IBIMA Publishing
Journal of Eastern Europe Research in Business and Economics
http://www.ibimapublishing.com/journals/JEERBE/jeerbe.html
Vol. 2013 (2013), Article ID 404582, 13 pages
DOI: 10.5171/2013. 404582

Research Article

The Use of Numerical Simulators to Determine the Daily Balance of the Natural Gas Distribution Network

Cristian Eparu, Sorin Neacșu and Doru Stoica

Petroleum - Gas University of Ploiești, Romania

Correspondence should be addressed to: cristian.eparu@gmail.com

Received Date: 24 April 2013; Accepted Date: 8 July 2013; Published date: 11 October 2013

Abstract

The paper presents a method to determine the daily gas balance from a distribution network that is based on the numerical simulator Simone and the GIS model of the network. The results obtained with this method applied for a distribution network of a town in Romania are presented. The main advantage of the method is that, based on the real data taken from the SCADA system on a limited number of monitored control points, the daily balance for the entire network can be obtained.

Keywords: gas, balance, network, distribution

Introduction

As a member of the European Union, Romania participates in the effort to construct a common energy market. The Romanian gas market has suffered from dramatic changes for the last few years. The transit from a unique company in the gas field, namely ROMGAZ, in 2000, to a multitude of companies (34) has produced major changes, especially from the legislative point of view. Gas distribution in Romania is currently dominated by two firms: E.ON GAZ ROMÂNIA and GDF SUEZ ENERGY and each of the two companies have approximately 1.4 million clients.

The market of the natural gas in Romania has recently suffered from significant changes due to the reorganization and restructuring of the sector and to the development of the regulation framework, based on the field's dynamics and on the implementation in the national legislation of the Community regulations. Gas distribution networks are destined to distribute this resource to consumers. In Romania, pressures in the transport networks are generally low, usually below 6 bars.

Natural gas consumption of the clients is generally variable, higher in the cold season, and lower in the warmer months of the year. Gas distribution networks must satisfy both transport capacity during the cold season, when consumed gas flows are higher, and the requirements of big consumers, usually the industrial ones. As the process of gas supply is a dynamic

Cite this Article as: Cristian Eparu, Sorin Neacșu and Doru Stoica (2013), "The Use of Numerical Simulators to Determine the Daily Balance of the Natural Gas Distribution Network," Journal of Eastern Europe Research in Business and Economics, Vol. 2013 (2013), Article ID 404582,
DOI: 10.5171/2013.404582.

process unrolled through transport and distribution networks that comply with well-defined regulations from the laws in force, gas distribution companies have to take over gas volumes that have been previously nominated on a daily basis. According to ANRE (2013), the difference between the nominated and taken-over gas quantities is penalized.

Regulations on the gas market coerce the distribution companies to elaborate methodologies as precise as possible that may further allow the estimation of gas consumption for consumers, on the basis of which daily, monthly or annual estimations can be done.

As a result of passing from monthly reading to the reading of the gas meters every three months downstream, gas distribution firms from Romania confront with a major problem, that of not having all the data for an accurate commercial balance. As shown by GTE (2005), prior to the commercial balance, one must elaborate the physical balance of the quantities of the distributed gas, for which it is necessary to know the input data, the outputs, technological losses and the quantity of gas existing in the distribution pipelines (the line-pack).

Because of the fact that gas transport process is not stationary and the quantities of the gas delivered to small consumers are known only every three months, there has been proposed an original method to calculate the daily balance on the basis of dynamic simulations made with the SIMONE simulator every other hour. As a result of simulations, the volume that is daily delivered to small consumers is deduced from the gas balance.

In order to make these simulations, the following elements are necessary: real data from the field received from the SCADA system, an estimation of daily and hourly consumption profiles for domestic consumers (B1-B3), a methodology to calculate technological losses and a soft that takes over all this information in order to process it and to create simulation scenarios as close to real conditions as possible.

This method is being currently tested in two Romanian cities. The paper presents data from one of the two. The initial data are:

- The system is supplied through 3 city-gates (regulation, measuring and delivery stations) with different SCP-es (Superior calorific power).
- There are 5 localities within the system.
- The number of consumers is 64.733, among which 45 are big consumers (B4-B6), whereas the majority (over 60.000) belong to B1 category.

After the analysis of the distribution system, the control points necessary for calibration were defined, a database was elaborated according to the data provided by the beneficiary and the model of the distribution system needed in the simulation process was designed. In the following stage, the model was calibrated on the basis of the readings made in the monitoring points. Figure 1 presents a layout of the distribution network.

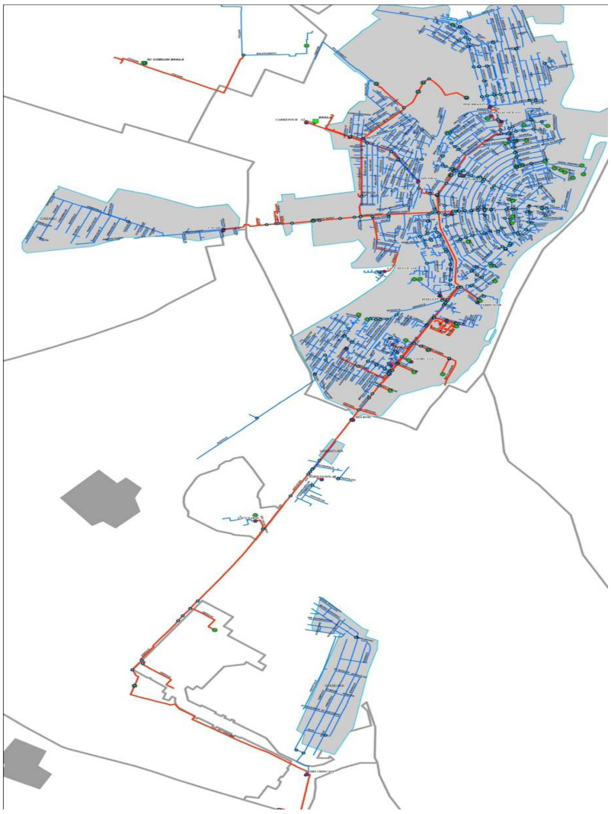


Fig. 1: Layout of the distribution network

After the analysis of GIS data about the distribution network, the following resulted:

- The length of the component pipelines – 321.8 km.
- The number of pipelines – 5867.
- The number of streets – 458.
- The number of regulation, measuring and delivery stations - 3.
- The number of SRS – 22.
- The number of valves - 418.

