HR Wallingford
Working with water

Sim-On GAS

SimOn Gas

Technical specification

Contents

About Sim-On Gas

Sim-On Gas is a software solution that enables a better understanding of gas distribution networks and allows their management to be improved.

Sim-On Gas uses a numerical solver that simulates, in real-time, the functioning of the entire distribution system, returning the current and future trends of the hydraulic variables such as gas flow rates, pressures and velocities.

Sim-On Gas stands out from traditional fluid-dynamic simulators due to the following features:

- a direct connection to the SCADA data: this enables it to acquire real-time field data and simulate the actual conditions of the network;
- system access through a web browser, enabling it to work quickly and flexibly from any device without having to install and manage desktop applications;
- user friendly due to its intuitive interface, allowing the platform to be used by those who do not have model or computer knowledge.

SimOn Gas enables the technicians assigned to operate the system to use advanced simulation tools. The software interface shows a defined number of options and commands and users are guided through the available processes and analysis in a simple and intuitive way.

Operators can quickly and easily obtain useful information for management directly on the SimOn platform.

Sim-On Gas can easily answer questions such as:

- What pressures are currently expected in the network?
- What demand, flow rates and pressure trends are we expecting in the system during the next 24 or 48 hours?
- What will the pressure and flow trends in the network be if, for management reasons, you need to interrupt the supply of a meter and regulator station (MRS) in the next few hours?
- If, for management reasons, a valve in the medium pressure network needs to be closed, could some users suffer inefficiencies? Will the network still be able to guarantee adequate operating pressures?

Summary

This document describes the technical features of the Sim-On Gas platform, providing a better insight into the technical and theoretical basis of the application. Additional documents are available, including user manuals for both users and system administrators.

A basic knowledge of off-line simulators such as InfoWorks WS Pro Gas software will help in understanding the information presented in this document.

An essential prerequisite for carrying out real-time simulations is to have ordinary simulation models that are functioning correctly and are representative of the gas distribution networks. These models can therefore be published and used “on-line” in the Sim-On Gas platform. To extend the use of gas simulation models to real time with SimOn Gas it is therefore necessary to know the techniques needed to build a basic model that is as reliable and representative of your system as possible.

Real-time simulations

Sim-On Gas establishes a direct link between the simulation model and the variables detected by the remote monitoring system (SCADA) of the methane distribution network, acquiring the boundary conditions necessary to generate the results of the simulations in real-time.

Using remote monitoring, Sim-On Gas acquires the following information and uses it in the simulation:

- **Flow rates delivered by MRSs**
  The flow rate delivered to the meter and regulator stations (MRSs) delivery points is one of the most important variables for the real-time representation of a system. Methane gas consumption has a typical hourly and daily variability and the measurement of the MRSs flows reproduces the actual consumption (total demand) of the system for every moment in time. Sim-On Gas acquires the inflow data from all the MRSs in the distribution from the SCADA and adjusts total demand in the simulation model so that they are consistent with the flow rates actually entered in the network at any time.

- **Pressure boundary conditions**
  Sim-On Gas can acquire MRSs and gas pressure regulators' (GPR) set pressures from the remote monitoring system, where available, to input into the calculation model in real-time a consistent pressure boundary condition, thus ensuring greater accuracy between the simulation and the actual conditions of the distribution system.

- **Pressure check in the network**
  Any other pressure measurement points, located, for example, within the distribution network or upstream of the pressure reduction units are used by Sim-On Gas as an element to verify the reliability of the calculation model. The Sim-On Gas user interface shows graphs comparing the calculated pressures with the pressures measured at the monitored strategic points. A good match or possible deviation of these graphs provides a continuous indication of the reliability of the model.

- **Significant consumptions**
  If remotely monitored customer meters are available for particularly high demand users, Sim-On Gas is able to accurately allocate the local demand measured or estimated in the model, so as to represent precisely, at specific points, any concentration of significant shares of the total flow distributed over the network.

