Ensuring security of local gas supply using pipeline gas storage

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Abstract This paper presents a natural gas supply system of a locality. Since power consumption is non-stationary, for supplying the consumption peaks it is used a gas deposit kept in a pipeline built near the locality. The viability of this solution was demonstrated by simulation with the numerical simulator SIMONE.

Keywords: gas, pipeline, storage, consumption

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1. Introduction

Most of the industrial facilities are connected to distribution networks located in urban areas. They also supply in the same time other categories of consumers. The consumption of gas is defined by the needs of the customers varying more or less during a day, or from a season to another, depending mainly on the temperature and on the day of the week. The total flow of a distribution network is made up of a basic flow , correspondent to industrial users who have an individual consumption level which depends on the type of industry to which it belongs, over which a variable consumption flow is superimposed in inverse ratio to temperature . The overlap of all these effects determines for the gas distribution company an irregular consumption with peaks and periods of low consumption.

For this reason, at all city gates from the gas carrier/transporter to the gas distribution networks, there is both a time fluctuation of gas consumption during the same day and a seasonal fluctuation of these consumptions. About half the gas consumption has a variable condition influenced by climatic factors (temperature, wind, precipitation). Creating new production and transportation possibilities only to ensure the gas yield surplus for a short period, cannot constitute an acceptable economical solution. A solution to compensate consumption peaks is to develop gas storage directly in the transportation

pipelines or in pipes designed specifically for this purpose. Storage of the gas in the pipeline can be made during periods of minimal consumption, when the nominal output exceeds the gas yield in use, the pipeline pressure reaching a maximum value. This operation loses its intensity when during the rate of the flow delivered/supplied to consumers is higher than the nominal transportation flow/output of the pipe and completely ceases when it reaches the maximal consumption peaks, then the pressure in the pipe tends to a minimum. Gas distribution companies, according to the Network Code, must submit to the transporter the necessary quantities of gas for the customers, along with daily consumption profile. Consumption profiles are functions built by the gas distributor based on which daily evaluations can be made, depending on the temperature forecast of the required gas. Any difference of more than 2% between the forecasted consumption and the real one is penalized.

Figure 1 shows the profile of natural gas consumption for one year and the one realized on the basis of temperature variation and daily balance.
To avoid penalties for not complying with the amount of gas supply in the contract, storage pipelines can be built for gas storage. This quantity of gas can be used to balance the differences between estimated volumes and the real ones. Besides the storage pipeline, a gas reduction plant is necessary.
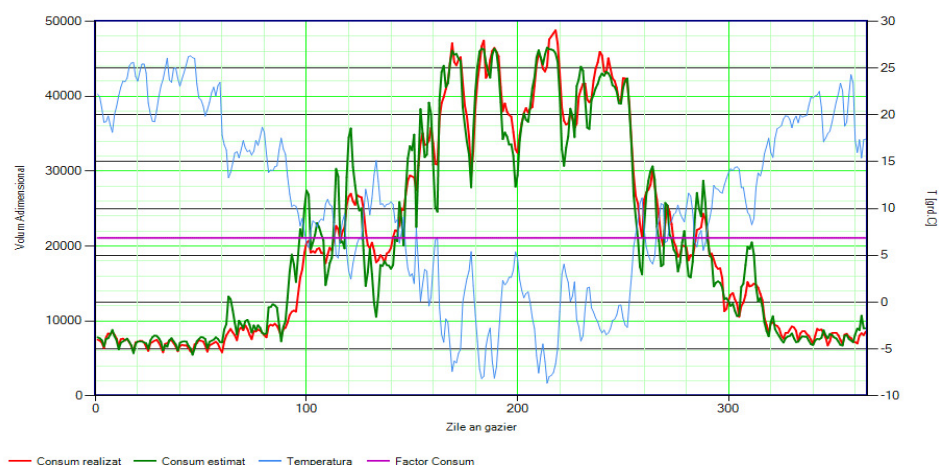
Fig.1 Sectional/Profiled consumption for a certain category of gas consumers

