IBP1076_11

GAS PIPELINE DESIGN UNDER MARKET RISK SCENARIO

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Abstract

Feasibility studies for Gas pipeline projects need to take into consideration some key uncertainties that have a direct and significant impact on the economics of a project. Such uncertainties if not properly addressed will expose project sponsors to economic risk and may destroy value. Such uncertainties includes, but are not limited to, gas reserve appraisal, gas market demand, CAPEX, OPEX and Construction Schedule. This paper will focus on Market risk and how gas demand uncertainty may be addressed and how pipeline designers and project sponsors may act to mitigate such risk while selecting a flexible strategy based on gas compressor station design, compressor units stand buy philosophy, pipeline sizing, MAOP definition and some other aspects to be considered in the gas transportation agreement.

1. Introduction

Gas pipeline projects are capital intensive and are normally exposed to risks (e.g. capital expenditure, completion, operation costs, environmental, operation, market demand, gas supply and so forth) that may impact their feasibility study and economic success. This paper will focus only on gas market risk – the risk of achieving the gas demand profile at the levels considered as part of the economical assumptions for the project – as perceived by the Shipper and Transporter. This is a typical scenario for green field projects in countries or regions where gas market is not fully developed and gas distribution infrastructure and companies are not readily prepared to handle this kind of energy of even when the gas commodity price is not fairly competitive against others sources of energy.

2. Gas Business Chain

The basic natural gas business chain from gas producers to the market is shown in figure 1. Producers normally are willing to guarantee to recover their investment on producing facilities and their business in general through long term gas supply agreements with take-or-pay clauses. Gas Transporters normally require long term firm transportation agreements with ship-or-pay clause that may cover up to one hundred percent of their calculated transportation rates although they also make use of interruptible transportation to lower rates. Local distribution companies – LDC also have take-or-pay agreements with the Shipper and with large end users such as gas fired power plants – GFPP following the same principle of protecting their exposure to risk. Shippers are the ones who buy gas from gas Producers, contracts transportation from gas Transporters and sell the gas to LDCs. Shippers are even more exposed to risks than Producers, Transporters and LDCs and therefore must negotiate agreements with them as to manage reasonable headings over the entire gas business chain.

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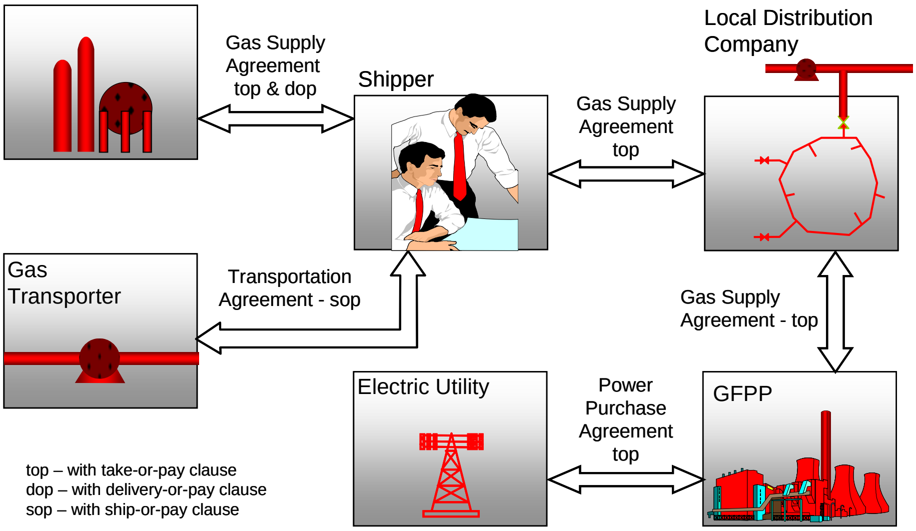

Figure 1 – Typical gas business chain

3. Risk Mitigation from Shipper's Perspective

From Shipper's perspective what would be the best approach is to have an agreement with gas Producer that guarantee gas supply at a take-or-pay percentage amount over the contractual volumes as low as possible, a ship-or-pay agreement with Transporter lower than 100% and a take-or-pay agreement with LDCs as high as possible. This configuration would guarantee that all players involved in the gas business chain will do their best to operate at maximum possible capacity reducing substantially or even eliminating Shipper's exposure to market risk.

The scenario of having a transportation agreement with 100% ship-or-pay with Transporter, Shipper can interact with Transporter to design a gas pipeline configuration – for new pipeline projects – that can mitigates market risk by scheduling capital expenditure – CAPEX in line with market growth and subject to closure of gas supply agreements with LDCs. This approach is presented in more details in this paper.