Presentation of the Method

Network balancing represents the mass balance of the gas that gets in or out the network, and the gas remaining in the network for a certain period of time. According to Keyaerts et al., (2008), if the period for which balancing is made is long (one day or more), there are taken into account the average values of the parameters considered in the balance range. In this case, balance is considered to be static. In the book by Trifan, Albulescu and Neacșu (2005), the authors emphasized that, if the variation of the parameters considered in the balance is rapid, then the calculus is made for shorter periods of time (hourly, for example) so that, within a certain range, the balance parameters may be considered constant.

In this paper, the considered balance range is a 24-hour day. For the dynamic balance, the variation of the parameters is hourly, and flows are expressed in Nmc/h.

After simulating the tests with real data, the result has shown that static balance cannot be calculated. There are sectors where the gas consumption of the big consumers is higher than the gas input through SRS, so that a static simulation cannot be performed. Dynamic simulations also consider the variation of the flow in the distribution pipelines (line-pack) that takes over the imbalance between inputs and outputs.

The flows of the gas delivered in the network are known, as they are equal to the values read at the city-gates that supply gas to the network. The flows of the output gas may be categorized as: hourly-read flows – for big consumers (B4...B6), and

Cristian Eparu, Sorin Neacșu and Doru Stoica (2013), Journal of Eastern Europe Research in Business and Economics, DOI: 10.5171/2013.404582.

flows estimated for other types of consumers owning B1...B3 categories gas meters. In the latter case, daily flow values for small consumers are to be determined after the balance. The big number of B1...B3 clients (64.961) does not make possible the use of a direct method of calculation (system of equations etc.) of the gas volumes consumed by every client per day. Therefore, daily volumes will be determined by means of a reiterative procedure that is to be further described.

As a basic value for the calculation, one considers the daily value of the gas volume delivered into the network V_{ziSRMP}. For all the clients supplied by this city-gate, the following factors are determined:

- *FCZIC*: the factor of client's daily consumption. This is determined for a period of time that is no shorter than a gas year.
- *PNDC*: represents the client's weighing coefficient, which is determined with the formula:

$$PNDC = \frac{FCZIC}{(\sum FCZIC)_{area}},$$

where *area* is supplied by the point (city-gate or SRS – sector regulation station) for which the calculation is made. Figure 2 presents a screen capture from a programme that calculates the ratios of the clients and the values of the volumes that are consumed per day, on the basis of the daily volume reading at the city-gate.

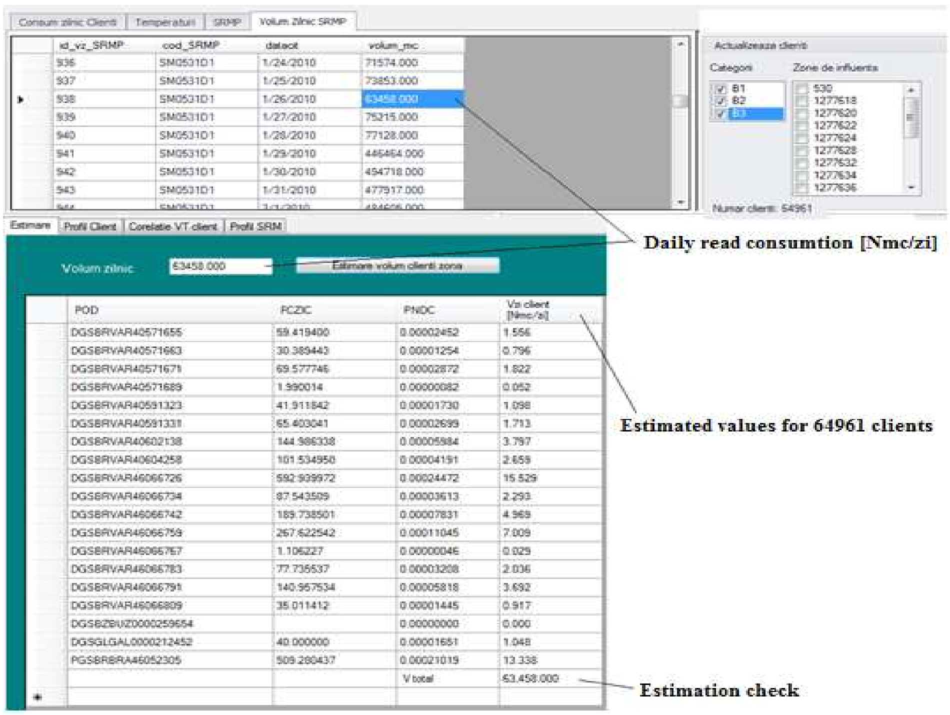


Fig. 2: Calculation of the B1...B3 clients' coefficients and daily-consumed volumes.

According to the model used in the simulation, clients are street- allocated, so that the gas flow on a certain street is the summation of the flows consumed by the clients residing on that street. In figure 3, the surveyed network is detailed, namely the monitored city-gates and SRS-s. Pipelines are marked with different colours, so that the area supplied by a certain SRS may be better visualised.

The balance calculation is repeatedly done, by modifying the flows of the clients within the SRS-s areas of influence, until the values of the calculated flows become equal to the readings. In that moment, calculation is stopped, henceforth the flows result for each street in the network and for each

B1...B3 client.

