Journal of Natural Gas Science and Engineering 35 (2016) 152–159

Contents lists available at ScienceDirect

Journal of Natural Gas Science and Engineering

journal homepage: www.elsevier.com/locate/jngse

Feasibility study on energy recovery at Sari-Akand city gate station using turboexpander

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ARTICLE INFO

Article history:
Received 12 May 2016
Received in revised form
20 July 2016
Accepted 19 August 2016
Available online 21 August 2016

Keywords:
Energy
Natural gas
Turboexpander
Payback period

ABSTRACT

Saving energy is a significant issue in the oil and gas industries because of the high cost of global energy sources. Turboexpanders are generally used to recover pressure energy of gas at city gate stations. The present study examined the challenges to turboexpander installation at gas station. These include fluctuations in natural gas (NG) flow and the high cost of installing new heating devices. The first line at Sari-Akand city gate station was simulated using HYSYS software for a nominal capacity of 120,000 SCMH. The NG pressure energy lost at the regulator was calculated using exergy analysis. The results showed that the pressure energy of NG lost during regulation was 7.1 GWh annually. Two scenarios were analyzed to find the suitable plan of turboexpander installation at the gas station. The scenario for installation of one turboexpander instead of one regulator had lower payback period than the scenario where one turboexpander was installed in place of two regulators. NG fluctuation resulted in inability to use the turboexpander for five months of the year and decreased electricity production 8.3% in the other seven months. The annual turboexpander electricity production was computed to be 3.2 GWh. The payback period for turboexpander installation was calculated as 12.9 years to account for the significant 2-fold increase in dollar price in Iran. A feasibility study for implementing a similar plan in England had a payback period of 2.2 years because of the higher price of electricity and lower interest rate in comparison with Iran. The connection of lines 1 and 2 increased annual turboexpander electricity production 54%, which resulted in an annual increase in revenue of $53,400. This decreased the payback period to approximately 8 years in Iran and 1.7 years in England. It is predicted that implementation of similar arrangement at the three other stations will significantly increase revenue about $160,000 annually.
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1. Introduction

Countries must devise plans to recover and avoid loss of energy sources. Natural gas (NG) is a significant source of energy and is widely-used by different consumers. To deliver NG to its consumers, it is compressed at compressor stations. Because NG consumers consume low pressure gas, it is then transferred to city gate stations (CGSs) to decrease the pressure after transport. The station decreases inlet gas pressure from (2.7–5.5 MPa) to 1.7 MPa using a regulator. When the gas pressure drops, the energy of the gas falls. This is a significant source of energy which could be recovered using devices such as turboexpander.

Installing a turboexpander at the station will reduce the amount of NG pressure energy lost from the JT valve and will also convert the potential energy to electricity. Howard et al. (2011) examined the installation of a turboexpander at a small CGS in Canada. They concluded that the addition of a fuel cell to the pressure reduction system increased the efficiency of a 12,000 SCMH turboexpander by almost 10%. Taheri et al. (2010) calculated the NG pressure energy lost through regulation at CGS with a nominal capacity of 420,000 SCMH. The results showed that the amount of NG pressure energy lost from the JT valve was approximately 40 GWh annually using regulators. Konukman and Akman (2005) examined integration of heat exchanger networks in a natural gas turboexpander plant used for recovery of ethane. They simulated integration of these components to study the performance interactions. Tripathy et al. (2014) concluded that the use of biomass is a short-term option to reducing CO_2 emissions, but that exergy loss, including the irreversible loss, were greater than that of coal-based power

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http://dx.doi.org/10.1016/j.jngse.2016.08.054
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plants. Rosen and Scott (1998) used computer simulation to analyze the energy and exergy of low-pressure processes for methanol production from gas. Andrei et al. (2014) and Taleshian et al. (2012) also studied turboexpander at CGSs.

Zehtabian and Saffar-Avval (2012) investigated a Ghazvin CGS with a flow of 20,000 SCMH. They concluded that the fluctuation of inlet gas to the turboexpander affected its efficiency. They calculated the real efficiency of the turboexpander to be 67.79% assuming a nominal flow efficiency of 80%. Pozivil (2004) simulated installation of a turboexpander in the parallel with the CGS regulator to recover energy and prevent its loss and concluded that the drop in gas temperature was 15–20 °C for each 1 MPa drop in gas pressure.

Zabihi and Taghizadeh (2015) simulated the Akand CGS in HYSYS software to determine the amount of decrease and economic benefits of the new controller installation using the Peng-Robinson (PR) and SRK equations of state. The real temperature data recorded at the station was compared with that from the simulation to select the equation of state. The results indicated that the PR equation showed less deviation from the real data. Veysi et al. (2014) compared PR, SRK, and AGA8 equations for calculation of energy loss from a heater at a CGS. They concluded that the AGA 8 calculation of the temperature of NG entering the regulator, deviated least from the data measured at the station.