4. Risk Mitigation from Transportation

4.1. From Transporter's Perspective

From Transporter's perspective risk mitigation is direct related to having a transportation agreement with 100% ship-or-pay clause. Although this approach provides heading to Transporter also benefits Shipper with lower transportation rate.

4.2. From Shipper's Perspective

Under a scenario of uncertainty of the gas market it is necessary to elaborate some inventive way of mitigating market risk. This is close related to the CAPEX investment profile. The smallest the CAPEX investment in the beginning years of the project and more flexible the project be, better economic results under risk scenarios can be achieved. This paper presents a case study that shows qualitatively the impact of some design variables on risk mitigation.

5. Shipper's Approach for Risk Mitigation at Transportation Side

5.1. Strategic Approach

The strategic approach is to minimize upfront CAPEX investment – the investment related to the pipeline itself – and postpone the investment related to compressor stations. With this approach we are oriented to select smaller pipeline nominal diameter and to rely more heavily on compressor station power to build up future potential pipeline capacities that are not previously contracted on a scenario of market risk.

Santos ( ) has presented a methodology for designing a gas pipeline project that includes the design of a variety of diameters versus compressor stations quantities and produces J-curves to help selecting the more appropriate configuration to be used for the project.

6. Case Study

This case study, as presented by Santos (2009) and updated in this paper, is based on a pipeline project that goes from a gas supply receipt point to targeted market 1,000 miles (1609 km) distant, delivering 1,059.4 MMSCFD (30 MMm3/d) at design capacity. Four pipeline alternatives have been considered as shown in Figure 2 and as described below:

Alternative I	: ND 30” and 19 compressor stations
Alternative II	: ND 32” and 13 compressor stations
Alternative III	: ND 34” and 9 compressor stations
Alternative IV	: ND 36” and 7 compressor stations

6.1. Technical Assumptions

Pipeline	
Diameter	: (alt. I, II, III, IV)
Length	: 1000 miles (1609 km)
Design code	: ANSI B31.8
Max. Allowed Working Pres. – MAOP	: 1440 PSIG
Pipe material	: API 5L X80
Pipe internal roughness (epoxy painted)	: 350 μ inches (0.009 mm)
Pipeline Inlet Pressure	: 1420 psig
Minimum Pipeline Delivery Pressure	: 498 psig
Pipeline overall heat transfer	: 0.39 Btu/h.ft2.F
Gas specific gravity	: 0.6
Soil temperature	: 61 to 86 F (16 to 30 C)
Depth of cover	: 3.28 feet (1 meter)
Compressor Station	
Maximum Compression ratio	: 1.4
Suction and Discharge Header pressure drop	: 7 psi (0.5 kgf/cm2)
After cooler pressure drop	: 14 psi (1.0 kgf/cm2)
After cooler outside temperature	: 122 F (50 C)
Site elevation	: 0 feet (0 meter)
Site Temperature	: 82.4 F (28 C)
Flow Equation	: Colebrook

6.2. Economic Assumptions

Construction schedule	: 2 years	
Pipeline material cost	: 2300 US$/ton	
Pipeline C&A cost		
30”	: 28,903 US$/mile-inch	17.96 US$/meter-inch
32”	: 28,428	17.67
34”	: 27,990	17.40
36”	: 27,583	17.14
Compressor Station CAPEX		
(2) x 15000 ISO hp	: 47.49 MMUS$	
(3) x 15000 ISO hp	: 63.42	
(1) x 10300 ISO hp	: 22.15	
(2) x 10300 ISO hp	: 36.32	
(3) x 10300 ISO hp	: 48.50	
(1) x 7800 ISO hp	: 18.17	
(2) x 7800 ISO hp	: 29.79	

(3) x 7800 ISO hp	: 39.78
O&M Compressor Station (without Fuel)	: 5% of Compressor Station CAPEX
O&M Pipeline	: 0.8% of Ppl. CAPEX
Depreciation	: 20 years
Taxes	: 40%
Fuel price	: 4.0 US$/MMBTU
Discount rate	: 12% a year
Economic life	: 20 years