- **Check of MRSs flow distribution**
  If a network has at least two MRSs, Sim-On Gas returns a graph for each of them that compares the flow rate detected by the scada. The simulated flow rate of the data illustrated in these graphs provides a continuous indication of the reliability of the model. These calibration graphs only prove useful if the networks is fed by two or more MRSs. If there is only one MRS, total demand will always equal the one provided by the MRS, the calibration graph is always completely consistent and therefore not significant.

Consumption management

One of the most important aspects of the real-time simulation system is the way in which Sim-On Gas guarantees an actual correlation between the total gas consumption (total demand) in the distribution system as detected by SCADA and the one which is represented in the calculation model.

The first basic principle used by Sim-On Gas is that the total demand of all the users served by the distribution system coincides, at any given time, with the total inflow rate delivered by the MRSs connected to the system at that time. This principle is based on the assumption, widely supported by real findings, that any losses in the gas distribution systems are negligible when compared to the total input. The effect of flow compensation from internal storage in distribution networks is also considered negligible. It is known that the storage effect in gas networks exists in reality, but it can be considered negligible in medium and low pressure networks as the internal volume of the pipes would normally be able to meet the total demand of users in winter consumption conditions in only a few minutes.

The method for how to adapt the overall demand of the simulation scenario to the values detected by the SCADA in real-time or extrapolated in future simulation scenarios is now explained in detail. With particular reference to the simulation models built in InfoWorks WS Pro Gas, consumption values are normally inserted in the off-line model through the customer points. Each customer point is characterised by an average consumption (expressed in Sm^3/h) that typically derives from the consumption values measured by the client meter (i.e. annual volume consumed / number of hours of a year). Each consumption value belongs to a user category (Category ID in InfoWorks) and for each category a demand diagram is defined with different hourly, daily and monthly coefficients. Figure 1 shows an example of a defined demand diagram for one category (called “domestic” – see red box). For each user category in the model, a consumption category and its multiplication factors must be defined.

These are non-dimensional profiles, or rather a series of factors that apply to the basic consumption indicated for each user point. These coefficients define a consumption reference value for each day and time in the year. The consumption value defined for a particular date/time is therefore calculated as the average consumption of the user multiplied by the hourly coefficient (green box), the weekly one (purple box) and the monthly one (yellow box).