After simulation, the quantity of gas which exists in the network can be obtained for each time range (daily or hourly). Closing per client may be done only after the three-monthly reading, by redistributing the possible difference of gas volume on the days of the interval between the readings.

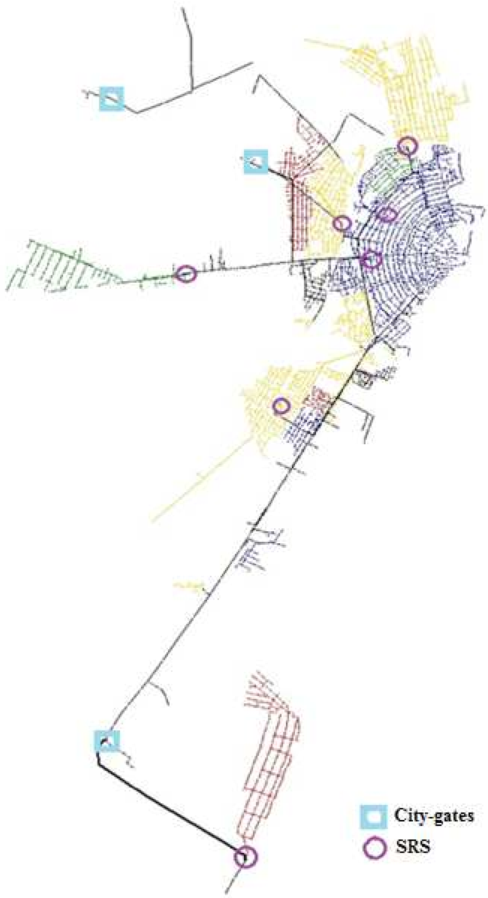


Fig. 3: Monitored SRS-s and city-gates network

Data Organisation and Processing

For a better organisation of the data deriving from different sources, a database was created. This database enables its users: to determine the volume of gas from the pipelines of the distribution system (Nmc/day), to physically balance the distribution networks every 24 hours by using a simulator, to monitor and to highlight natural gas losses and abnormal consumption from the distribution system, to identify hourly consumption profiles and to calibrate them, based on hourly data that are available for the chosen distribution system and on the data collected from the analyzed distribution system (Figure 4).

The following information provided by the beneficiary was introduced in the database:

- Operating parameters of the chosen distribution system;
- Daily (read) consumption of the B4-B6 categories consumers and the history of daily consumption per gas year;
- Values of the natural gas quantity delivered from the national transport system into the chosen distribution system, through city-gates;
- Estimated consumption data for profitable consumers from B1-B3 categories;
- Consumption history per gas year

for B1-B3 categories profitable consumers;

- The distribution of profitable consumers on streets;
- The history of daily inputs through city-gates per gas year;
- Daily average temperatures recorded in a gas year.

The database also includes the information on the consumption profiles of the clients and the simulation results.

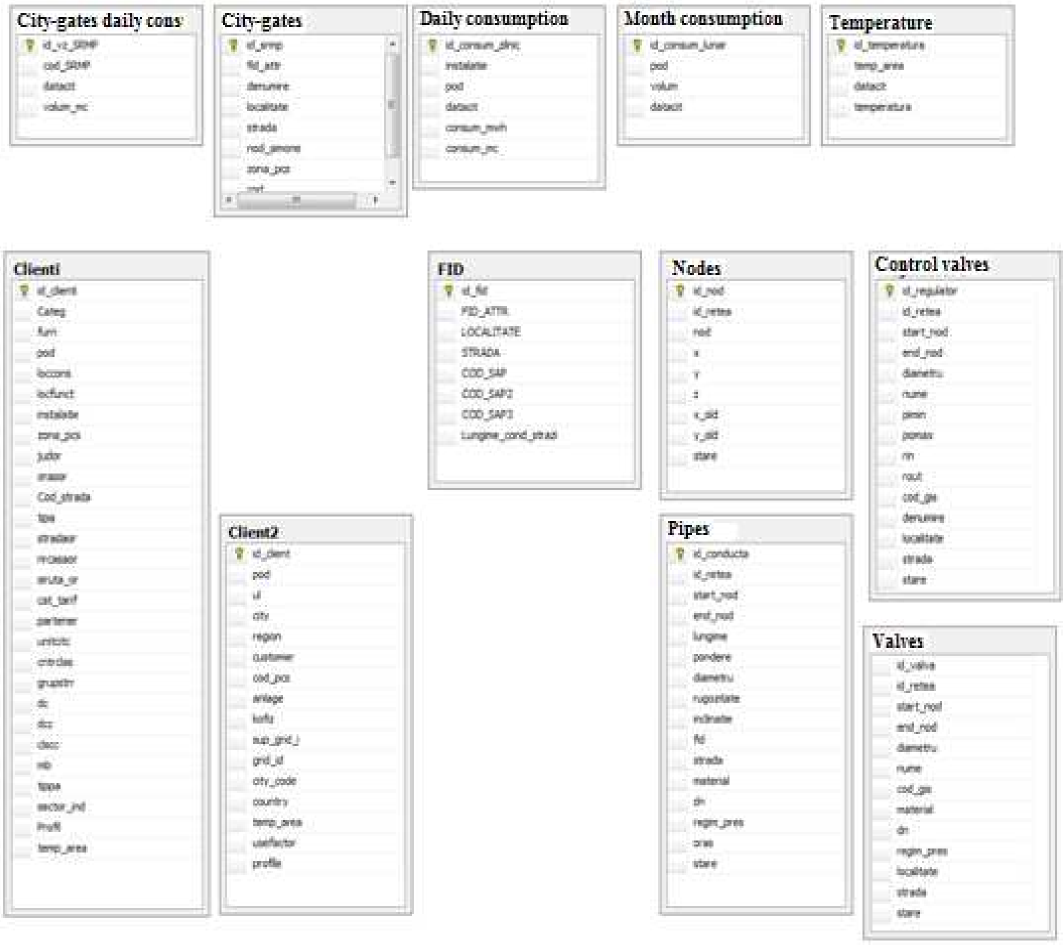


Fig. 4: Database diagram

The Consumption Profile of the Area

As shown by Neacşu et al., (2011), consumption profiles are functions on which gas consumptions per certain periods of time may be forecast. Taking into account the fact that, for the distribution network from Brăila, B4...B6 categories consumers are read on a daily basis and that the consumption behaviour of the B1..B3 consumers is influenced by temperature, we consider that there may be used only one consumption profile, henceforth named zonal profile set on daily gas values delivered through city-gates. In the future, as further data are gathered, the daily consumption data of B1…B3 clients to create the regional profile may be used.