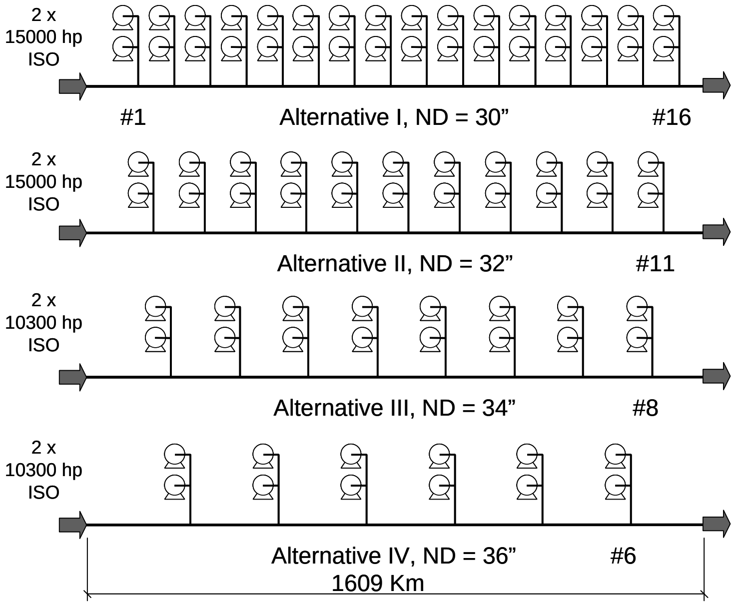

Figure 2 – Case Study – Gas Pipeline Alternatives I, II, III and IV

6.3. Thermohydraulic Results

The thermohydraulic results for all alternatives for the case study are shown on table 1.

Table 1 – Pipeline Alternatives I, II, III and IV – Thermohydraulic Results

Pipeline Alternative	Nominal Diameter ND	Capacity PPL End Point MMCFD	Pipeline Length	Discharge Pressure (At Comp. Flange)	Compression Ratio (Pd/Ps)	Station Quantity	Total Required Power	Mean Required Power per Station	Fuel required	Comp. Unit size
	inches	(MMCMD)	miles	psig	-	Qty.	hp	hp	MMCFD	HP ISO
I	30	503 (14.26)	1000	1420	1.4000	3	24,563	8,188	5.0996	1 x 10300
		611 (17.30)			1.4000	5	49,935	9,987	10.3673	2 x 7800
		811 (22.97)			1.4000	10	137,246	13,725	28.4943	2 x 7800
		1059 (30.00)			1.3859	19	345,971	18,209	71.8288	3 x 7800
II	32	424 (12.02)	1000	1420	1.4000	1	6,915	6,915	1.5081	1 x 7800
		594 (16.83)			1.4000	3	28,994	9,665	6.3231	2 x 7800
		775 (21.93)			1.4000	6	76,647	12,774	16.7154	2 x 7800
		1059 (30.00)			1.3836	13	229,400	17,646	47.6265	3 x 7800
III	34	355 (10.04)	1000	1420	-	0	-	-	-	-
		605 (17.12)			1.4000	2	19,664	9,832	4.2883	2 x 7800
		772 (21.87)			1.4000	4	50,393	12,598	10.9899	2 x 7800
		1059 (30.00)			1.3854	9	155,752	17,306	32.3362	3 x 7800
IV	36	411 (11.65)	1000	1420	-	0	-	-	-	-
		576 (16.30)			1.4000	1	9,370	9,370	2.0435	2 x 7800
		805 (22.78)			1.4000	3	39,243	13,081	8.5582	2 x 7800
		1059 (30.00)			1.3389	7	106,289	15,184	22.0670	2 x 10300

6.4. Economic evaluation – J-curves

The J-curves shown in figure 3 represents the transportation rates (cost of service or tariff) as a function of capacity. Each calculate rate for each pipeline configuration alternative at a given capacity value is based on the economic assumptions defined on item 6.2.

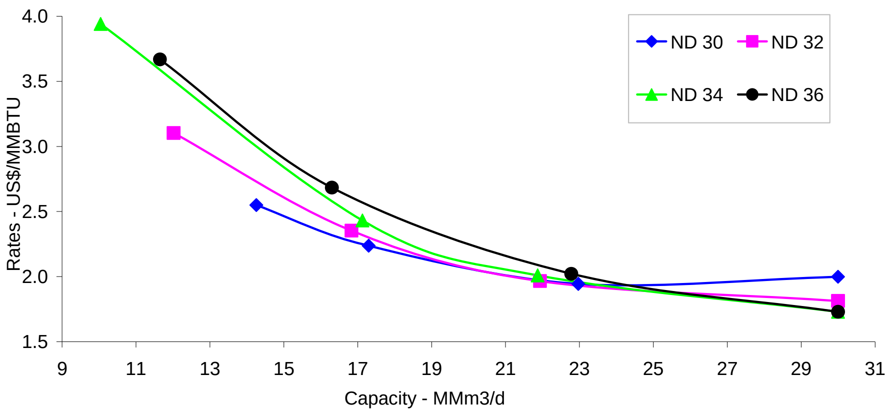

Figure 3 – J–Curves for Alternative I, II, III and IV - Without Standby Compressor Units

7. Market Scenarios and Risk Mitigation Approach

Two scenarios are considered for the purpose of defining a risk mitigation approach and these scenarios are compared to the project design capacity of 1,059.4 MMSCFD (30 MMSCMD).