2. Presentation of the solution for gas storage within a pipeline, to balance peak loads

The solution for gas storage in the pipe was studied by creating a model using SIMONE simulator. The model is formed by the gas pipe which supplies a large consumer such as a city, four pipelines for gas storage, a gas controlling device to co-ordinate the taking-over of the gas from the storage pipeline and a reduction plant. The scenario reflects the situation in which during periods of minimal consumption the gas is stored in a pipe through a reduction station, so it can then be extracted when the gas consumption reach an hourly peak. For this we started from a distribution pipeline linking a SRM through which TRANSGAZ delivers gas to a distributor (e.g. GDF Suez) to a large consumer (City X) (**Fig.2**).
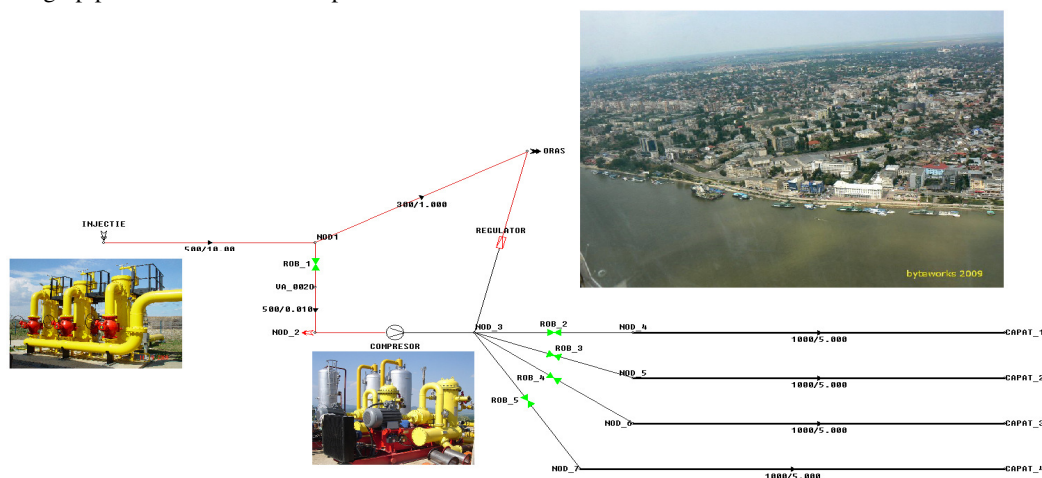

Fig.2 Scheme for gas storage in the pipeline, realized using SIMONE

3. Description of the simulation scenario

The simulation was performed for a typical day in which the gas consumption was variable. In **Fig. 3** you can see exactly how the system is operated/used, respectively the times when the controlling device/ regulator is programmed to open/start in order to meet the consumption peaks and when it is scheduled to start the compressor in order to restore pressure within the storage pipeline. To stop the compressor, a maximum value of the pressure in the storage pipe is disposed. When this value is achieved the compressor shuts down
The simulation was made taking into account the hourly consumption affected by the needs of each client, modeled through a consumption profile.

Table 1 presents the values of consumption profile based on time.

4. The simulation results

The simulation results show the viability of using the solution of gas storage in the pipeline to cover peak loads. As shown in the analysis of the results the reduction plant is operating intermittently to restore the supply of pipeline gas when the gas consumptions are low.
Figures 4 and **5** present the pressure variation and respectively the gas yield in the injection point in the distribution system represented by the SRM. One can easily see the irregularity of the flow as it enters the pipeline.

Time	Condition	Object	Type	Parameter	Value	Unit	Source	Comm
		INJECTIE	NS Supply node	PSET Set pressure	5	barg		
		ORAS	NO Node	Q Supply/Offtake	P1*50.	1000 Nm³/h		
0:00		COMPRESOR	CS Compressor station	SM Flow-rate setpoint	40	1000 Nm³/h		
0:00		REGULATOR	CV Control valve	OFF Close				
6:00		COMPRESOR	CS Compressor station	OFF Close				
6:00		REGULATOR	CV Control valve	SPO Output pressure setpoint	4	barg		
8:00		ROB_1	VA Valve	ON Open				
10:00		REGULATOR	CV Control valve	OFF Close				
10:00		COMPRESOR	CS Compressor station	SM Flow-rate setpoint	20	1000 Nm³/h		
13:00		COMPRESOR	CS Compressor station	OFF Close				
13:00		REGULATOR	CV Control valve	SM Flow-rate setpoint	15	1000 Nm³/h		
14:00		COMPRESOR	CS Compressor station	SM Flow-rate setpoint	15	1000 Nm³/h		
14:00		REGULATOR	CV Control valve	OFF Close				
15:00		COMPRESOR	CS Compressor station	SM Flow-rate setpoint	20	1000 Nm³/h		
17:00		COMPRESOR	CS Compressor station	OFF Close				
17:00		REGULATOR	CV Control valve	SM Flow-rate setpoint	10	1000 Nm³/h		
20:00		REGULATOR	CV Control valve	SM Flow-rate setpoint	15	1000 Nm³/h		
21:00		REGULATOR	CV Control valve	SM Flow-rate setpoint	20	1000 Nm³/h		
23:00		COMPRESOR	CS Compressor station	SM Flow-rate setpoint	10	1000 Nm³/h		
23:00		REGULATOR	CV Control valve	OFF Close				

Fig.3 Working scenario for the simulation

Table 1 the values of consumption profile based on time.

