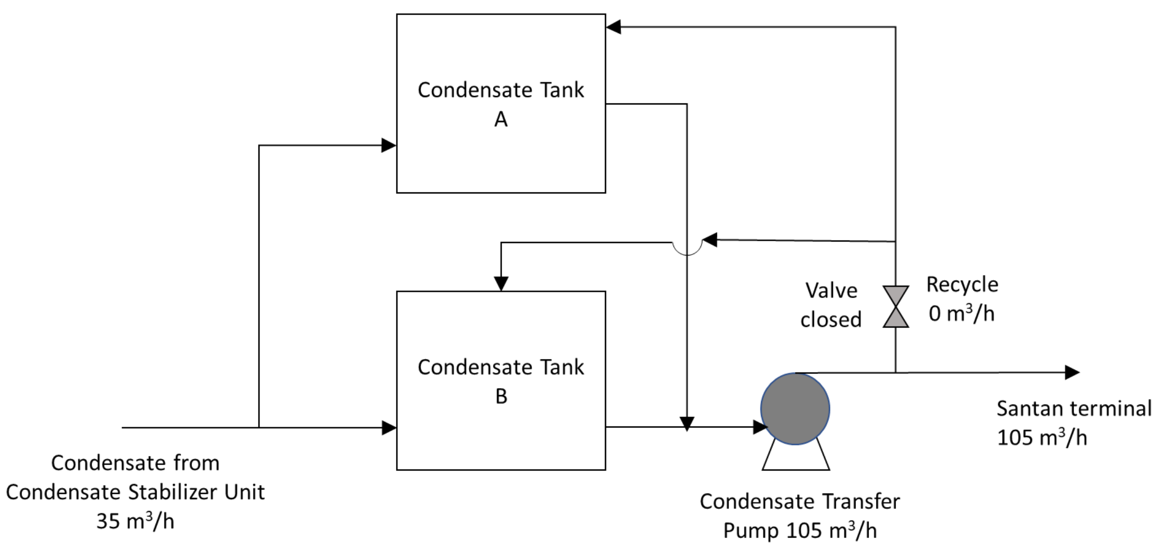

Figure 3. Intermittent Condensate Transfer Block Diagram

2.2 Tools and Data Analysis

The pump power consumption is used as based data for comparison between two operations in terms of energy saving. It can be calculated using the electric current (I) data recorded by Relay GE Multilin 369 as per equation (1) where PF is power factor, V is voltage, and η is pump motor efficiency.. Due to the alteration of the pump's operational procedure, the pump was also tested to examine its reliability. This evaluation will elaborate on several parameters including condensate tank level, pump performance, and condensate quality.

$$Power\ consumption\ =\ \sqrt{3}\ x\ PF\ x\ I\ x\ V\ x\ \eta \quad (1)$$

3. Results and Discussion

3.1 Energy Saving

As shown in figure 4, in the first two seconds, the electric current was recorded at 253 A but it declined rapidly to steady during the operation at 47 A. It happened because the pump operated with Direct Online (DOL) starting method.