7.1. Scenario 1

This scenario will offer firm capacity from 576 to 611 MMSCFD (16.30 to 17.3 MMSCMD) as shown in table 2 and the more competitive alternative – the one that charges the lowest transportation ratio – is alternative I. As market develops we can move to scenario 2 or even to design capacity by installing compressor stations as required.

7.2. Scenario 2

This scenario will offer firm capacity from 772 to 811 MMSCFD (21.87 to 22.97 MMSCMD) as shown in table 2 and the more competitive alternative is alternative I. As market develops we can move to design capacity by installing compressor stations as required.

7.3. Base Case – Design Capacity

This scenario represents a market development – risk free – where the maximum designed pipeline transportation is contracted as firm capacity on a 100% ship-or-pay clause providing the lowest possible transportation rate.

Table 2 – Economic Results for Scenarios 1, 2 and Design Capacity, in Present Values

Scenario	Alternative	Nominal Diameter, Inches	Compressor Station Quantity	Capacity MMSCFD (MMSCMD)	CAPEX Pipeline MMUS$	OPEX Pipeline MMUS$	CAPEX Compr. Sta. MMUS$	OPEX Compr. Sta. MMUS$	Fuel Gas MMUS$	Total MMUS$	Transportation Rate US$/MMBTU
1	I	30"	5	611 (17.30)	1,942	109	188	66	104	2,409	2.2375
	II	32"	3	594 (16.83)	2,111	119	113	40	64	2,447	2.353
	III	34"	2	605 (17.12)	2,286	128	75	27	43	2,559	2.431
	IV	36"	1	576 (16.30)	2,468	139	38	13	21	2,679	2.6835
2	I	30"	10	811 (22.97)	1,942	109	376	133	287	2,847	1.9442
	II	32"	6	775 (21.93)	2,111	119	226	80	168	2,704	1.9661
	III	34"	4	772 (21.87)	2,286	128	151	53	111	2,729	2.0097
	IV	36"	3	805 (22.78)	2,468	139	113	40	86	2,846	2.021
Base Case Design Capacity	I	30"	19	1059 (30.00)	1,942	109	878	309	722	3,960	1.9994
	II	32"	13	1059 (30.00)	2,111	119	601	212	479	3,522	1.8136
	III	34"	9	1059 (30.00)	2,286	129	416	147	325	3,303	1.7293
	IV	36"	7	1059 (30.00)	2,468	139	321	113	222	3,263	1.7299

As we move from scenario 1 to scenario 2 and then to design capacity it is produced a substantial drop on transportation rate. Transporter will be covered against market development risk by transportation agreements with Shipper, with take-or-pay clauses of 100%. Shipper will also be satisfactorily covered against market development risk by gas supply agreement with Producers and LDCs with take-or-pay clauses as close as possible to 100%. This approach will minimize exposures to pipeline unused capacity that may not be repaid by the gas business chain.

8. Compressor Station Design on Market Risk Scenarios

Compressor stations are capital intensive and any improvement in cost reduction will impact positively the pipeline project feasibility. In this paper is proposed some project configurations – where applicable – that may provide substantial cost reduction as explained onward.

8.1. Compressor units exposed to the weather without housing

This weather exposed configuration as seen in figure 4 may reduce something in the range of 5 % of the total compressor station CAPEX in comparison with a compressor station inside housing.

8.2. Containerized Control station

This containerized control station, pre-assembled and pre-tested at manufacturer facilities will save assembling and commissioning time at compressor station site and will provide flexibility should there will be any need to replace the compressor station.

8.3. Containerized Compressor Units

Same benefits as item 8.2 above.

8.4. Skid mounted Fuel Gas Utilities

Same benefits as item 8.2 above.

Figure 4 – Weather Exposed Compressor Station in Argentina

10. Conclusions

As can be observed from table 2 the optimum design is Alternative III for pipeline capacity of 1059 SCMD (30 MMSCMD) that produces the lowest transportation rate on a risk free market.

Under a risk scenario that assumes market will not develop as planned and without relying on firm transportation and gas supply agreements with take-or-pay clauses that fully guarantee project cash flow, project sponsors should take measures to mitigate risk exposures by postponing CAPEX until market is defined and agreements can be signed supporting the decision making process related to the installation of additional compressor stations to increase pipeline capacity.

The final decision on which alternative to implement will take into consideration not only economic results but also strategic vision of the project sponsors and their risk profile – more towards risk aversion or more towards risk takers. But the methodology presented in this paper will support the decision making process.

A more detailed, accurate and comprehensive study should incorporate Monte Carlo simulation and quantitative risk analysis – QRA as recommended by Santos (2009).

11. References

SANTOS, S. P., Monte Carlo Simulation – A Key for a Feasible Gas Pipeline Design. In: *Pipeline Simulation Interest Group, 2009, Galveston, TX, USA.*