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Research Article

Modelling natural gas pressure reducing stations for power generation using expansion turbines

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Abstract: Natural gas has a high pressure before consumption in industries and cities. This pressure is reduced using relief valves in urban gas pressure reducing stations. Pressure drop results in great energy loss and accordingly stations are able to generate power. If we could install an expansion turbine parallel with the station and to move an axis, we could gain electricity from axial work. In this paper, first urban gas pressure reducing stations are modelled using HYSYS Software. After installation of an expansion turbine in the direction of station, productivity of the station is investigated, followed by examination of temperature, pressure, and productivity in the station and their results.
Keywords: gas pressure reduction, expansion turbine, power generation

INTRODUCTION

Regarding the high pressure of natural gas in intercity gas transmission lines amounting to 700-1000PSI and necessity of gas pressure reduction in pressure reducing stations for consumption in cities and various industries, it is possible to generate power during pressure loss. To produce work out of this pressure drop, various pieces of work have been done. For example, Dresser and AGKK Companies have utilized this technology to generate power. Power can be generated when high-pressure gas enters cylinder-piston. Here, it pushes back the cylinder resulting in space development in the cylinder and gas expansion. However, to enhance efficiency and elevate the output gas temperature, it is better to preheat the gas [1,2,3], implemented by the mentioned company through Internal Combustion (IC) engines. When the engine itself generates power, the output gas is used for gas preheating which is an effective Combined Heat and power (CHP) system with an efficiency of above 80%. Power Verde Company [5] has performed generation of power during pressure drop of 150 PSI. Fig. 1 presents a schematic view of gas pressure reducing station together with its facilities.

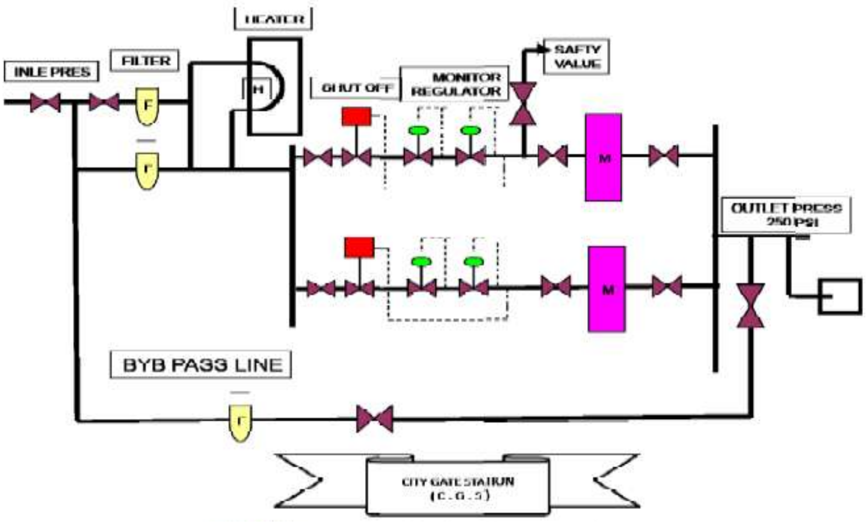

Fig-1: Schematic view of Pressure reducing station (City Gate Station)

In order to reduce pressure, regulators with rubber openings are placed in the gas direction. Thermodynamically, in regulators, high-pressure gas passes through the orifice and expands. Gas expansion leads to reduced temperature. This may result in generation of solid and liquid particles, a process called gas freezing. If we write energy equation for this delivery, we have:

$$h_1 + \frac{v_1^2}{2g} = h_2 + \frac{v_2^2}{2g} \qquad (1)$$

Where, h_1 and h_2 are enthalpies of input and output gas in the regulator, respectively, and v_1 and v_2 are gas flow rates in input and output of the regulator, respectively. Since gas expands in this process, its specific volume grows leading to enhanced potential energy if gas orifice is fixed. If velocity changes are neglected, the process becomes as follows:

$$H_1=h_2 \qquad (2)$$

Therefore, pressure reduction process is an enthalpy-constant process from which Thompson-Joule coefficient is obtained. Thompson-Joule coefficient [4] is:

$$\mu = \left(\frac{\partial T}{\partial P}\right)h \qquad (3)$$

During transformations in the gas, if Thompson-Joule coefficient is negative, then temperature increases, while if it is positive, temperature diminishes. As Thompson-Joule coefficient is positive in natural gas and pressure variations are negative, then temperature variation is also negative leading to decreased temperature. This reduced temperature is significant when the gas and ambient air temperature is low, causing liquid and water vapor particles create freezing in the regulator. On the other hand, pressure reduction is regarded as a special potential for power generation. However, currently suppression process is used in the country to reduce pressure in natural gas pressure reducing stations with no power generation.

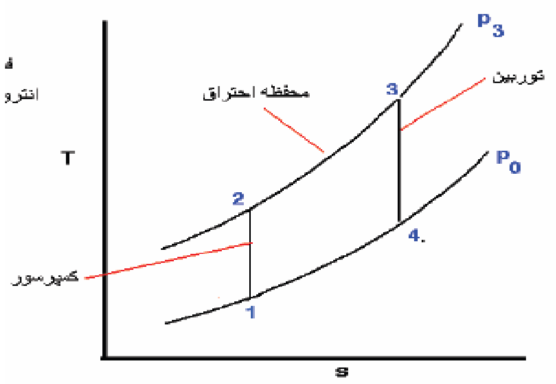

Fig-2 : Gas turbine cycle (Brayton cycle)

The turbine gas cycle demonstrated in Fig. 2 indicate that much of the gas produced from the turbine bring about pressure elevation in the fluid used by the compressor. If high-pressure gas exists here, there is no need to gas compression. Therefore, compressor is removed from the system and process efficiency develops. It should be noted that in this process the gas is preheated to enhance generated power, which is not combusted as evident in Fig. 3. Here, the objective is to use the exergy caused by the high pressure of natural gas, shown in Fig. 3.

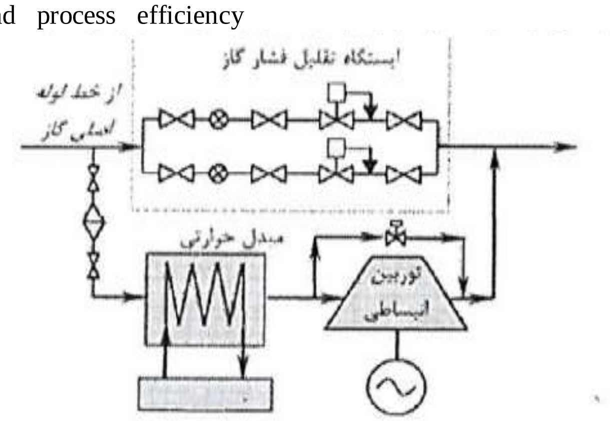

Fig-3: Utilization of expansion turbine in pressure reducing stations

According to the mentioned potential in regulators and the fact that a huge amount of energy is lost as a result of pressure reduction, then it is possible to calculate the generated power and examine them by analyzing natural gas pressure reducing stations using HYSYS [4] and by entering temperature and pressure values in the software recorded within a six-month period.

METHODOLOGY

In this research, initially the input and output temperature and pressure values of a reducing station in Kerman were recorded and further investigated within a five-month period. The components of pressure reducing stations were then modelled by HYSYS, where an expansion turbine was placed in the output gas direction beside regulators. Finally, the turbine generated power was calculated for different months. The natural gas specifications entered into the software are as follows:

Table-1: Molar percentage of natural gas constituents

Element name	Element	Molar ratio
methane	CH_4	87/85
ethane	C_2H_6	3/57
propane	C_3H_8	1/32
iButane	i- C_4H_{10}	0/3
nbutane	n-C_4H_{10}	0/41
Ipentane	C_5H_{12}i-	0/15
pentane	n-C_5H_{12}	0/1
nhexane	+C_6	0/13
hydrogen sulfide	H2S	0
oxygen	O_2	0
nitrogen	N_2	5/77
carbon dioxide	CO_2	0/4
water vapor	H_2O	0
carbon monoxide	CO	0
ethylene glycol	E-glycol	0

Recorded data of the station

As the data were recorded experimentally, through validation it can be observed that if they are entered into the modelled station, obtained results will have a very minor error. Accordingly, the data were fed in the software on a monthly basis through various tables. /the station studied here has a capacity of 50000 SCMH (m^3/h). The process of station modeling: According to Fig. 1, it is possible to feed components of the station in the software. Fig. 4 represents this process.

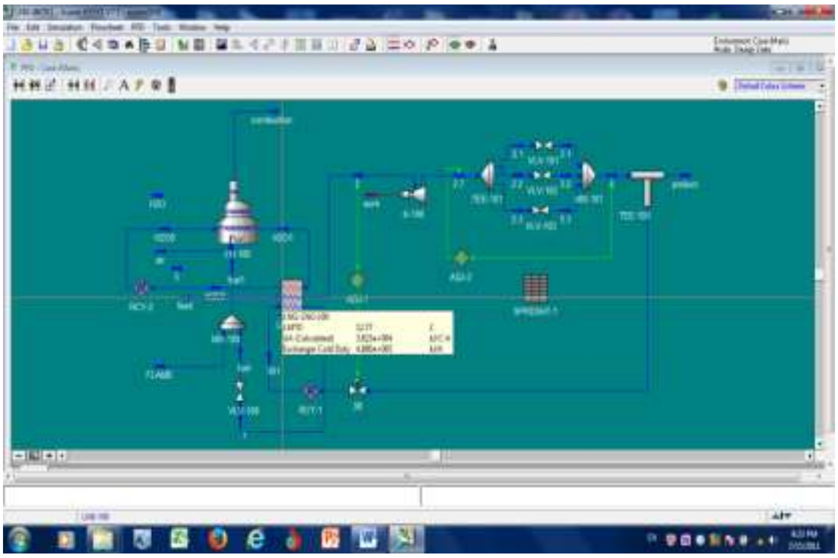

Fig-4: The pressure reducing station modelled in HYSYS

In this paper, the problem of power generation in regulators is addressed, therefore other components of the station such as heater that have a central role in the performance of the station are not investigated. This modelling is consistent with real regulator conditions. In HYSIS, first the percentage of natural gas components is fed in to calculate compressibility factor, where state equation such as Peng-Robinson Equation are used. The Equation is as follows:

$$p = \frac{RT}{\nu - b} - \frac{aT}{\nu(\nu + b) + b(\nu - b)}$$

$$b = 0.07780\frac{RT_C}{P_C}$$

$$a = \sum_i \sum_J X_i X_J a_{ij}$$

$$b = \sum x_i b_j$$

Where, a and b factors are calculated in terms of critical temperature and pressure and gas constants [4]. In pressure reducing station, the input gas with a pressure of 700-1000 PSI enters the stations and because its pressure reduces in regulators, then its temperature diminishes as well. In warm water heaters, the gas temperature slightly grows so that it does not freeze in response to temperature reduction when pressure reaches 250 PSI in the regulator. In regulators there is a potential for power generation since the gas pressure declines by ¼ of its value. This is the fundamental principle of expansion turbines.

The components of modelled station

1. LNG-100: the sector of input gas to the water inside the heater designed as a heat exchanger.
2. FH-100: the combustive sector of the heater modelled as a furnace.
3. K-100: The expansion turbine sector installed in the gas direction to generate work.
4. VLV-100: Relief valve of heater fuel direction that reduces gas pressure for the heater flame.
5. VLV-101,102,103: three regulators of output line of the station reducing pressure from 700-1000 PSI to 250 PSI.