Previous researches has primarily focused on only the installation of a turboexpander at a gas station without addressing the major challenges of the sharp fluctuation in flow of gas entering the station during the hot months of the year and the high cost of implementation, which includes heating devices to heat the gas passing through the turboexpander. To our knowledge, no prior work has been done to assess all this limiting challenges regarding turboexpander installation at the gas stations and to refine its design in order to decrease the initial cost and increase the revenue.

The present study investigated a new approach to turboexpander installation at a CGS to mitigate the economic and operational challenges. The effect of daily and monthly fluctuations in NG flow on turboexpander design and operation were investigated and the temperature drop of gas passing through turboexpander was analyzed. New methods have been suggested to make turboexpander installation economically and operationally feasible at large CGSs belonging to Mazandaran Gas Company. Line 1 to Akand CGS with a nominal capacity of 120,000 SCMH was selected. The scenarios of turboexpander installation were simulated and the results were discussed to determine the economic and operational benefits.

2. City gate stations

2.1. Sari-Akand gate station

Sari-Akand CGS has two stations with capacities of 120,000 and 200,000 SCMH. The first station has two units with capacity of 60,000 SCMH each. The units run in the same mode. Fig. 1 shows that NG is first sent through filters to remove impurities and is then transferred to the heater for preheating to prevent it from freezing in the regulators. Next, it is sent through three pipes in which the NG pressure is reduced in two identical regulators. It is then sent to the town boundary station (TBS) to reduce the pressure from 1.7 to 0.4 MPa (NIGC.MZ Engineering Department, 2011).

2.2. NG composition, inlet and outlet flow rate, pressure, and temperature at Sari-Akand CGS

The chemical composition and physical specifications of the inlet gas must be determined in order to simulate a CGS (Tables 1 and 2). The monthly average values for NG inlet and outlet pressure, inlet and outlet temperature, and NG flow rate were recorded for the first line of the station as shown in Table 3 (Data sheets, 2013).

The drop in heater gas pressure was assumed to be 0.068 MPa. Fig. 2 portrays the simulation of the first line at Sari-Akand CGS at a nominal capacity of 120,000 SCMH.

3. Calculating lost energy

The amount of NG pressure energy lost during reduction was calculated using exergy analysis. Exergy is the amount of useful energy available when the system is brought into equilibrium with its surroundings. The exergy of a system is calculated as shown in Equation (1). The heat and work exergies are calculated in Equations (2) and (3).

$$\Delta X_{system} = \Delta X_{heat} - \Delta X_{work} \tag{1}$$

$$dX_{heat} = dq_{reversible} - T_0 dS \tag{2}$$

$$\Delta X_{work} = W_{reversible} - P_0 dV \tag{3}$$

$$\Delta X_{system} = \Delta U - T_0 dS + P_0 dV \tag{4}$$

Substitution of Equation (2) and Equation (3) into Equation (1) produces Equation (4), which can be used to calculate system exergy. Because NG moves through a regulator, the “flow exergy” must be computed. Equation (5) shows the exergy of a flowing fluid calculated by adding NG system exergy to the flow exergy as shown in Equation (6).

$$X_{flowing\ \ fluid} = X_{non-flowing\ \ fluid} + X_{flow} \tag{5}$$

$$X_{flow} = V(P - P_0) \tag{6}$$

The exergy of the NG as it passes through the regulators is calculated using Equation (7). The differential exergy of the NG before and after the regulators is required and can be calculated by subtracting the outlet exergy from the inlet exergy as shown in Equation (8) (Taheri et al., 2010).

$$X_{flowing\ \ fluid} = \Delta H - T_0 \Delta S \tag{7}$$

$$\Delta X = X_2 - X_1 = (H_2 - H_1) - T_0(S_2 - S_1) \tag{8}$$

Fig. 2 shows the station simulation in HYSYS software used to calculate station NG inlet and outlet enthalpy and entropy. Zabihi and Taghizadeh (2015) concluded that Peng-Robinson equation (Table 4) was most suitable for simulation of Sari-Akand CGS in HYSYS software; therefore, this equation was used to simulate the installation of a turboexpander at Sari-Akand.

After specifying the monthly averages for NG inlet and outlet pressure, temperature, and flow rate of regulator in the software, the average monthly NG differential entropy was calculated. Because gas pressure reduction was adiabatic, the NG enthalpy remained constant. Calculated monthly differential exergy and pressure of NG passing through the regulators are shown in Fig. 3. This figure indicates that there is a direct relationship between exergy and the differential pressure of the NG passing through the regulators.

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