Thermal billing and counting of gas by pipeline dynamic simulator

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Abstract:

The counting of gas is an essential activity in gas industry. A modification of only 1% on the uncertainty of measurement represents a significant amount of money within the trade framework between states or gas companies. We show in this communication the possibility of significant reduction of the investments by using a dynamic simulator of "SIMONE" type for measuring and calorific invoicing of the gas amount supplied to the customers. The process is validated on the basis of real data exploitation of a prototype network. The general idea consists in installing a reduced number of metering systems at the nodes of the significant customers and to count the calorific quantities of non significant customers, generally representing the majority of tie-ins, by dynamic simulation. In this last case the majority of the measurement equipment is replaced by a simple pressure transmitter.

Keywords: Pipelines , Simulation , Modeling , Counting Variable flow .

1. Introduction

The measurement of gas quantities - commonly called gas counting - is a very important activity of the gas industry. It is the basis of contracts purchase application, sale and transit. It gives indispensable information for rational conception and exploitation of the transportation or distribution networks. It allows the establishment of the balance of a gas network. It also permits, in the consuming factories, the outputs control. The counting operation can have mainly two objectives:

- A transactional objective for the counting and the invoicing of the hydrocarbons quantities delivered to the customers or in transit. The diaphragm “voludéprimomètres” used in this case, is equipped with the most modern secondary devices and their error can be situated at 0.2%.

- An exploitation objective, because the knowledge of the speed flow value is an essential parameter in the conduct and the operational management of any technical installation, in particular the pipelines networks. A 5% to 10% error is in this case acceptable.
  The natural gas is commercialised as energy, it can be estimated in calorific power or in volume, by the metric or imperial system [1].

Since the composition of natural gas changes and that these changes are frequent it is necessary to apply a procedure of calorique gas invoicing. However, the infrastructure necessary is not available in most cases. This situation gave the innovating idea to employ the simulation of pipe to calculate the composition out of gas for the invoicing, in order to reduce the investment and the costs operating in the measurement equipment of gas analysis which would be otherwise inevitable.

2. Counting of the Energy

"An eye on the meter, the other on the invoice, the customer is sometimes perplexed: on the first, of the cubic meters, on the second, of the kilowatt-hours. Between the two, a complex calculation, that transforms the volumes in energy while using the higher calorific power of the PCS gas".

The counting of gas energy consists in measuring all physical parameters [3] that are going to influence the quantity of energy contained in the sold gas volume. The gas producer specifies the quantity of energy contained in a normalized volume of gas by the Higher Calorific Power that is measured in kWh/m^3 (n) or Thermie/m^3.

The meter tots up the expanded or compressed by the pressure and temperature variations and the section of counting. It is necessary to do a correction therefore in temperature and in pressure to carry back the measured volume to a transactional normalized volume (volume added brought to 101 325 Pa and 273, 15 °K).

The normalized volume must also be multiplied by the PCS of the gas to determine the quantity of sold primary energy. One comes to the following counting equation:

$$\text{Volume } (m^3) \text{ x Correction } (T°, P, Z) \text{ (without unit) x PCS } (kWh/m^3) = \text{Energy } (kWh)$$

A gas energy meter implies therefore a measure of volume, a measure of temperature and pressure, the determination of the compressibility Z factor and the measure of the PCS. Thus, the quantity of delivered energy is determined by the product:

- Of the gas higher calorific power (PCS), discontinuous measure whose frequency depends on the importance of the transit and the possibilities of change of the gas origin.
- Of the volume mass (V) of delivered gas, determined in the same conditions :

$$Q = pcs(n).V(n) \quad (1)$$

2.1. Classic Devices of Measurement

A flow meter like system Figure. 1 contains therefore [8]:

- A disruptive system,
- Transducers or sensors allowing to measure the state parameters
- A system of calculation of the equation flow,
- An integrator system giving the quantities of gas (mass or volume) passing in transit in the conduct during an interval of given time.