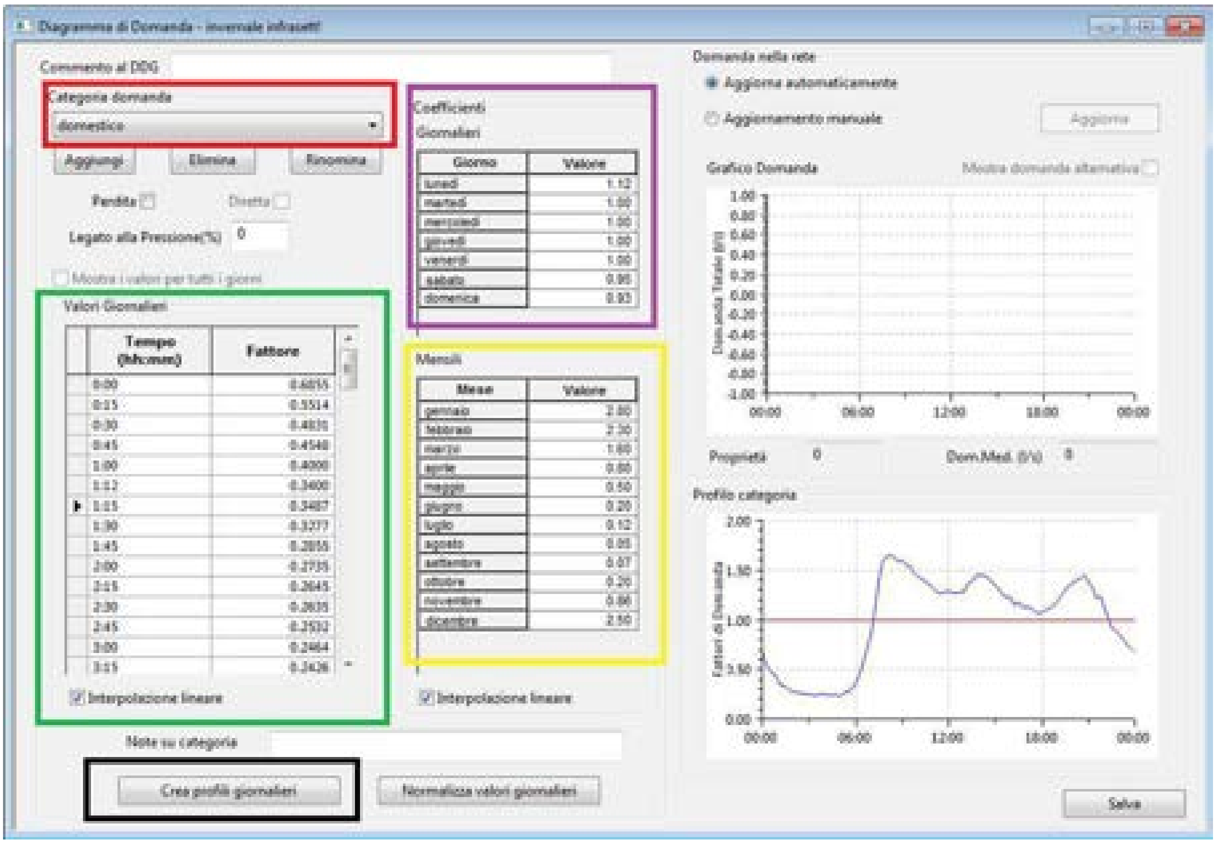

Figure 1: Hourly, weekly and monthly non-dimensional profiles

Basically, each user represented in InfoWorks WS Gas (off-line model) is associated with an average consumption level and, through the non-dimensional coefficients, with a consumption level for any date/time in the year.

A specific tool has been created (a desktop software utility called DDG Creator) that is able to load the following data:

- flow rates incoming through one or more MRSs in a network over a one year period (historical data) in CSV format;
- consumption values from large customers monitored meters during the same period. This data is normally provided hourly and for large meters only.

DDG Creator will be able to read the input files and perform the following operations:

- Identify a subset of large meters that are worth being singled out because, in the historical archive, they show significant consumption levels with regards to any of the four parameters: maximum flow rate per hour in the winter, maximum flow rate per hour in the summer, maximum daily volume in the winter, maximum daily volume in the summer. DDG Creator will identify the list of customer points with such features and will classify them individually by creating an individual profile in the DDG file. These delivery points are called “IPIs”, i.e. "Individually Profiled Intensive Users".
- For each IPI a complete historical hourly series of the consumption levels for the year will be extracted. Such series will be similar to the one which has been used as input data, but with the advantage of being complete, as DDG Creator will fill any empty values in the series by retrieving data from previous time periods. This historical series will be loaded in Sim-On Gas, which will use it only in special cases, when the remotely monitored meter does not transmit information for long periods.
- All remotely monitored meters that do not fall under the IPI category will be profiled using another

method called NIPI, or “Non Individually Profiled Intensive Users”. This profiling is calculated first by working out the algebraic sum of all the consumption values of this group hour by hour, and then by generating hourly, weekly and monthly non-dimensional profiles.

- Creating a generic profile (called “ordinary”) which follows the trend of all normal small house meters (typically domestic users). This profile is calculated from the flow rate obtained as the difference between the values of inflows by the MRSs and all the remotely monitored meters (both IPI and NIPI). For the historical series of the flow rates obtained from this operation, an hourly, weekly and monthly curve is calculated.

During real-time simulations, the consumption values defined in the off-line model and shown in the demand diagrams are multiplied by an additional multiplicative factor, to factor all consumption proportionally so that the overall consumption levels of the model exactly matches the ones observed in the SCADA system.