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12
Profile	0.777	0.76	0.769	0.771	0.778	0.849	0.965	1.073	1.125	1.129	1.125	1.077	1.037

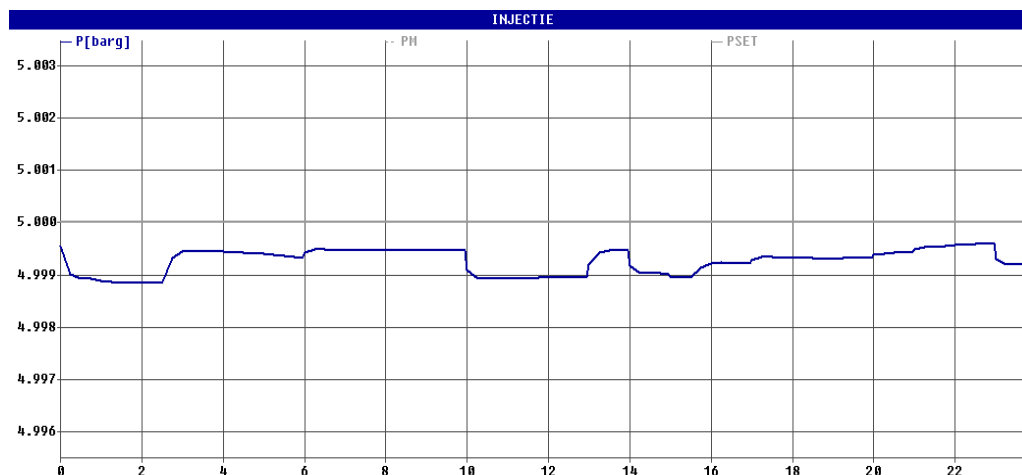| Hour	13	14	15	16	17	18	19	20	21	22	23	24
Profile	1.047	1.051	1.060	1.057	1.110	1.151	1.160	1.121	1.071	0.993	0.926	0.9

Fig. 4 The variation of the intake pressure in the proposed scenario
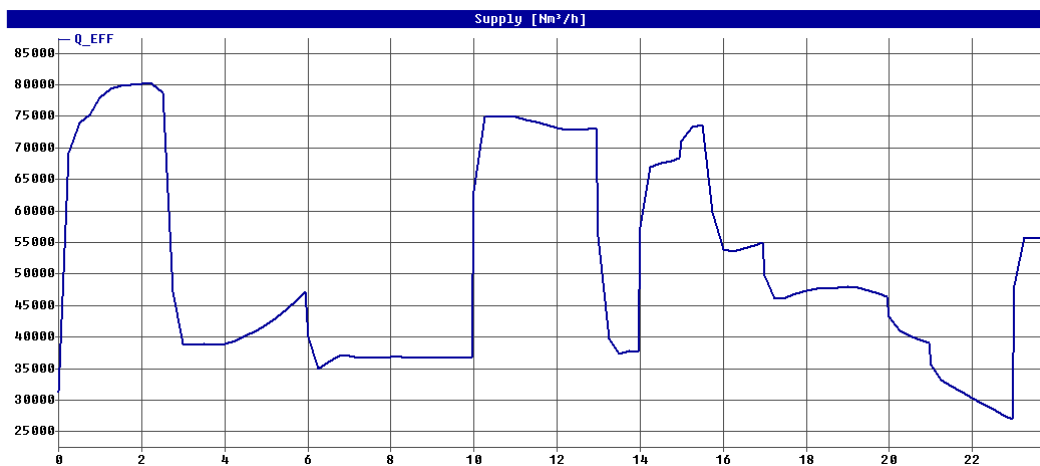

Fig.5 The variation of injection flow in the proposed scenario

Figures 6 and **7** present the variations of pressure and flow at the Consumer. The output of the system follows the consumption profile. The starting quest was the one of the two consumption peaks which can be observed in Fig. 7.