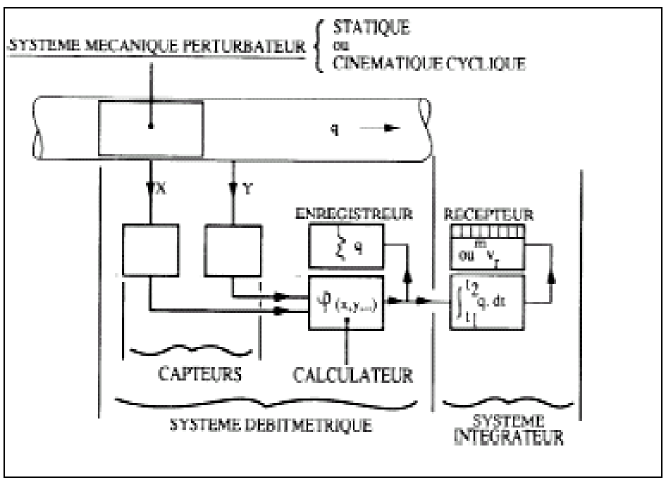

Figure 1. Devices of measurement

2.1.1. Meter With Diaphragm

It is about a disk with a hole in its centre Figure. 2, designed in the compatible material with the used fluid. The concentric diaphragm compresses the fluid flow, which generates a differential pressure on both sides of this one. A high pressure results upstream from it and a low downstream pressure, proportional to the square of the speed flow. It is the simplest device, the less cumbersome and less expensive.

2.1.2. Turbine Meter

In this type of meter a free helix, centred on the axis of the conduct, is placed in the gas flow flux. To the parasitic influences of frictions, the fluid leads to a rotation of the helix whose speed almost varies linearly with the flow. The number of turns done by the helix permits to deduct the volume of fluid having passed in transit through the meter.

The mechanical frictions fix the low bottom limit of working of the turbine. These two types of meters are the more used, other types exist as the meters ultrasonic sounds, vortex, etc.

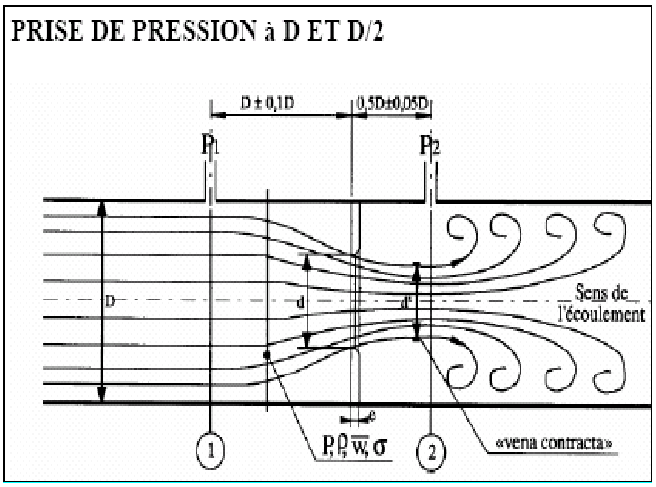

Figure 2. Meter with diaphragm

3. Simulator.

Mainly because of the fluctuations of the demand at the consumers' level, the gas flow in a network of gas pipelines is of dynamic and transitory type. The mathematical difficulties inherent in the modelling of this type of behaviour led to the appearance in the market of very powerful dynamic simulators which can take into account networks of gas pipelines comprising several thousands of nodes and all the configurations possible in stationary regime and especially non stationary (Schmidt, Lappus) [2] (SIMONE, TGNET…). They are computer codes allowing the modelling of complex networks of gas pipelines and especially the simulation of any decision of extension or control system, of damage situations, parameters evolution, which allows, a posteriori, to the analysis of the consequences resulting from these events on the whole of the network.