Flow directions

1. Feed direction: input gas to the heater
2. Direction 2: output gas from the heater with elevated temperature entering expansion turbine.
3. H_2O direction: the output water of heat exchanger and combustion chamber input.
4. H_2O1 direction: input water to the heat exchanger and output from combustion chamber.
5. Air direction: input air to the combustion chamber.
6. Combustion direction: The output combustion products from heater chimney.
7. FLAME direction: pilot flame of heater burner.
8. Fuel 1: The input fuel into heater furnace.
9. R1: the output heater fuel consumed gas from the exchanger.
10. 2.7 direction: the output gas from expansion turbine and input to the regulator.

RESULTS AND DISCUSSION

Fig. 5 illustrates variations in the input gas pressure entering the station in terms of output gas temperature at different flow rates and at input temperature of 19 ^{0}C in Mehr. As can be observed, at all input temperatures, variations in the input gas pressure are correspondent in terms of the station output gas temperature and are independent of flow rate. In this diagram, the output gas temperature is inversely correlated with input gas pressure. When the flow rate increases, the output gas temperature slightly diminishes. This fact is applicable to the real world since higher gas consumption reduces the output gas temperature of the station.

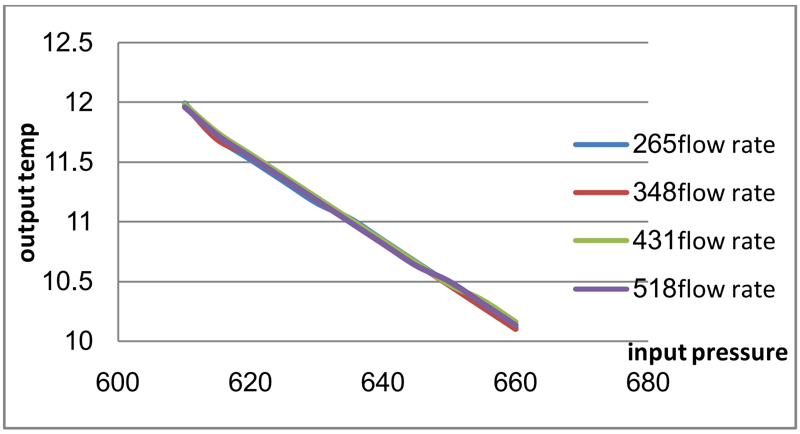

Fig-5: Input gas pressure against the station output temperature at various flow rates and at 19 ^{0}C

Fig. 6 manifests the amount of input gas pressure versus power generated at various flow rates and at input temperature of 19 ^{0}C.

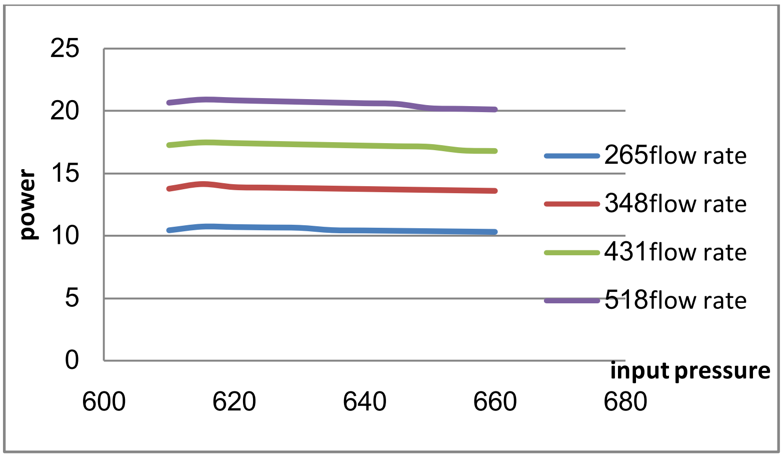

Fig-6: Input gas pressure in terms of power generated at different flow rates and at input temperature of 19 ^{0}C.

In the above diagram we can see that when pressure heightens at various flow rates, the generated power remains constant. Furthermore, as the station gas flow rate increases, so does the generated power. This is completely logical since the higher the flow rate the more the power generated at the station.