In order to compensate/ balance the peak demands, the regulator opens/starts when needed and uses the gas from the pipe storage. The operation mode of the regulator is shown in Figure 8. The pressure values before and after the regulator are shown in **Fig. 9.** The gray color represents the gas pressure before the regulator (in the storage pipe) and the blue color represents the pressure after the regulator.
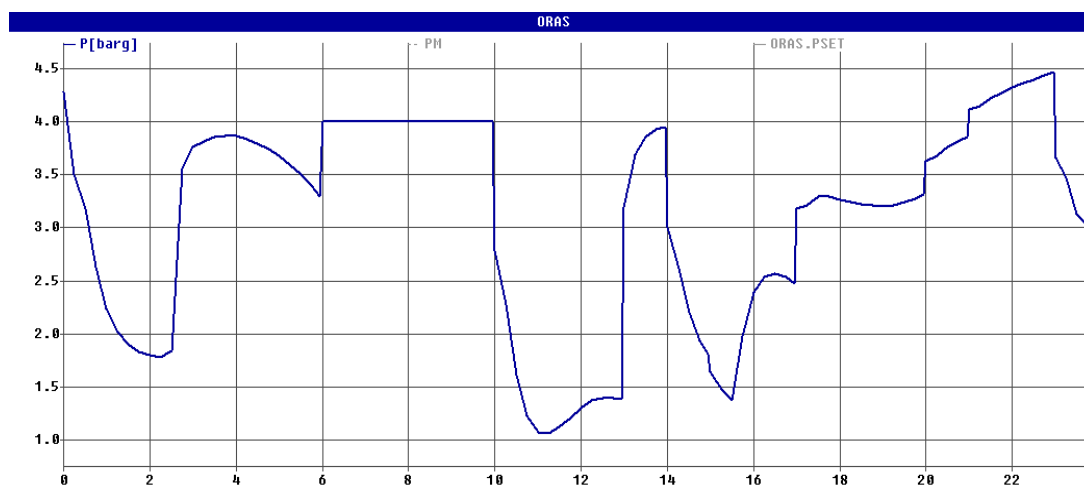
Fig.6 The variation of pressure at the Consumer
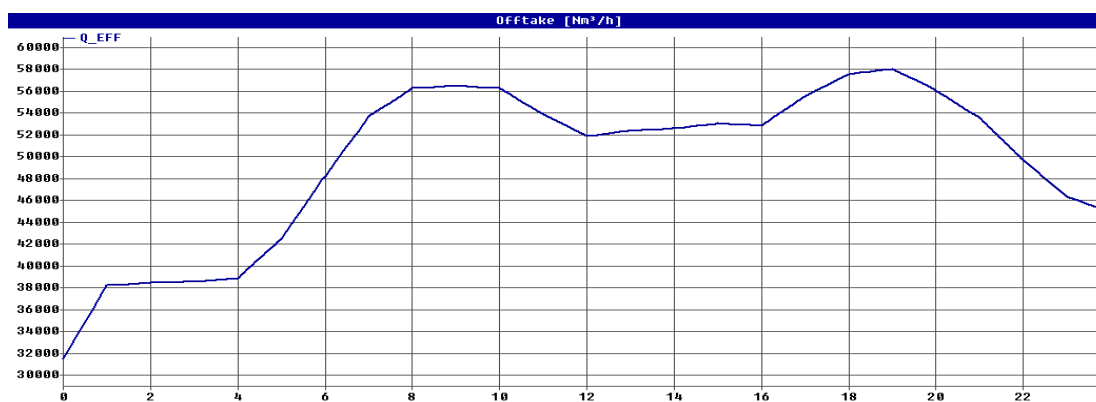
Fig. 7 The variation of gas flow at the Consumer according to the profile
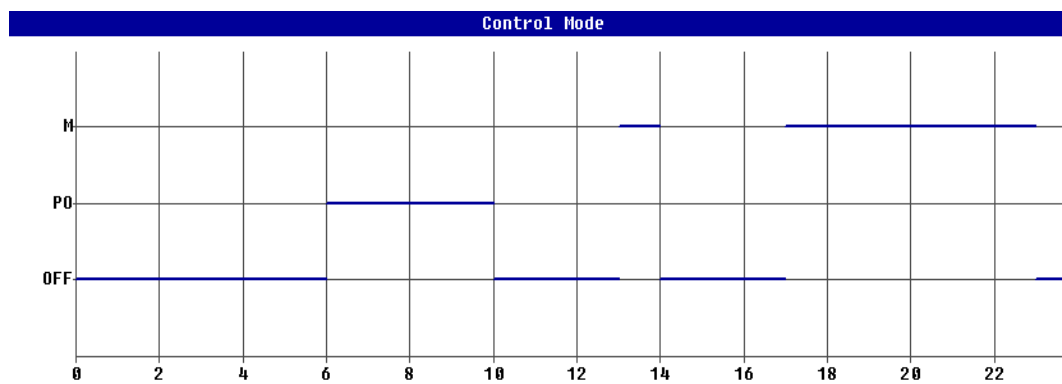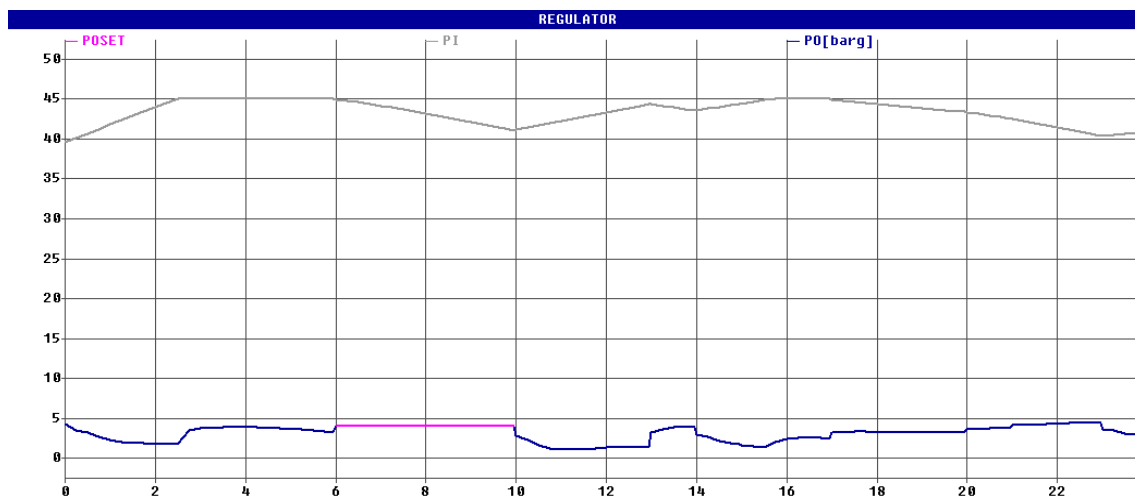
Fig.8 The operating mode of the regulator