3.1 Handling the Computer Code.

The system used is a management tool of the pipelines. It is equipped with many functions which can be divided into four groups

- Simulation of the constant and dynamic state out of connection.
- Cyclic simulation and control of the gas transport on line (one Line).
- Optimal gas transport.

All calculations can be carried out for a system of pipelines whatever would be its configuration. Each calculation is organized in series for simulated particular lapses of time. The system is provided in standard dimensions of 48000 elements (the elements are: conduct, compressor station, control valve, counting station, valve, resistance, union).The high precision of calculations is tested for amplitude of pressure of 0.01 bar with 150 bars and for a gas or a mixture of gas of any type.

4. Use of a Simulator as a Counting Device

4.1. Methodology General Principle.

The principle of a counting device by "voludéprimomètres" is to create ΔP in order to measure the flow in a system where the relation between ΔP and Q would be perfectly known.

$$q_m = 0.04cE\varepsilon_1 d^2\sqrt{\Delta P\rho} \tag{2}$$

$$q_m = f\left(\Delta P\right) \tag{3}$$

If one doesn't use a restriction ΔP would be too weak to be measured. One can increase ΔP without creating restrictions and this is obtained while increasing the length significantly.

Knowing the pressures P1 and P2, it would be therefore possible to determine the flow Q that passes in the conduct, since the relation of the pressure losses linking P1, P2 and Q is known.

$$P_1^2 - P_2^2 = k\lambda\Delta Z_m T_m \frac{L}{D^5}Q^2 \Rightarrow P_1^2 - P_2^2 = \alpha Q^2 \tag{4}$$

$$Q = \frac{1}{\sqrt{\alpha}}\sqrt{P_1^2 - P_2^2} \quad (5)$$

This last relation allows only an approached evaluation of the value of the flow. The precision of such an approach would be mediocre. This relation cannot be used under this form for the counting because:

- Hypothesis of a steady state flow;
- The roughness and environmental parameters are not taken into account ;

- Nonlinear profile (local pressure losses).

In order to use such an approach with an objective of counting, it is necessary to eliminate the uncertainties related to the 3 previous parameters; therefore it will be necessary that one utilise:

- Non stationary models (dynamic)
- Reconstitution techniques of state to take into account the last 2 parameters.

The dynamic flow is described by a system of differential equation with partial derivatives; in the case of a simple network, one can solve the system of algebraic equation, but for a complex network of which the number of nodes and variables is important one will have a problem of big numeric complexity. This problem is solved by using a dynamic simulator (in our survey it is SIMONE of LIWACOM) [4]. One introduces as input values the pressures of nodes periodically measured (at discrete intervals of time). In the classic simulation the input data are flows profiles of, one will have as results the pressures of the nodes. In the case of the counting by simulator (reverse problem), the input data are the pressures and one gets as results the flows in each node.

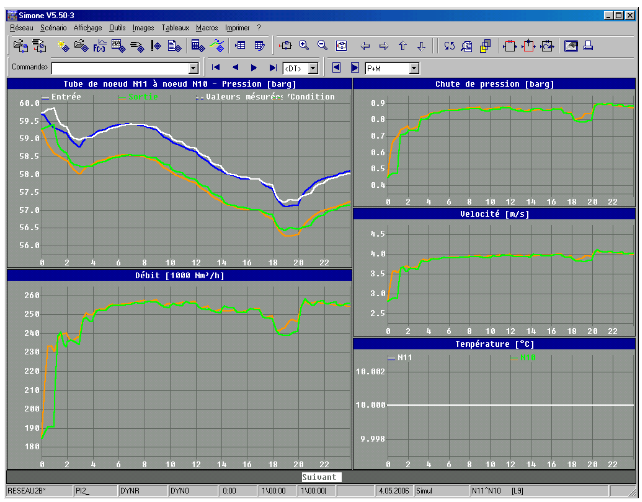

Figure 3. Reverse Problem

4.2. Dynamic Model of a Network Flows

The process of the dynamic simulation in the transportation and distribution of gas is based on the nonlinear differential equations, the equation of the continuity (conservation of the mass) and the equation of movement that expresses the dynamic balance of the mass forces. For a more sophisticated process and a detailed description one takes account also of the heat transfer between gas and the outside environment [5].