For every client within the area for which the profile has been defined, the zonal profiling function corrected with PNDC may be used, i.e. the weighting coefficient of the consumer.

Further on, we present the way in which the zone profile is designed and operated with. Figure 7 represents the consumption per a gas year within the SRS influence area. The consumption is dependent on temperature. In figure 5, the day weighting coefficients for 3 time intervals are presented.

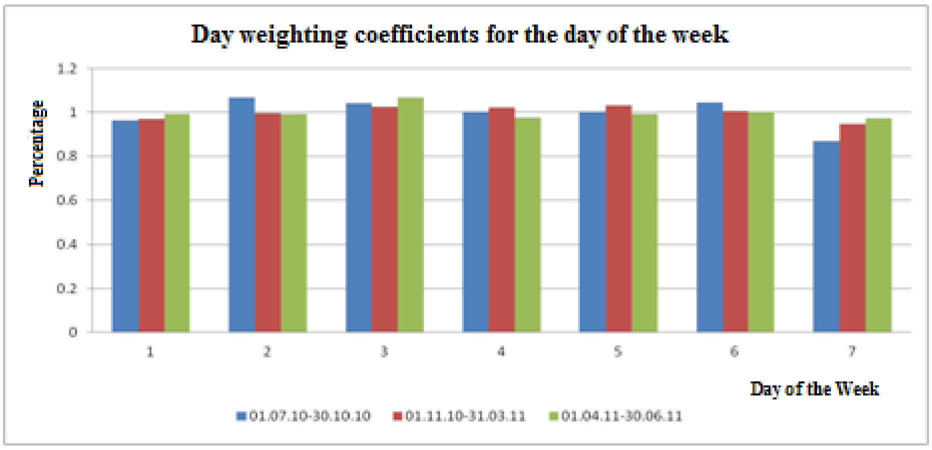


Fig. 5: Day weighting coefficients for the day of the week

The consumption values, calibrated and sorted depending on temperature, make possible the defining of the profiling function, as shown in figure 6.

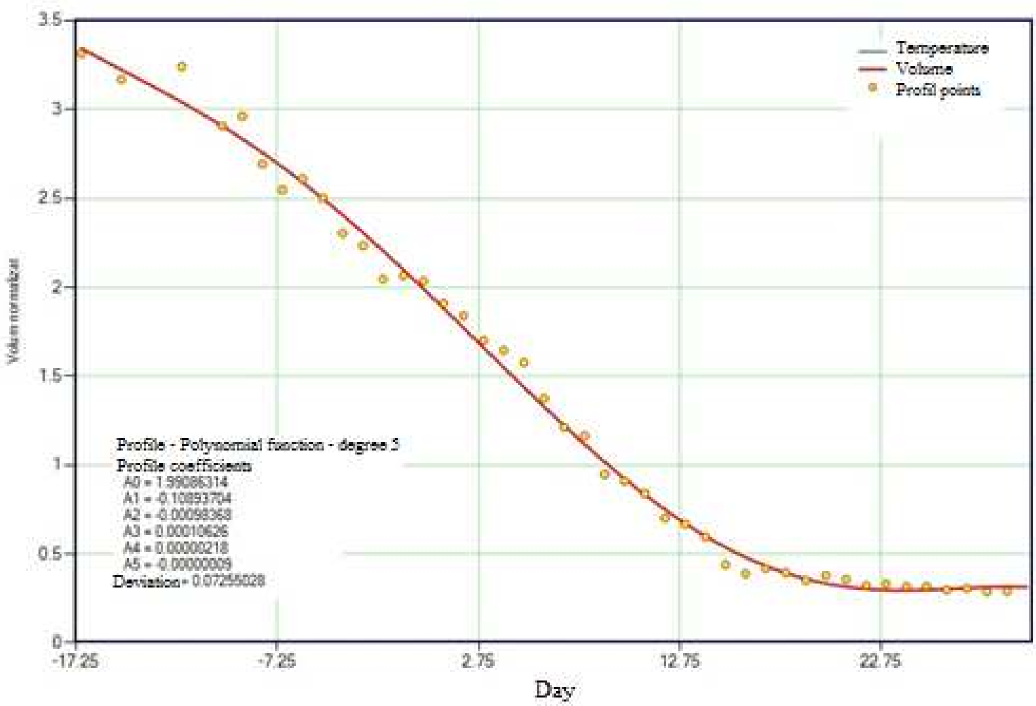


Fig. 6: The defining of the profiling function

Eparu et al., (2011) emphasized that daily values may be determined by using the zone profile, the zone consumption factor represented by the average value of the daily consumption per gas year and the correction coefficients, in this case, the day of the week weighting coefficients. The profiled volume and the real volume have been compared, as presented in figure 7.

The consumption factor is usually derived from history (the previous gas year) and it is considered constant throughout the prognosis interval, namely one gas year.

When analyzing the graph, one remarks notable differences between the profiled and the realized volumes. In order to minimize these differences, a variable consumption factor will be used for the prognosis. In this case, the difference between the estimated values and the real ones falls below 1%.