Fig.9 Variation of the pressure before and after the regulator

The gas yields/flows extracted from the pipeline can be seen in **Fig. 10** (red is the color for disposed boundaries), and **Fig. 11** presents the rates of the gas through the pressure-controller/ regulator.
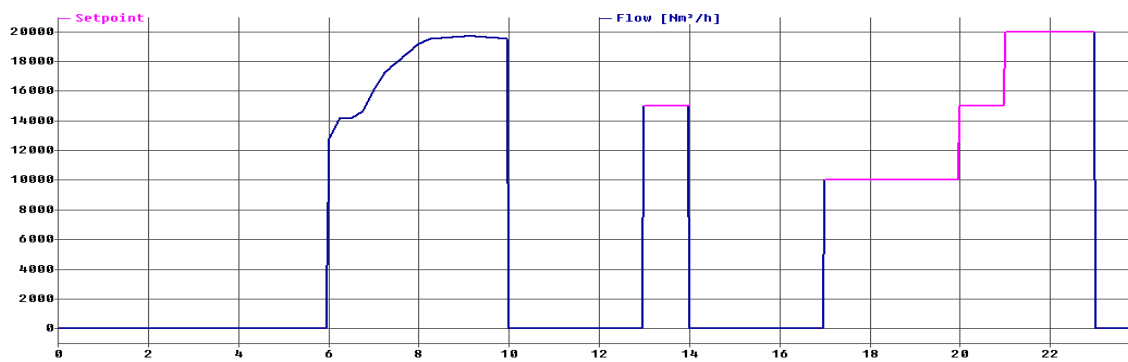

Fig.10 The variation of the gas flow when passing through the regulator
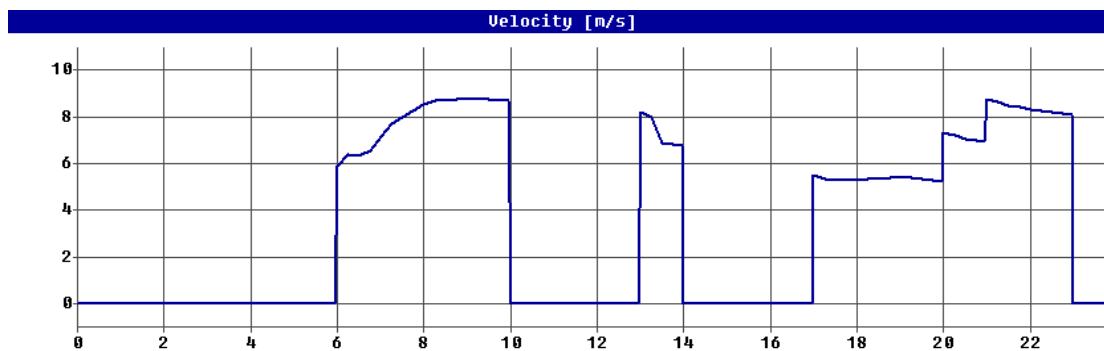
Fig.11 The variation of the flow rate through the regulator

When the gas flow used in the town is small, the gas can be stored using a reduction plant. Therefore, its operating mode will be intermittent. The operation mode of the plant is shown in **Fig. 12**, and the variation of suction and discharge / lifting pressure of the compressor is shown in **Fig. 13.**
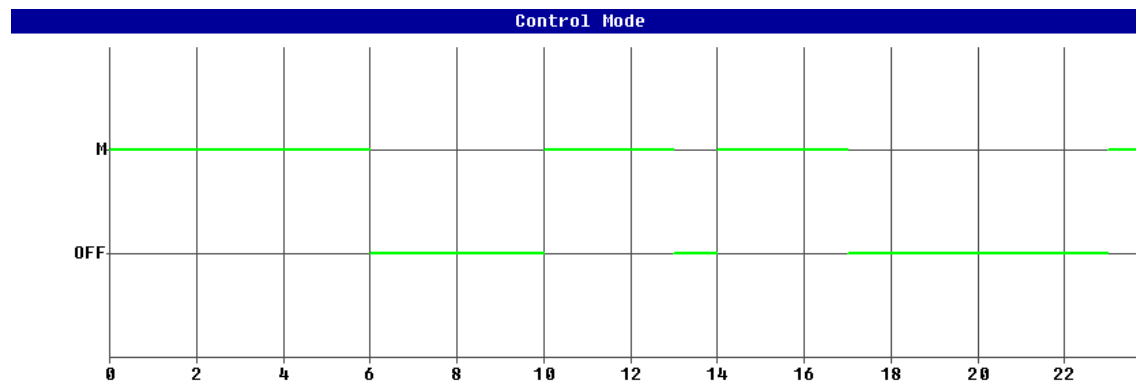