5. Caloric Counting by Dynamic Simulation

5.1 System Configuration

The simulated system includes a network of gas pipeline of 750 km with 400 nodes. Gas pipeline of different diameters (800, 900 ...) mm.

(02) Source points
(02) Compressor stations (which one is in project)
(01) Pressure reducer regulators.
(01) Underground Tank the capacity is of 1, 2 10^9 m^3 of gas in place in summer.

The series of measurements of flow and pressures were obtained according to a partner programmed by the mean of SCADA system

5.2 Validation on a Network Prototype

To validate the possibilities to use the simulator as counting device, we have chosen the network represented in figure 5. The network contains:

- 1 supply node,
- 8 delivery nodes,
- 71 sections,
- 1 compression station,
- 16 valves and 3 regulators.

6. Results and Discussion

The obtained results, as an example, for the node of N10A delivery and the length of the L8 section (of the Simulation model) are provided in Figures 6 and 8. After statistical treatment of the results it comes:

- The mistake on the fluctuations of flow in the section is very weak.
- For cons, the error rate fluctuations on node delivery is relatively high (12%)
- However, the mistake on the amount of the delivered quantities in 24 hours, which is an essential parameter of the invoicing, is less than 3%.

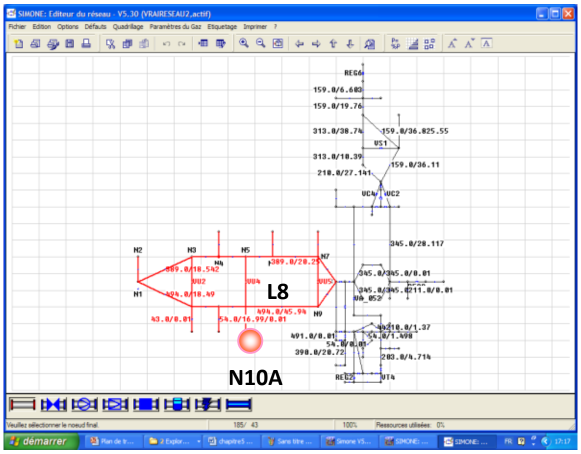

Figure 4. Simulation Model

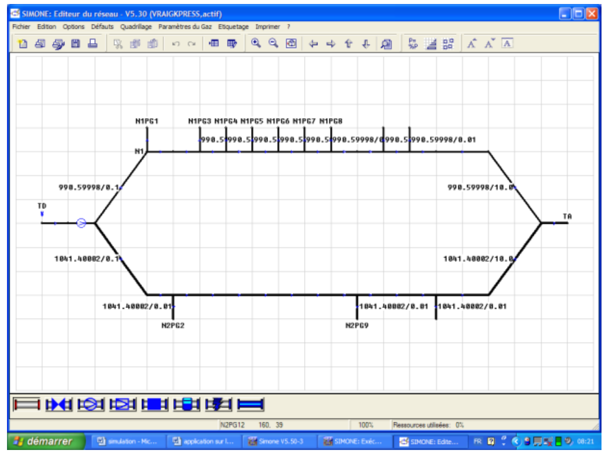

Figure 5. Network Model

To study the possibility of using software SIMONE like opposite device, we chose model represented in figure 5. Initially, one introduced the flows into each node and one had like results the pressures. One does the opposite work by using the pressures obtained previously like data input; then one compares the real flows with the flows calculated with the nodes, the results are given in the following table:

The following table gives the error computation at the N10A, L8 section level

a) For the node of (N10A)

b) For the node of (L8)

Tableau 1.Flow measured and calculated x (1000 Nm^3/h)