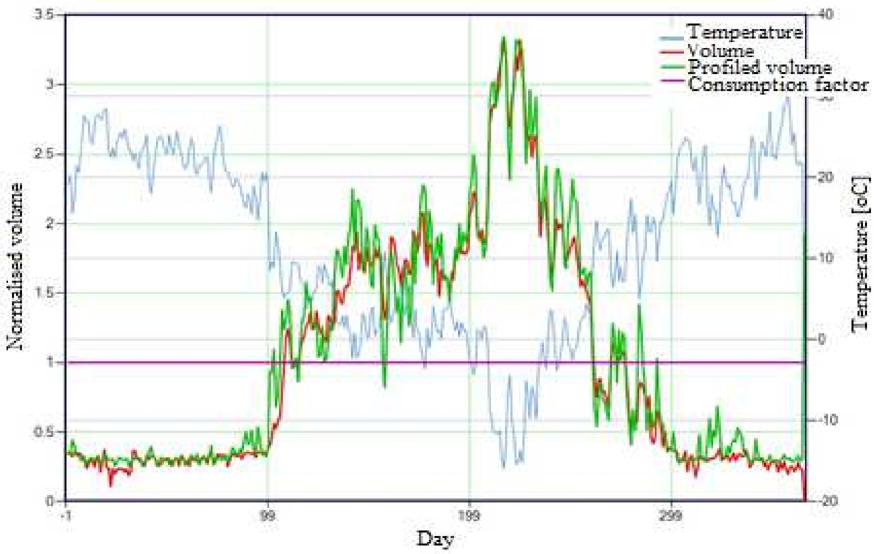


Fig. 7: Graph representing the profiled volume and the real volume

Gas Loss

For a maximum accuracy of the calculation, the technological escape from the grid must be considered. The most significant are caused by: the flaws resulted from the inappropriate correction of the gas volume that is delivered to some small consumers owning gas meters without regulator, as shown by Albulescu et al., (2008), and Neacşu et al., (2008), the replacement or commissioning of the distribution network, the permeability of the material, while Eparu et al., (2011) highlighted the inappropriate regulation of the pressure in the regulation stations, the sensitivity of gas meters, escapes as a result of maintenance activities etc.

Technological losses depend on several factors such as: pipeline locations (above ground or buried), material (cast iron, steel and polyethylene), and type of flaw (weld pores, corrosion, and non-tightness). As the monitoring of all the above-mentioned aspects may prove difficult, there is a methodology to calculate all types of technological losses, presented in ANRE (2013). These are calculated once a year. In Romania, technological losses represent approximately 3 % from the total of distributed gas.

Test Procedure

Daily flows were converted into hourly flows and, in cases where hourly information was available, this was used in simulation.

In order to generate a scenario, one needs information on the inputs (pressure and flows at the city gates), on the outputs of the network (estimated consumptions for B1-B3 consumers and measured values for B4-B6 consumers), on possible restrictions (turned-off valves and regulation activities within SRS-s), and on the parameters from the established control points.

Once the total consumption of the clients residing on a certain street has been established, this is distributed to the afferent pipelines, considering their length. After estimating the consumption per each pipeline, this is further delivered to one of the pipeline's points.

To these types of consumption, one adds the gas delivered to B4-B6 categories consumers, in certain nodes of the network. In order to create accurate scenarios, the location of the valves throughout the system was put at our disposal.
Simulation provides a series of results,

which, in order to be accurate, should coincide with the values from the control points. In case the values from the control points are not similar, the initial estimated consumption for B1-B3 consumers should be modified and simulations rerun until the values obtained during simulation and the real values from the control points become similar. We designed specialized software (see Figure 8) that allows the above-mentioned procedure. Once the results obtained by the simulator have been introduced, the soft checks the differences registered at the control points, calculates the new coefficients for each consumption area, and simulation scenarios are regenerated based on the new consumption values. These scenarios are further introduced in the simulator and, after approximately 3 reiterations, accurate consumption values are obtained.

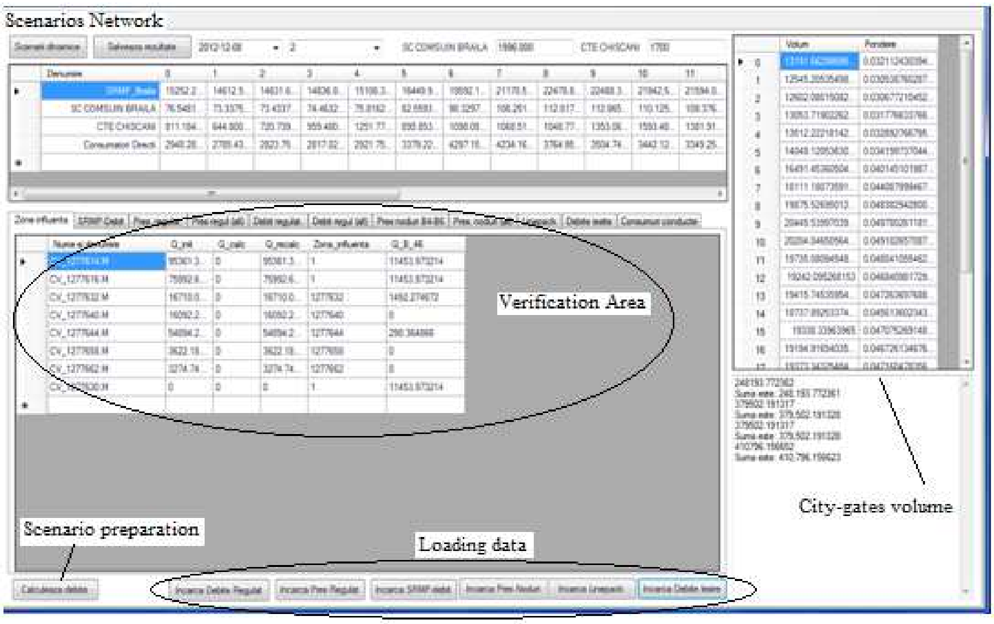


Fig. 8: Soft designed for redistribution and automated scenarios generation

At that point, data resulted during simulation may be stored in the database, which further on supports the determination of the volume of gas in the pipeline, the physical balancing of the network every 24 hours, the monitoring and highlighting of gas escapes or abnormal consumptions throughout the distribution system.