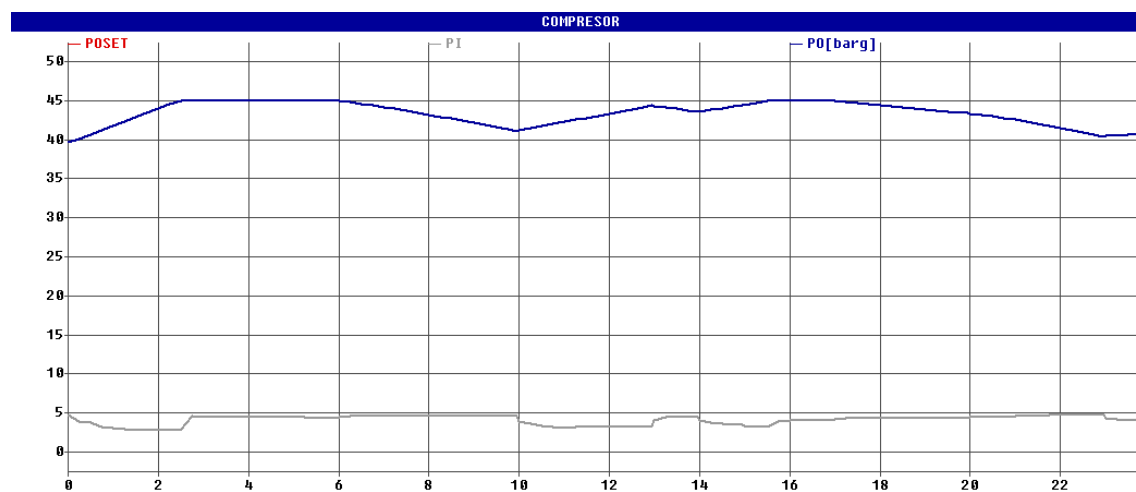**Fig.12** Operation mode of the reduction plant

Fig.13 Suction and discharge pressure variation of the reduction plant

Fig. 14 presents the compressed gas flow. It can be observed that although between 3 and 4 o' clock, respectively 4 and 6 o'clock 6 it was supposed to store 40,000 Nm^3 / h , respectively 45000 Nm^3 / h (red line) because the storage pipeline had reached a maximum pressure, the station/ plant stopped. The same thing happens between the 15 and 17 p.m.
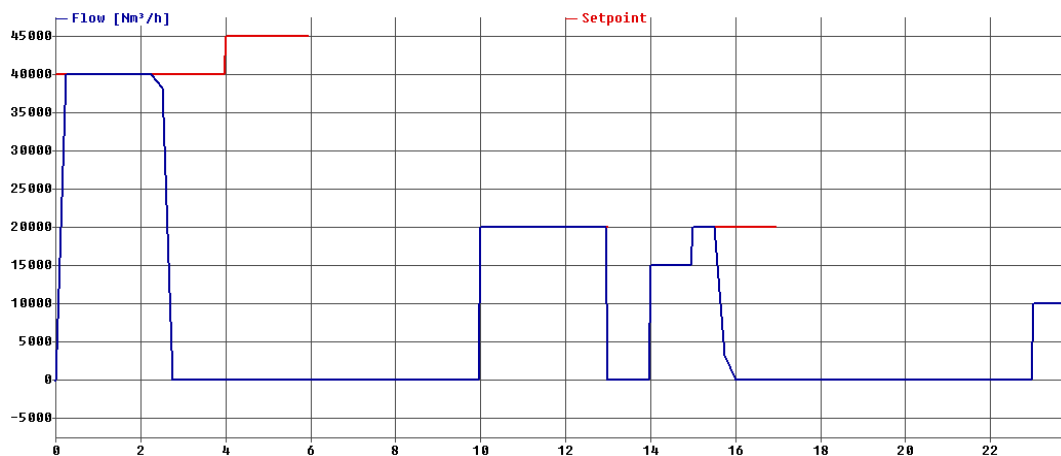
Fig.14 The variation of the reduction plant's flow

The following, are some graphics specific for the reduction plant. **Figure 15** shows the changes in the compression ratio, **Fig. 16** presents the necessary power and **Fig. 17** the amount of fuel consumed by the reduction plant.
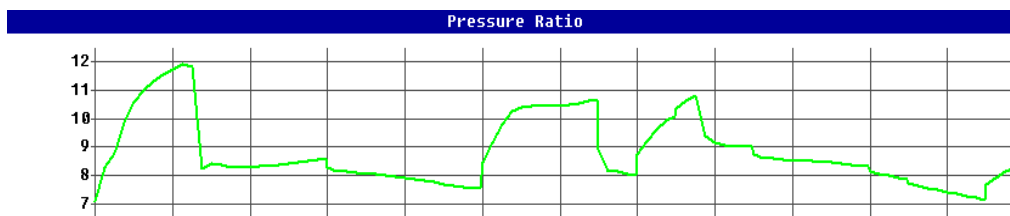
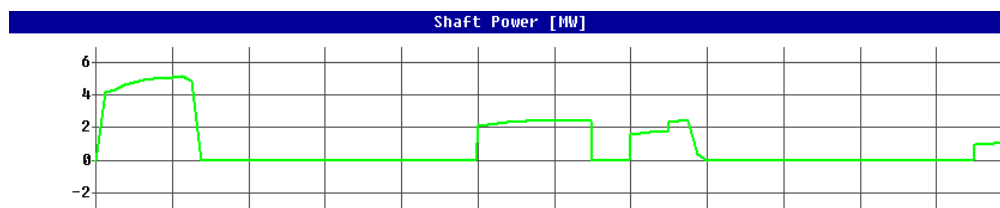