Tableau 2. Flow measured and calculated x (1000 Nm^3/h)

Time	N10A measured	N10A calculated	Errors in %
1	6.552	6.51	0.64
2	6.587	9.99	51.66
3	6.463	7.51	16.20
4	6.356	4.77	24.95
5	6.285	5.8	7.72
6	6.339	5.74	9.45
7	6.41	5.88	8.27
8	6.891	6.79	1.47
9	7.693	7.65	0.56
10	7.513	7.87	4.75
11	7.549	8.13	7.70

12	7.532	8.05	6.88
13	6.517	7.19	10.33
14	6.73	7.43	10.40
15	6.82	7.32	7.33
16	6.713	6.67	0.64
17	6.677	6.94	3.94
18	6.48	6.46	0.31
19	6.437	6.94	7.81
20	6.414	8.33	29.87
21	3.374	3.67	8.77
22	5.497	3.41	37.97
23	5.928	3.57	39.78
24	5.607	4.84	13.68
	155.354	**157.46**	
	Average error	**12.96**	

Time	L8 measured	L8 calculated	Errors in %
1	156,11	156,14	0.02
2	199,88	198,14	0.87
3	206,25	208,39	1.04
4	205,94	209,01	1.49
5	212,51	211,51	0.47
6	215,57	214,5	0.50
7	217,61	216,56	0.48
8	218,59	218,54	0.02
9	219,65	220,02	0.17
10	220,33	221,28	0.43
11	219,37	221,37	0.91
12	219,58	221,27	0.77
13	220,04	221,38	0.61
14	218,4	220,4	0.92
15	216,74	222,31	2.57
16	215,9	216,1	0.09
17	215,49	216,4	0.42
18	216,12	216,05	0.03
19	213,84	215,36	0.71
20	209,72	212,03	1.10
21	211,99	214,46	1.17
22	216,91	213,56	1.54
23	217,86	216,44	0.65
24	217,43	216	0.66
	5101.83	**5117.22**	
	Average error	**0.74**	