Presentation of the Results

The results of the simulations for each gas day are stored in the database. In order to visualize the data on which scenarios were generated and the results of the simulations, the beneficiary is given the access, via internet, to an interface that allows the selective display of the results.
The table in Figure 9 presents the physical balance calculation for a gas day, based on hourly balances. One may notice that the input volume of gas was, in that day, 1481,523 Nm^3 lower than the consumed gas.

Hourly exit data

Day	Hour	Supply flow	Initial linepack	Offtake flow	Final linepack	Balancing
2012-11-26	6	15814.170	13650.177	17380.6510	13547.269	-1463.573
2012-11-26	7	18550.640	13547.269	18723.3865	13527.966	-153.444
2012-11-26	8	18649.790	13527.966	18189.3559	13604.756	383.644
2012-11-26	9	17576.960	13604.756	17322.9927	13650.452	208.271
2012-11-26	10	16674.530	13650.452	16738.3034	13676.600	-89.921
2012-11-26	11	16435.220	13676.600	16123.1558	13671.876	316.788
2012-11-26	12	16517.410	13671.876	16377.3304	13663.487	148.469
2012-11-26	13	16408.940	13663.487	16266.9422	13679.570	125.915
2012-11-26	14	15864.070	13679.570	16101.6959	13672.035	-230.091
2012-11-26	15	16185.770	13672.035	16089.9833	13664.911	102.911
2012-11-26	16	16602.310	13664.911	16443.1695	13611.129	212.923
2012-11-26	17	17549.750	13611.129	17961.5935	13567.706	-368.420
2012-11-26	18	18299.400	13567.706	18382.0029	13538.146	-53.043
2012-11-26	19	18706.440	13538.146	18770.9350	13560.981	-87.330
2012-11-26	20	18255.680	13560.981	18236.1012	13620.207	-39.647
2012-11-26	21	17073.480	13620.207	16739.4138	13685.159	269.114
2012-11-26	22	15772.020	13685.159	15351.0143	13716.313	389.852
2012-11-26	23	14915.070	13716.313	14310.0629	13757.205	564.115
2012-11-27	0	12116.940	13757.205	13312.3560	13866.493	-1304.704
2012-11-27	1	13339.970	13866.493	13443.4047	13861.122	-98.064
2012-11-27	2	13557.270	13861.122	13521.8911	13865.060	31.441
2012-11-27	3	13395.610	13865.060	13334.1424	13853.711	72.817
2012-11-27	4	13794.770	13853.711	13653.4381	13826.564	168.479
2012-11-27	5	14809.590	13826.564	15495.6631	13728.516	-588.025
Zi gaziera	Total: 24h	386865.800	328338.895	388268.986	328417.234	-1481.523

Fig. 9: Hourly balancing

This is further illustrated in Figure 10, where the following elements are graphically marked: the hourly variation of the gas flows (top), the quantity of gas in the distribution network (middle), and hourly balancing (bottom).

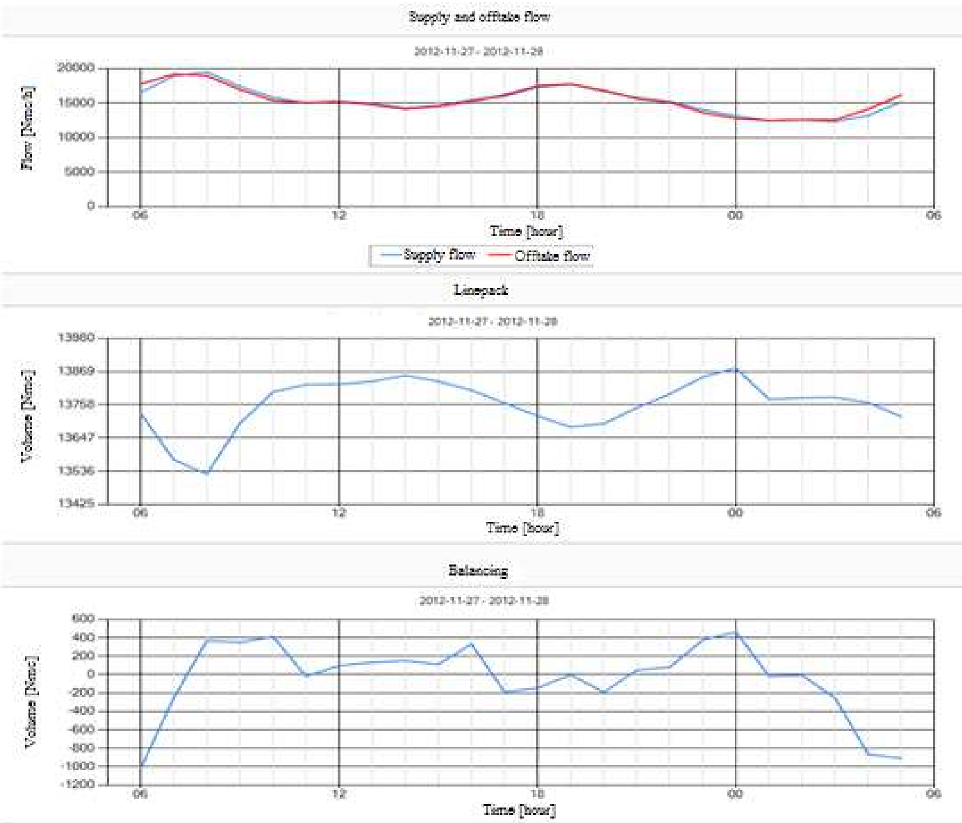


Fig. 10: Daily variations of the input/ output flow, of the line-pack and of the balancing

Cristian Eparu, Sorin Neacșu and Doru Stoica (2013), Journal of Eastern Europe Research in Business and Economics, DOI: 10.5171/2013.404582.