Fig. 15 The variation of reduction plant ratio

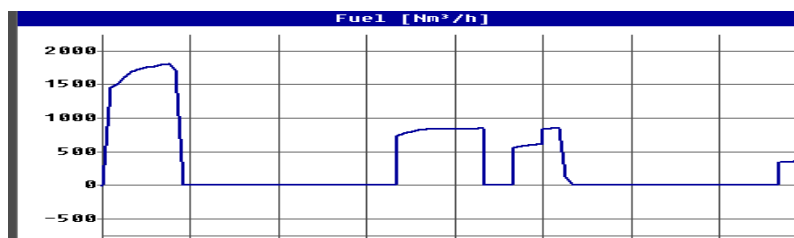**Fig.16** The variation of power for the reduction plant

Fig.17 The variation of fuel consumption of the reduction plant

To have a complete picture of the process there are presented some aspects concerning the storage pipe.

Thus, **Fig. 18, 19** and **20** present the pressure, intake gas flow and the flow rate inside the pipe.
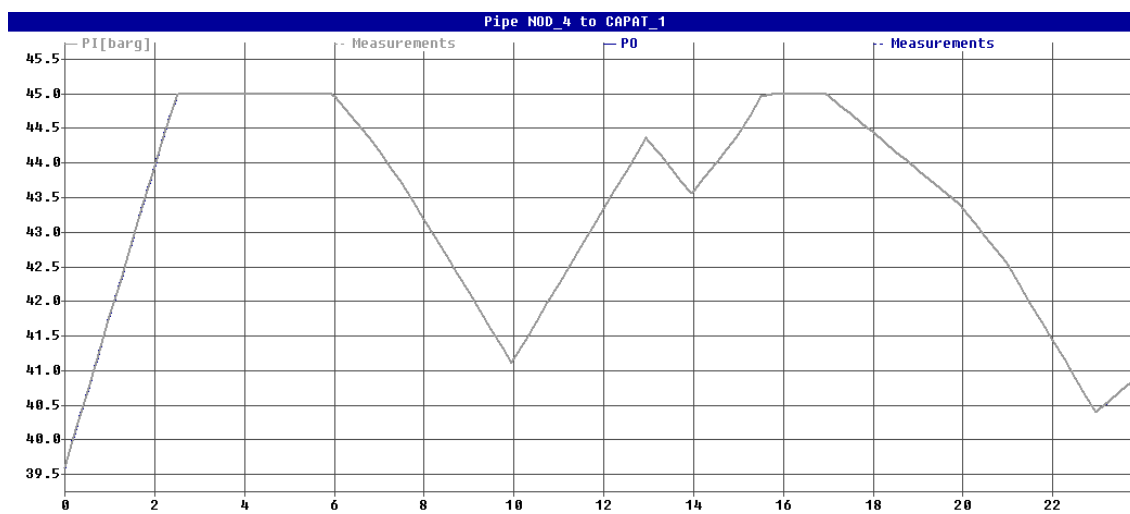

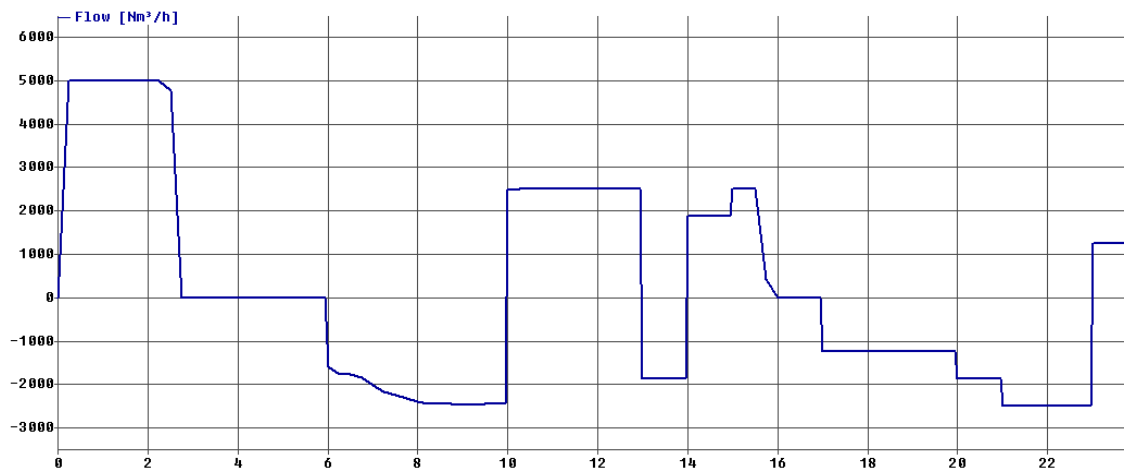**Fig.18** The variation of the pressure inside the storage pipeline

