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Assessment of Saving in Energy by Replacing Three Stage Compressor with Two Stage Compressor with Higher Suction Pressure for Natural Gas Compression at City Gate Station : A Case Study

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ABSTRACT

At room temperature, Natural gas in its gaseous form is very energy consuming for transportation as well as its use, because of large volume. So, it is compressed to transport through cylinders and expanded again at the point of its distribution/use. Two of the most important factor influencing the energy consumption in compression of gases are the type of compressor control and proper compressor sizing [1]. It is expected that the current work through this paper will create awareness on the potential energy savings in CGD system.

Keywords: City Gas Distribution, Natural Gas Compression, Three Stage Compression, Two Stage Compression, Energy Saving in CGD.

I. INTRODUCTION

To curb the rising pollution level in metropolitan cities, Government of India emanated with City Gas Distribution (CGD) projects in Mumbai and Delhi initially. City Gas Distribution can simply be termed as the system of interconnected network of pipeline, which is used for supplying Natural gas throughout the city [2]. As a result of its success in Mumbai and Delhi, phase-wise expansion of project was planned throughout the country. To execute this expansion plan and regulate CGD in country, Petroleum and Natural Gas Regulatory Board (PNGRB) was formed through PNGRB Act- 2006. PNGRB has granted authorization for development of CGD in many cities of country. Indian government is considering for full-fledged expansion of CGD, which will also help reduce huge oil import bill for transportation.

II. CGD PRESSURE REGIME

At room temperature and pressure, Natural gas transportation in its gaseous form is highly energy consuming, because of its high volume. Hence it is transported as pressurized gas through inter-city or cross-country pipelines over long distances. Also, it may be carried over very long distances in the form of LNG. Different pressure regimes of Natural gas chain are described in below picture.

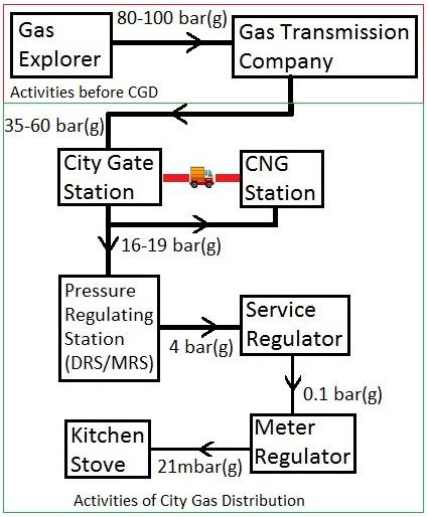

Fig 1: Pressure regimes of Natural Gas chain

After necessary separation of different gases, Gas explorer (i.e. ONGC, GSPC, Reliance, Niko resources etc.) supplies it through very high-pressure pipelines to Gas transmission companies (i.e. GAIL, RGPIL, GSPL etc.) at pressure range of 80-100 bar(g). The gas supplied is added with odorant Ethyl Mercaptan (C_2H_6S), which helps in leakage detection. CGD companies (i.e. MGL, IGL, GGL etc.) purchase gas from transmission companies at City Gate Station (CGS), generally at pressure range of 35-60 bar(g). The pressure reduction takes place in CGS to 19 bar(g), which is supplied to CNG stations/District Regulating Station (DRS)/Meter Regulating Station (MRS) through high pressure pipeline [2]. Similarly, pressure continues to reduce till kitchen stove, as shown in figure.

Sometimes it is not possible to supply gas to some locations, through pipeline due to site constraints. In that case, gas is transported to that location through LCV mounted cascade cylinders at pressure of 220-230 bar(g). These cascade cylinders are generally filled at mother CNG stations, used at required site location and empty cylinders are sent back for filling. The pressure required for cascade cylinders are achieved through three stage reciprocating compressors from 19 bar(g) supply at CNG mother station to 220 bar(g) pressure in cascade cylinder.

III. STUDY METHODLODY

We adopted following methodology for study: -

- We estimated expected saving in energy theoretically by replacing three stage compressor with two stage compressor.
- Necessary data obtained from site for getting power consumption of three stage compressor operation for 10 days.
- Now the replacement of compressor done by company with all needed piping work.
- Necessary data obtained from site for getting power consumption of two stage compressor operation for 10 days.
- The difference in above two power consumption is energy saving, we achieved based on site data.

IV. CASE STUDY & OUTCOME

Theoretical power saving: - The required three stage compressor specification for site operation to compress Natural Gas are as below (obtained from a CGD company).

Suction Pressure or inlet pressure of compressor, Pi = 13 bar(g);

Discharge Pressure or Outlet Pressure, Po = 250 bar(g); RPM of compressor = 1000 RPM;
Temperature of Gas at compressor Inlet, Ti =T1= 35 ^{o}C = 273 +35 = 308 ^{o}K;
Standard Temperature, Ts = 15.55 ^{o}C (= 60 ^{o}F) = 273 + 15.55 = 288.55 ^{o}K;
Natural Gas flow, Qi =1200 SCMH; Specific Gravity of Natural Gas, γ = 0.606; Adiabatic Constant, K = 1.3.
Based on these data, power consumption for each stage estimated theoretically using following formula [3]: -
Capacity of n^{th} stage,

$$Vn = \frac{(Flow\ Rate)x\ (Standard\ Pressure)x\ (Gas\ Inlet\ Temperature)}{(Inlet\ Pressure)\ x\ (Standard\ Temperature)x(Compressibility\ Factor)}$$

Power input required for n[th] stage, $Wn = \frac{K}{(K-1)\ (\varepsilon)}\ Pn\ Vn\ \left[r^{\left\{\frac{(K-1)}{K}\right\}} - 1\right]$

Theoretical power consumption of each stage compressor can be represented in P-V diagram, as below.