Figure 11 presents the values of the daily gas flow in the control points.

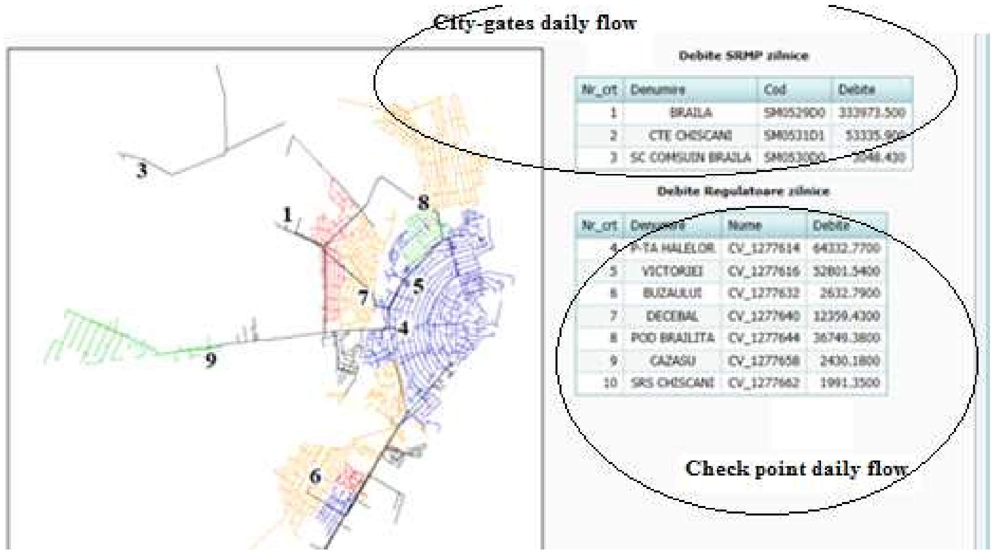
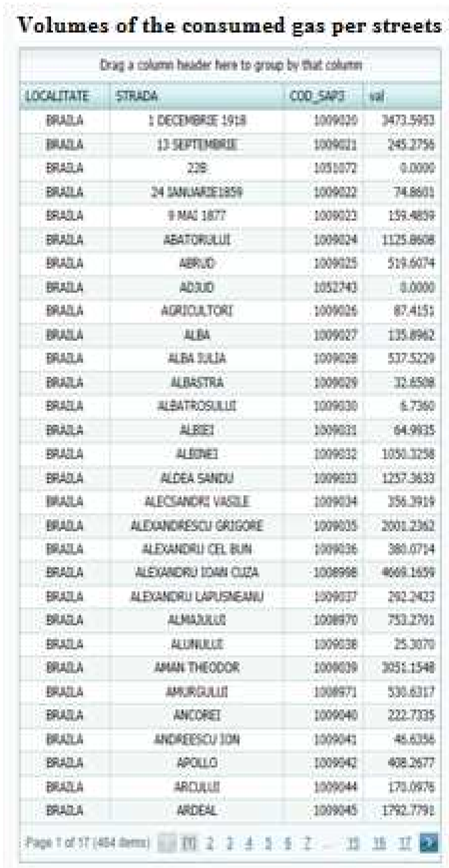


Fig. 11: The daily gas flow in the monitored city-gates and SRS-s

Once the volume of gas distributed to the pipelines is determined, the volumes of gas per streets are calculated, by associating pipelines to the streets (Figure 12).



Volumes of the consumed gas per streets

Drag a column header here to group by that column

LOCALITATE	STRADA	COD_SAP3	val
BRAILA	1 DECEMBRIE 1918	1009020	3473.5953
BRAILA	13 SEPTEMBRIE	1009021	245.2756
BRAILA	22B	1051072	0.0000
BRAILA	24 IANUARIE1859	1009022	74.8601
BRAILA	9 MAI 1877	1009023	159.4859
BRAILA	ABATORULUI	1009024	1125.8608
BRAILA	ABRUD	1009025	519.6074
BRAILA	ADJUD	1052740	0.0000
BRAILA	AGRICULTORI	1009026	87.4151
BRAILA	ALBA	1009027	135.8962
BRAILA	ALBA IULIA	1009028	537.5229
BRAILA	ALBASTRA	1009029	32.6508
BRAILA	ALBATROSULUI	1009030	6.7360
BRAILA	ALBIEI	1009031	64.9935
BRAILA	ALBINEI	1009032	1050.3258
BRAILA	ALDEA SANDU	1009033	1257.3633
BRAILA	ALECSANDRI VASILE	1009034	356.3919
BRAILA	ALEXANDRESCU GRIGORE	1009035	2001.2362
BRAILA	ALEXANDRU CEL BUN	1009036	380.0714
BRAILA	ALEXANDRU IOAN CUZA	1008998	4669.1659
BRAILA	ALEXANDRU LAPUSNEANU	1009037	292.2423
BRAILA	ALMAJULUI	1008970	753.2701
BRAILA	ALUNULUI	1009038	25.3070
BRAILA	AMAN THEODOR	1009039	3051.1548
BRAILA	AMURGULUI	1008971	530.6317
BRAILA	ANCOREI	1009040	222.7335
BRAILA	ANDREESCU ION	1009041	46.6356
BRAILA	APOLLO	1009042	408.2677
BRAILA	ARCULUI	1009044	170.0976
BRAILA	ARDEAL	1009045	1792.7791