The creation of consumption profiles is particularly important to ensure a better accuracy of the model, as shown in the following example.

Let’s assume that we have a distribution network serving only households and that we have loaded into the base model the average consumption level per hour obtained from the billing database. In this case, default profiles can be used, i.e. with all the multiplicative coefficients of the consumption geographically distributed to the nodes equal to 1, as shown in Figure 2 below:

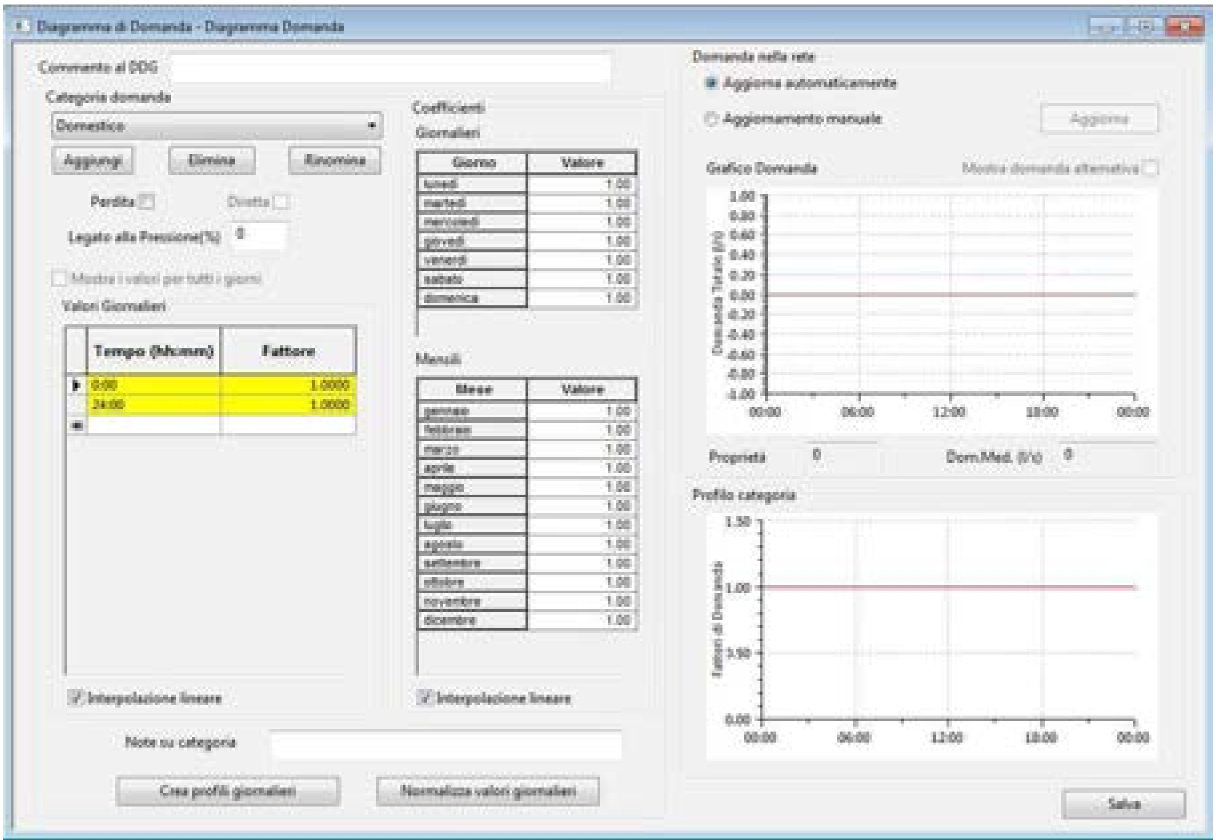

Figure 2: An example with constant profiles

In real-time simulations, Sim-On Gas independently modifies the total model demand consistently with that observed by the SCADA, or in forecast simulations, based on estimated total demand. In this case there is no distinction between one type of user and another, the same correction factor is applied to all users so as to obtain the overall simulation consumption.