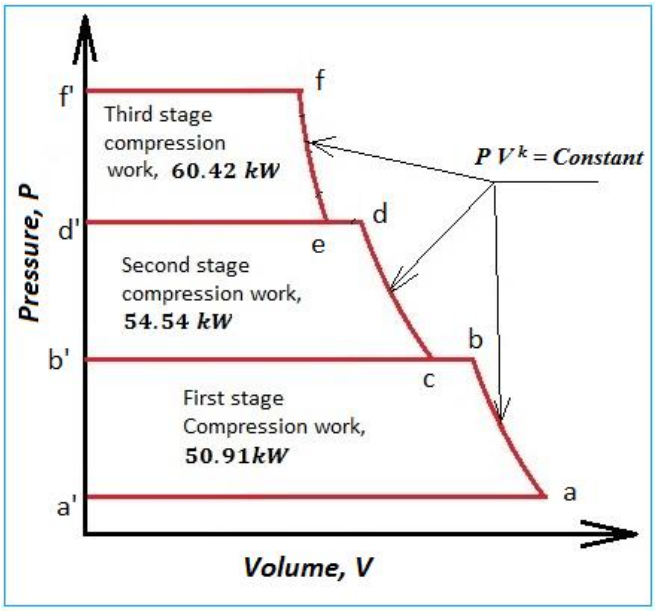

Figure 2: P-V diagram of three stage compression in adiabatic process

Compressor suction pressure i.e. pressure at a, a' = 13 bar(g);

First stage suction pressure i.e. pressure at b, c, b' = 34.71 bar(g);

Second stage suction pressure i.e. pressure at d, e, d' = 92.68 bar(g).

For compressors located at City Gate Stations, if CGD companies makes some agreement with Gas Transmission company to allow to use gas from their pipeline at pressure range 35-60 bar(g) then first stage of compression could be eliminated completely, from above three stage compression arrangement. This elimination of first stage does allows to save power consumption up to ***50.91 kW*** theoretically.

Actual power saving: - To get actual power saving, following 10 days average compressor operation data were collected from site.

Sr No	Parameter	Three stage compressor	Two stage compressor
1	**kWh**	745.16	598.31
2	**HMR**	5.71	6.54
3	**PF**	0.87	0.87
4	**kVA**	0.77	1.11

Table 1: Three stage and two stage compressor data from site operation.

Energy saving estimated from above table 1 data as

Energy saving in kW

$$= \frac{745.16}{5.71}\ kW\ - \frac{598.31}{6.54}\ kW$$
$$= \mathbf{39.01\ kW}$$

Based on above data the monthly energy bill for operating three stage compressor and two stage compressor comes out to be Rs 1,84,990.92/- and Rs 1,32,278.71/- respectively [4].

Additional cost for replacing three stage compressor with two stage compressor (collected from one of the leading CGD company, excluding compressor cost) = Rs 22,50,000/-

Cost saving per month with compressor replacement
= Rs 1,84,990.92 − Rs 1,32,278.71
= Rs 52,712.21 per month

Payback period of additional investment = $\frac{22,50,000}{52,712.21} = 42.68\ months < 4$ years

Thus, additional investment made is recovered in less than 4 years. After 43 months the cost of 2 stage compressor is same as that of 3 stage compressor, with continuous saving for entire lifespan of compressor.

The three-stage compressor, removed from city gate station could be used at CNG stations, wherein it is necessary to have suction pressure of 16-19 bar(g).

V. CONCLUSION

From the above case study, we see that the significant amount of energy is saved through the replacement of three stage compressor with two stage compressor. The difference in theoretical estimation and actual power saving is due to the difference in the inlet pressure. We see that the theoretical estimation considered the suction pressure as 13 bar(g), while actual power saving has the suction pressure in 16-19 bar(g) range.
Generally, Natural Gas compressors are supplied with warranty of five years in India. We got payback period of less then four years, based on site data of operation, which is an added advantage. Energy saving from two stage compressor will continue for its lifecycle.

VI. FUTURE SCOPE

In India, many major cities have been considered for the development of City Gas Distribution (CGD) infrastructure in next 5-10 years by PNGRB. To promote the development of CGD, currently PNGRB is providing marketing exclusivity of 5 years and infrastructure exclusivity of 25 years to CGD companies. This allows not only the growth of CGD entity as well as area considered for development. After completion of 25 years of infrastructure exclusivity period, competition is allowed by providing open access, through the choice of customer. The number of CNG stations in country has increased at a CAGR of 19% while pipeline network continues to grow at 32% CAGR in the period of 2009 to 2015 [5]. Natural Gas can help in reducing the fiscal pressure by large amount through the relieve of subsidies provided by government on Petrol, Diesel and LPG.

Also, LNG fueled vehicles has been developed in many countries by improving the storage vessels and gas dispensing facilities. The range and refueling time of LNG vehicles are similar to that of diesel fueled vehicles with advantage of power to weight ratio. Recently developed LNG storage cylinder allows LNG to be stored at less than -162ºC for two weeks or more [6]. This shows that, in near future the Natural gas market will continue to grow in various forms. Thus, the talk of energy efficiency in this sector is as well of very importance.

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