The following graph show the comparison between measured and calculated

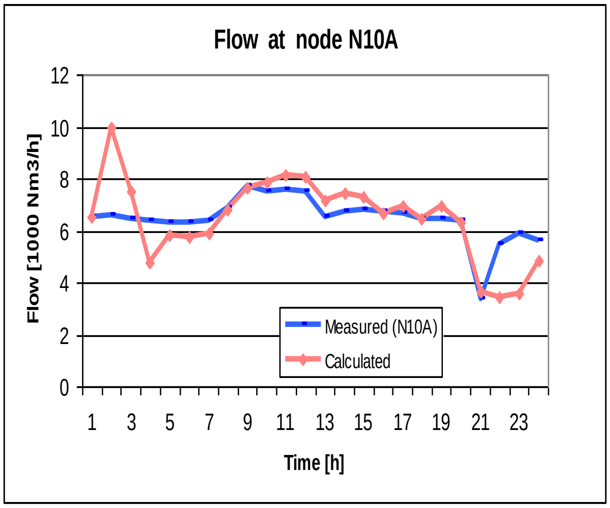

Figure 6. Flows Comparison at node N10A

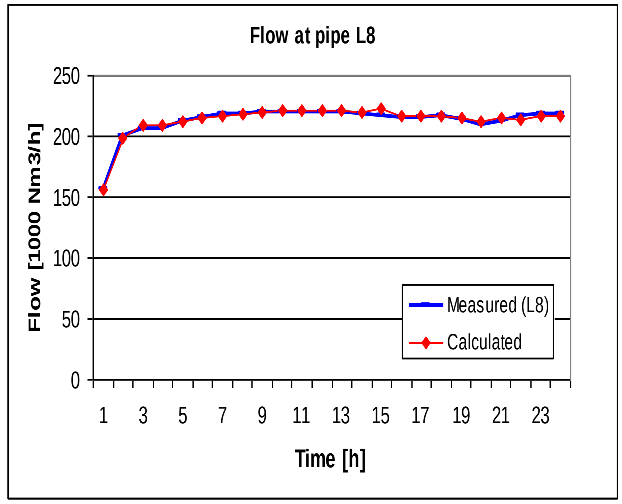

Figure 8. Flows Comparison at node L8

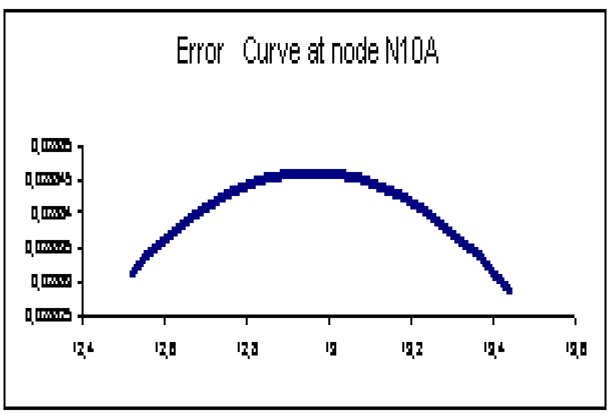

Figure 7. Error curve at node N10A

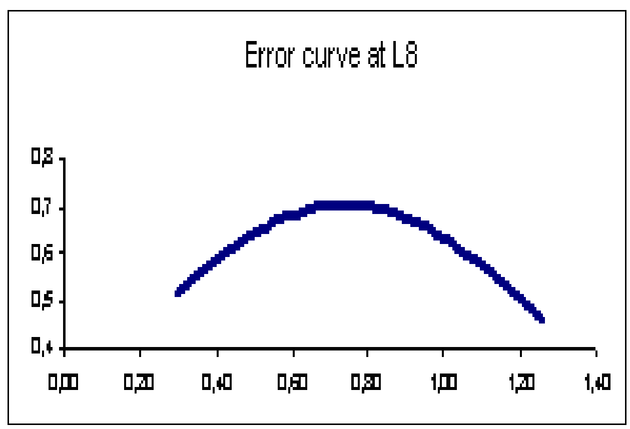

Figure 9. Error curve at node L8

7. Conclusion

For a purpose of a caloric invoicing, the network must have practically complete devices of counting, in number equivalent to the number of customers, which realization would require heavy investments. The use of a dynamic simulator as tool of counting permits to reduce considerably the number of counting devices to achieve. The evaluation of the quantities delivered to less important customers is done by simulation [6]. The tests done on a real prototype network showed very encouraging results (mistake less than 3% for the cumulated delivery flow). The quality of the results can be refined again by the improvement of the observability [7] of the system. This last point, which would be an objective target in the future, could be concretized by increasing the number of the pressure measuring points and the reduction of the simulation intervals.

References

[1] Centre de coopération technique de Gaz de France 1992. Grandeurs physiques dépendant de la composition du gaz,

[2] Schmidt G. ,Weimann A., Lappus G., Application of simulation techniques to planning, supervision and control of natural gas distribution network, 1978.

[3] Endress Hauser, Flow Handbook, 19893. Jolivet M., Mesure du Gaz Septembre 1989, GSO – Sud Ouest.

[4] SIMONE *Research Group s.r.o* LIWACOM www.simone

[5] Pascal H , 1970 " Ecoulements non permanents dans les gazoducs Edition Technip ,Paris .

[6] R.Michon-M-Sorine,"Modèle numérique de calcul de l'écoulement des gaz en régime variable " DETN Gaz de France1988.

[7] Sood AK., Funk GL., Delmastros A. C., Dynamic optimization of natural gas pipeline using has gradient search technical "Int J. Control, flight.14 N°6, 1971

[8] Mesure du Gaz M.JOLIVET Septembre 1989 GSO –Sud Ouest