Fig. 7 presents the diagram of output gas temperature of the station at various flow rates and input pressure of 610 PSI in Mehr. As can be observed, variations in the output gas temperature versus enhanced flow rate are very slight and almost constant. When the temperature of input gas to the station increases, its output temperature remains constant in response to the presence of expansion turbine in the output gas direction. This process is almost similar at all input pressures.

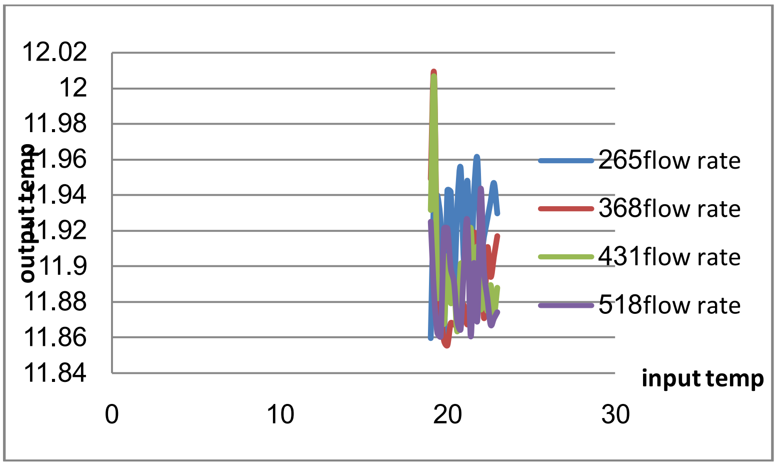

Fig-7: The diagram of output gas temperature in terms of input gas temperature for various flow rates at input pressure of 610 PSI.

Fig. 8 represents the diagram of input gas temperature in terms of power generated at various flow rates at 610 PSI in Mehr. It is observed that as the heater input temperature increases (implying increased air temperature), the amount of power generated at the station remains constant. However, when the gas flow rate elevates, this value grows owing to enhanced flow rate and potential of power generation.

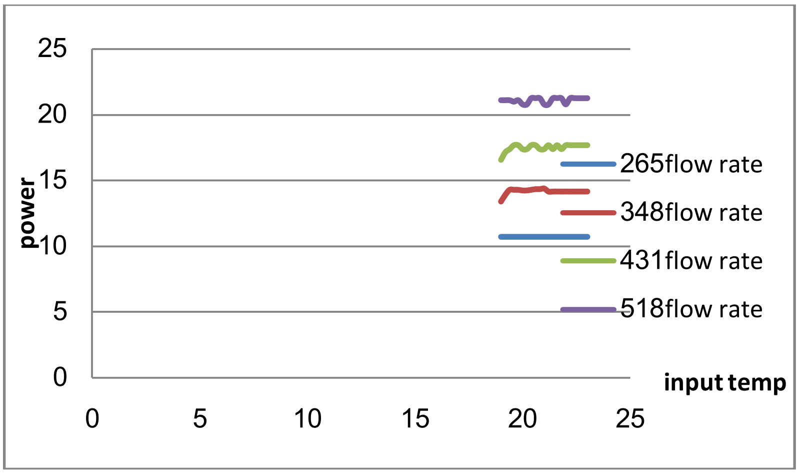

Fig-8: The diagram of input gas temperature in terms of power generated at various flow rates at a pressure of 610 PSI.

Fig. 9 demonstrates the output gas temperature in terms of gas flow rate at different input pressures at 19 °C in Mehr.

According to the above diagram, In Mehr when the gas flow rate increases, no change occurs in the output gas. This is attributed to the presence of expansion turbine in the station direction. As input gas pressure to the station grows, the output gas temperature declines. This signifies that increased pressure results in generation of power in the expansion turbine, decreasing output gas temperature.

Fig. 10 illustrates the diagram of gas flow rate in terms of power generated at the station at various flow rates and at input temperature of 19 °C in Mehr.