If, on the other hand, you wanted to capture with greater precision the behaviour of certain specific users, typically very high demand users or users with particular consumption patterns, these should be individually profiled so that the hourly, weekly or seasonal variability of each user is well represented, on the basis of recorded historical behaviour (1 year of data). This approach is essential if there is a significant industrial consumption in the network with a strong time variability (hourly, weekly or seasonal). Clearly, the other application categories in the model must also be profiled in this case, and by using the DDG Creator you can automatically obtain a generic profile for all other generic users (called “ordinary” profile).

If the consumption data of the single meter was available via remote monotoring, then Sim-On Gas could use in real-time simulations the actual consumption value recorded; this topic will be developed in more detail later on in this document.

Results of real-time gas simulations

Sim-On Gas uses the same calculation engine normally used in off-line simulations such as InfoWorks WS Pro, the results of which are widely proven by multiple users and also by comparison to other standard off-line simulation software results. The added value of real-time simulations carried out by Sim-On Gas lies in the use of boundary conditions for the model (consumption and boundary conditions setting) which are aligned with the actual operating conditions of the network at a given time, resulting in more accurate and reliable results.

The plan view that is used in the Sim-On Gas interface allows you to quickly and effectively analyse the results of any simulation in real-time. All important state variables can be analysed:

- pressures at the nodes – any nodes with pressure results below the minimum allowed threshold value for the specific pressure range will be highlighted;
- flow rates and speeds in pipes – any speeds exceeding the maximum admissible threshold value will be highlighted;
- flow rates delivered by the MRSs – any flow rates exceeding the maximum limit value indicated for each MRS will be highlighted;
- flow rates delivered by Gas Pressure Regulators (GPRs) – any flow rates exceeding the maximum limit value for each GPR will be highlighted;
- any network areas not being served and the count of customers with no service will be highlighted. A customer with no service can either be completely isolated because of a network closure that occurs in extraordinary operating conditions or on part of the network experiencing operating pressures too low to ensure a proper service.

Sim-On Gas simulations are carried out in “pressure driven” mode, i.e. similar to the most advanced option for off-line calculation already used by the InfoWorks simulator (ReteGas calculation engine). This means that customers that are below the minimum pressure threshold values indicated for each type of pipe during the simulation are gradually disconnected from the network and no longer contribute to the overall demand on the network. Similarly, pressure reduction devices that are not correctly supplied upstream (i.e. with insufficient upstream pressure for correct operation) are considered to be in a functional block state, and therefore not capable of supplying the downstream system. Finally, the calculation does not admit negative flow rates to MRSs or GPRs (the MRS that may see a counter pressure and deliver a zero flow rate).

All of the above represents the most realistic simulation of the gas distribution system.

Types of simulation

Sim-On Gas can manage three different types of simulation, which are described below.

Type 1 simulations: current state

Current state simulations are automatically launched by Sim-On Gas at regular intervals. This interval can be chosen by the system administrator between the values of 30 and 60 minutes; the simulation frequency can coincide with the interval of data saving in the SCADA system but it definitely must not be lower because in the absence of new telemetric data, there is no benefit in producing new simulations.

In the current state simulation the following variables are included in the model:

- the output pressures of MRSs and, if available, GPRs, with the actual data received from the SCADA;
- individual demand of "IPI" users are also included if the data is readily available. If this is not the case, a consumption level recorded at the same time on a similar previous day is used (mid-week days are considered similar, but Saturdays and Sundays are kept separate);
- finally, all the consumption values present in the model (IPI, NIPI and ordinary) will be proportionally rescaled so that the overall consumption of the entire system coincides with the flow rates delivered by MRSs as recorded by the remote monitoring system.