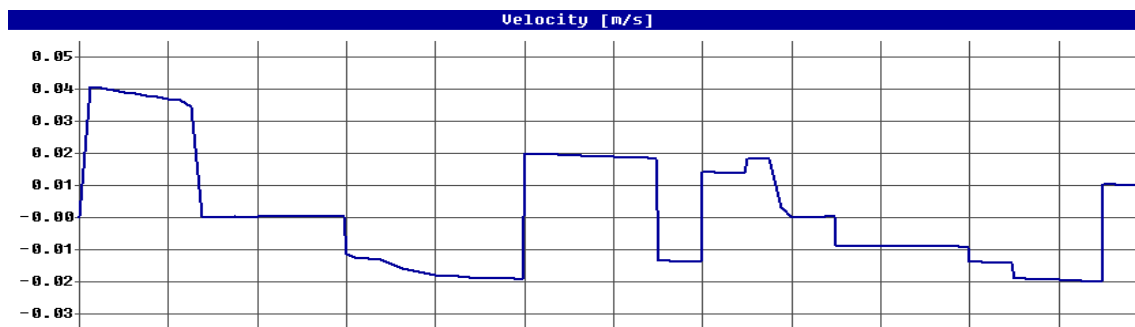**Fig. 19** The variation of gas flow inside the storage pipeline

Fig. 20 The variation of flow rate within the storage pipeline

Pipe Elements

	M [Nm³/h]	V [m/s]	P [barg]	PD [barg]	VOL 1000 Nm³	L [km]	D [mm]	Roughness [mm]
NOD_4^CAPAT_1	-2500.026	-0.02	41.98	0.00	179.51	5.000	1000.00	0.012
NOD_5^CAPAT_2	-2500.026	-0.02	41.98	0.00	179.51	5.000	1000.00	0.012
NOD_6^CAPAT_3	-2500.026	-0.02	41.98	0.00	179.51	5.000	1000.00	0.012
NOD_7^CAPAT_4	-2500.026	-0.02	41.98	0.00	179.51	5.000	1000.00	0.012
SUM					718.04			

Close   Save   Object set   EditSet

Fig. 21 The variation of the parameters for the pipes constituting the storage pipeline at 21:30

Fig. 21 presents a summary for the storage pipe at a certain time. One can see the amount of gas stored at 21:30 (718,040 Nm³).

Since storage pipe is used to offset/ balance the peak demands (consumption peaks), its parameters (pressure, stored capacity etc.) will change every time you extract gas from the pipe or when the reduction plant is started in order to restore the pressure. It was therefore considered necessary to present the variation of gas volume stored in the pipe (**Fig.22**).
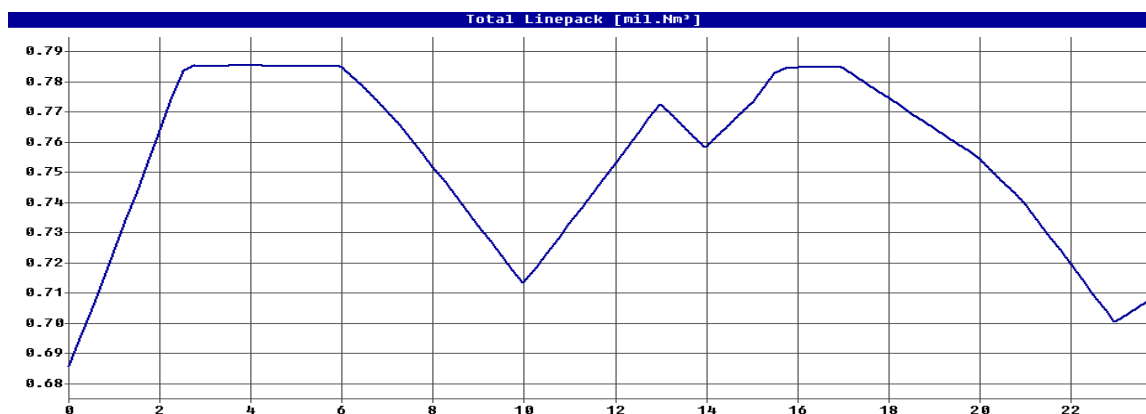

Fig. 22 The variation of gas volume in the storage pipeline

5. Conclusions

The advantage of using the gas storage system in the pipes to cover peak loads consists in balancing the forecast consumption and the real consumption in order to eliminate penalties.

Currently in-pipe storage pressures in Romania are 40bar, but in the future the storage pressures may increase up to 70bar.

This system of gas storage in the pipe, during exploitation, requires a relatively low gas flow, used to balance the peak loads. For this reason, as it is shown in the model, the reduction plant is operating intermittently, as needed. During the day it works only a few hours, usually after over-passing the peak load.

6. References

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