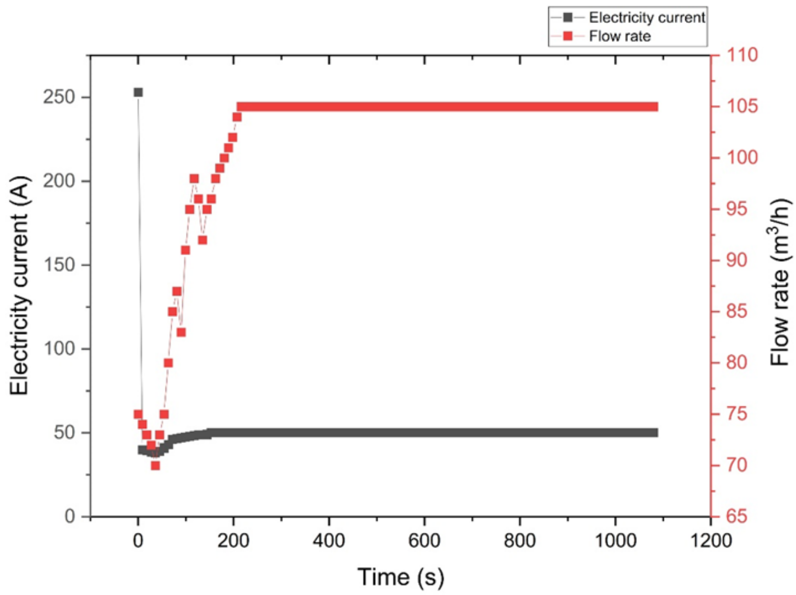

Figure 4. Electric Current consumption vs flow rate and operating hours

Table 1 shows the total energy saving from the new configuration of transfer pump operation. The total energy is simply obtained by multiplying the power consumption by the operating hours. Even if the intermittent pump required higher power consumption, the total energy consumption is lower than the continuous one. It was calculated that the continuous pump consumes energy more than three times compared to intermittent operation, reported at 4.62 MWh/day compared to 1.89 MWh/day (figure 5). As shown in table 1, the energy saving was actually coming from the lower running hours of intermittent pump operation. It can be seen that the total energy reduction is up to 60% with 67% lower operating hours. With regards to electricity cost at 130 USD/MWh, the operating cost is spared to around 130,000 USD per year.

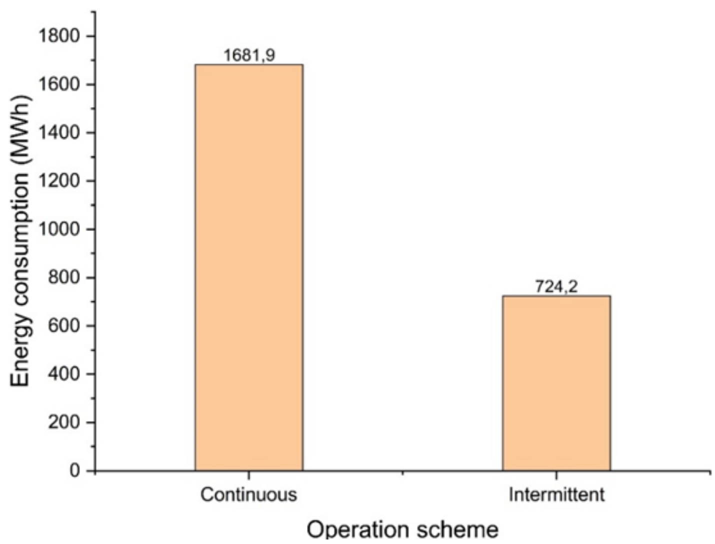

Figure 5. Annual Energy Consumption

The energy saving from the new configuration of pump operation is also being reflected as lower steam consumption in PT. Badak NGL Steam Turbine Power Generation. By assuming the condensing steam turbine-specific steam rate of 2.5 ton/h HP steam per MW, the annual energy saving of 957.7 MWh is equivalent to 2,394 ton HP steam annual saving. This energy saving also contributes to an annual CO_2 emission reduction of 412 ton eq CO_2.

Table 1. Continuous Pump vs Intermittent Pump

Comparison	Continuous	Intermittent
Discharge flow rate (m^3/h)	60	105
Power consumption (kW)	192	248
Daily Running hours (hr)	24	8
Annual Running hours (hr)	8760	2920

3.2 Pump Performance

The pump reliability was examined in terms of vibration and motor performance during 3 days intermittent transfer test. During 3 days test, each pump operated for 8 hours/days with consecutive start-stop. It means that the pump has a cooling time of around 16 hours. According to (NEMA, 2009) the allowable pump consecutive restart frequency is twice for the cold start condition and once for the hot start condition. The standard determines that the sufficient cooling time is around 6 to 12 hours. It can be concluded that the pump operation is still safe and acceptable. In terms of the vibration parameter, the result shows that the vibration value is still acceptable in the range of 0.21 in/sec on electric motor driver. While the motor pump performance is evaluated by monitoring ampere data. The result shows that the temperature winding was steady at 64^{o}C and performance at 0.7 FLA.