Page 1 of 17 (404 items) [1] 2 3 4 5 6 7 ... 15 16 17

Volumes of the consumed gas per streets

Drag a column header here to group by that column

LOCALITATE	STRADA	COD_SAP3	val
BRAILA	GRADINA PUBLICA	1009207	629.5730
BRAILA	GRADINARILOR	1009208	7.1994
BRAILA	GRATIEI	1009209	972.1388
BRAILA	GRIGORESCU EREMIA	1009211	5742.7619
BRAILA	GRIGORESCU EREMIA	1009212	736.7153
BRAILA	GRIGORESCU NICOLAE	1009213	450.2140
BRAILA	GRINDULUI	1009214	219.9989
BRAILA	GRIVITA	1009215	6188.2270
BRAILA	HARET SPIRU	1009216	87.7474
BRAILA	HASDEU PETRICEICU BOGDAN	1009217	254.3883
BRAILA	HEPITES CONSTANTIN	1009218	360.3202
BRAILA	HIPODROM	1009219	4523.0905
BRAILA	HORIA	1009220	29.4241
BRAILA	HUMULESTI	1009221	551.6395
BRAILA	IASOMIEI	1009223	57.8586
BRAILA	IBRAILEANU GARABET	1009224	116.7674
BRAILA	IEZERULUI	1009225	714.9586
BRAILA	IMPARATUL TRAIAN	1009226	854.3164
BRAILA	INDEPENDENTEI	1009001	2737.6324
BRAILA	INDEPENDENTEI	1009009	20.3194
BRAILA	INDEPENDENTEI	1009227	7097.9232
BRAILA	INDUSTRIA SARMEI	1009228	30621.4392
BRAILA	INDUSTRIEI	1009229	5368.8002
BRAILA	INULUI	1009230	174.6521
BRAILA	INVATATORILOR	1008978	1821.5856
BRAILA	IOAN VODA CEL CUMPLIT	1009231	465.9477
BRAILA	IONESCU DE LA BRAD ION	1009233	695.0857
BRAILA	IORGA NICOLAE	1009234	520.1461
BRAILA	IOSIF STEFAN OCTAVIAN	1009235	103.2973
BRAILA	IPATESCU ANA	1009236	242.9660

Page 7 of 17 (404 items) 1 2 3 ... 6 [7] 8 9 ... 15 16 17

Fig. 12: Volumes of the consumed gas per streets

Conclusions

By using the method presented in this paper, the daily consumption for domestic consumers (B1-B3) could be determined for the pilot cities. In order for the daily consumption values to be as near as possible to the real ones, double closing is applied, which means that, every 3 months when reading of the clients is made, the estimated daily gas values are readjusted in the network balance, so that the balance may be closed for each client.

The model presented in the paper enables various simulations that may be used in the analysis of critical situations and in finding the best solutions. By means of the computer-generated model, there may be also studied different modalities to operate the distribution system under various conditions (winter, summer) in order to define the most efficient operating programmes.
One may notice the imbalance between the output volumes of gas and the inputs, fact that may be explained by the presence of a quantity of buffer gas in the pipelines.

Network balance for a gas day represents the total of hourly balances for that day. For the dynamic balance, the input data had to be processed, so that the values correspond to the same periods of time. The dynamic calculation is much closer to the real network operation.

Besides the input data (i.e. flows, pressures), the location of the valves in the system – the operating elements of the network – are extremely important in the simulating process. The manoeuvres carried out in the physical network must be introduced in the simulator in the moment they were realized.
For B1-B3 categories consumers, hourly consumption profiles determined by means of the input data dynamics were introduced.

The results of simulations may highlight, whenever the case, the areas with abnormal gas consumptions.

The computer-generated model of gas distribution enables:

- Predictive simulations made on the basis of temperature prognoses, in order to define necessary operating manoeuvres.
- The analysis of special situations (the lack of supply in certain points, the commissioning for big consumers, breakdowns), and defining operating manoeuvres to maintain the distribution system functional.
- The analysis of the influence of hourly consumption profiles and the necessary measures (operating, pressure level) that are to be taken to overcome possible problem.

Based on the obtained physical balance, a precise commercial balance may be done. The differences between the current method to calculate the commercial balance and the proposed method, implying daily calibration on the basis of simulations, consist in several percents.

References

Albulescu, M., Neacşu, S., Trifan, C. and Ionescu, E.M. (2008), 'Theoretical Considerations and Experimental Measurements Concerning the Defining of Correction Coefficients in Case of Measuring Natural Gas Volumes for Household Consumers,' *Materiale Plastice*, 45 (1), 38-41.

ANRE, (2013), 'Codul Retelei pentru sistemul naţional de transport al gazelor naturale,' http://www.anre.ro/documente.php?id=739.

Eparu, C., Albulescu, M., Medrea, L. and Metea, V. (2011), 'Analysis Regarding the Influence of the Atmospheric Pressure on Natural Gas Consumption,' *Petroleum-Gas University of Ploieşti Bulletin: Technical Series*, LXIII (3), 68-76.

GTE, (2005), 'Comments on ERGEG "Gas Balancing" Discussion Paper, Gas Transmission Europe, Brussels, www.energy-regulators.eu

Keyaerts, N., Meeus, L. and D'haeseleer, W. (2008), 'Natural Gas Balancing: Appropriate Framework and Terminology,' *Katholieke Universiteit Leuven*, Last update June 08, TME Working Paper, http://www.mech.kuleuven.be/en/tme/research/energy_environment/Pdf/WPEN2008-03.

Neacşu, S., Eparu, C., Stoica, C., Rusu, A. and Olteanu A. (2011), 'Metodă de estimare a consumurilor de gaze naturale folosind profilele de sarcină ale clienților,' *Termotehnica Revue*, XV (1), 18-26.

Neacşu, S., Trifan, C. and Albulescu M. (2008), 'Considerations on the Errors Associated to the Measuring of the Amounts of Natural Gas Delivered to Household Consumers,' *Chemistry Magazine*, 59 (7), 796-801.

Simone 5.7, http://www.simone.eu/simone-company-about.asp.

Trifan, C., Albulescu, M. and Neacşu, S. (2005) Elemente de mecanica fluidelor şi termodinamică tehnică, Petroleum-Gas University of Ploiești Publishing House, Ploiești.

Cristian Eparu, Sorin Neacşu and Doru Stoica (2013), Journal of Eastern Europe Research in Business and Economics, DOI: 10.5171/2013.404582.