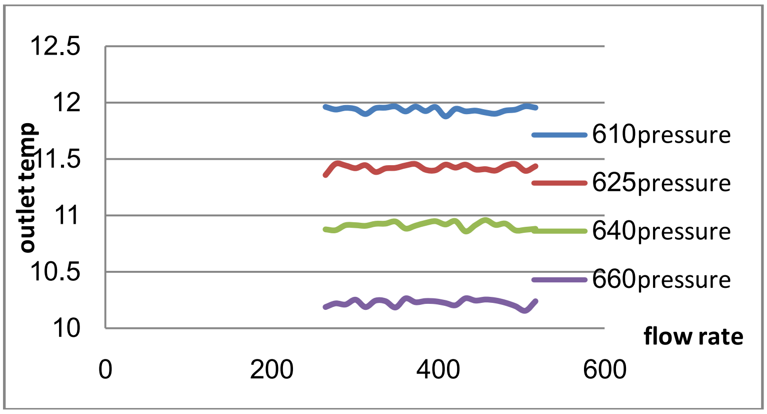

Fig- 9: The diagram of output gas temperature in terms of gas flow rate at different input pressures at 19 °C.

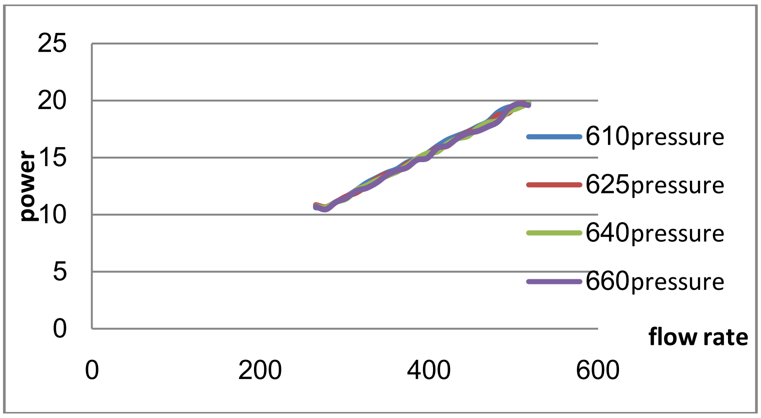

Fig-10: The diagram of gas flow rate in terms of power generated at different flow rates and input temperature of 19 °C.

In the above diagram we observe that at various pressures, the amount of generated power is constant. As the gas flow rate passing through the station increases, so does the generated power. This is a logical pattern since the more the gas flow rate, the higher potential for power generation.

CONCLUSION

Regarding gas pressure drop in relief regulators, in gas pressure reducing stations temperature decreases based on Joule-Thompson phenomenon. Accordingly, the gas should be heated in heaters prior to entrance to regulators so that it does not freeze in case the temperature diminishes. Since gas pressure shrinks as one quarter of its initial value, then there is a high work potential in regulators, where this power can be achieved and calculated from pressure drop by installing an expansion turbine in the gas direction. If all gas reducing stations throughout the country are taken into consideration, this can have a very high potential for power generation and is consumable in the station itself and is even injectable in power network. This paper has calculated the power generated at a station, generalizable to all other stations.

REFERENCES

1. Bakhshali M; An Introduction to pressure reducing stations. human resource training at Iranian National Gas Company, 1382(hizri).
2. Sadeghi J; Energy recycling by expansion at Kermanshah Biston Power Plant", 6thNatioanl Energy Conference, 22th and 23th of Khordad, 1386(hizri).
3. Moghimi M; Introduction to expansion turbines and their applications in Power Plants. Power Ministry, Javan Consultants Group.
4. Van wylen; Sontagg, Introduction to Classical Thermodynamics, fifith edition, 2008.
5. Dahm KD, Hesketh RP, Savelski MJ; Is process simulation used effectively in ChE courses?. Chemical Engineering Education, 2002; 36(3):192-197.