3.3 Condensate Quality

Table 2 shows the hydrocarbon condensate quality parameter before and during the intermittent transfer test. The parameter data was examined in PT Badak Laboratory with samples collected during the condensate transfer to Santan terminal. It can be seen that %BS&W remained constant at 0.25% while the RVP value varied from 11.5 to 11.9 psi. According to the specification, it can be concluded that hydrocarbon condensate quality is still acceptable

Table 2. Hydrocarbon Condensate Quality

Parameter	Continuous	Intermittent
%BS&W		
Experiment-1	0.25%	0.25%
Experiment-2	0.25%	0.25%
Experiment-3	0.25%	0.25%
RVP (psi)		
Experiment-1	11.4	11.9
Experiment-2	11.8	11.5
Experiment-3	11.4	11.5

3.4 Condensate Tank Liquid Level

Figure 6 represents the condensate tank level during the intermittent operation test. The level is adjusted by the valve opening percentage managed by Flow Indicator Controller. It can be seen that the operation started at an average tank level of 3.4 m and then stopped an average of 7.5 hours later when the tank level reached 3 m. The operation duration actually finished 30 minutes earlier than the design.

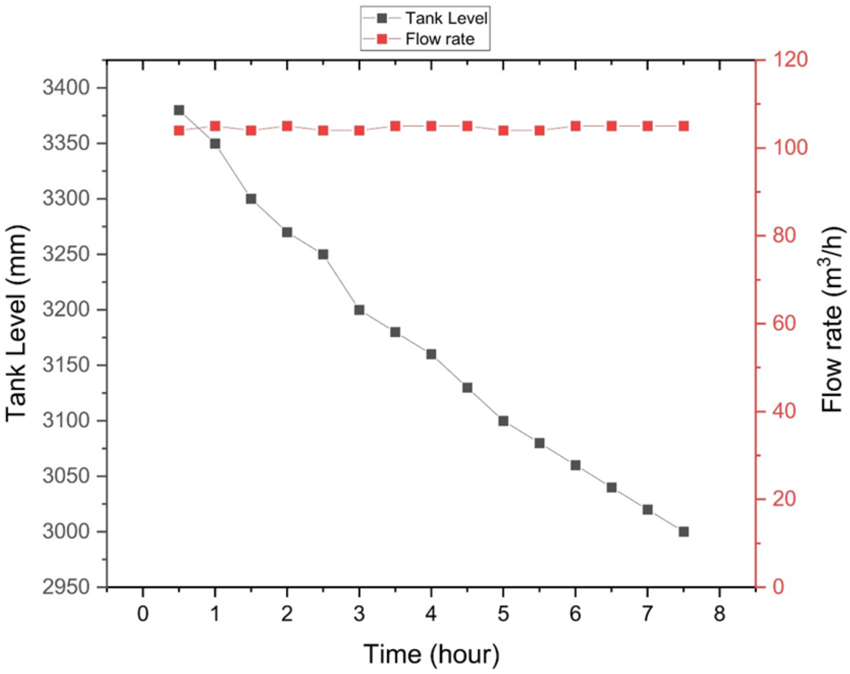

Figure 6. Actual Operating Duration vs Tank Liquid Level

4. Conclusion

The study recommends the intermittent transfer pump operation be applied in the PT Badak NGL to reduce the energy consumption of the pump due to the decline of hydrocarbon condensate production. The study resulted in 60% energy saving with pump performance and hydrocarbon condensate still meets the specification. This contributes to annual energy saving of 957.7 MWh or 2394 ton HP steam and CO_2 emission reduction of 412 tons eq CO_2.

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