The results of the simulation carried out in this way on a well-calibrated model can represent an extension of the information provided by the SCADA system to the entire network, and they enable Sim-On Gas users to know the value of all the hydraulic variables (pressures, flow rates, speed), which are in this case calculated, at any point of the network. Figure 3 shows an example of a screen with a plan view of a network area for a type 1 simulation.

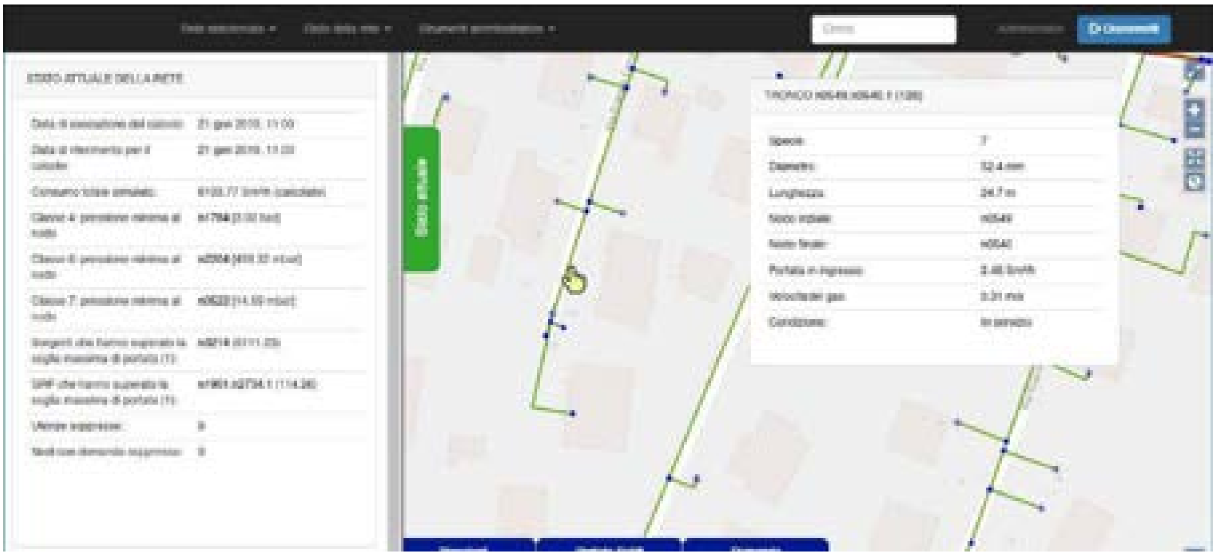

Figure 3: An example of a type 1 simulation result

Type 2 simulations: future state

Sim-On Gas automatically starts forecasting simulations at regular intervals (usually every 6 hours). Future state simulations analyse the hourly evolution of the expected consumption in the entire defined time span (using the method described below) and return the expected values for the state variables at any time.

For example, when the simulation interval is 1 hour and a future analysis time frame of 3 days is requested, the future simulation will perform 3*24=72 independent simulations. For each simulation both the total demand and any planned changes in the network operation are considered (as in type 3 simulation, described below).

In this type of simulation, Sim-On Gas will manage the SCADA data as follows:

- the output pressures of MRSs and GPRs will be set as equal to the last valid value or the minimum value recorded in the last 24 hours in the SCADA;
- the IPI type consumption levels will be estimated assuming that the future behaviour is similar to the one previously recorded for each user (as described for type 1 simulation);
- the total demand expected hour by hour (calculated with a forecasting algorithm that takes into account the temperatures and which will be later described) will be imposed by rescaling all the demand data in the model.

The results shown in the Sim-On Gas plan view indicate the variables for each element at the moment of maximum network stress, so:

- minimal pressures at each node;
- flow rates and maximum speeds for each pipe;
- maximum flow rates in MRSs and GPRs.

This picture does not reproduce a particular instant in time, but the envelope of all the most critical instants for each variable of each element of the model, so for each variable the date/time at which the maximum/minimum occurs is indicated; an example is shown in Figure 4.

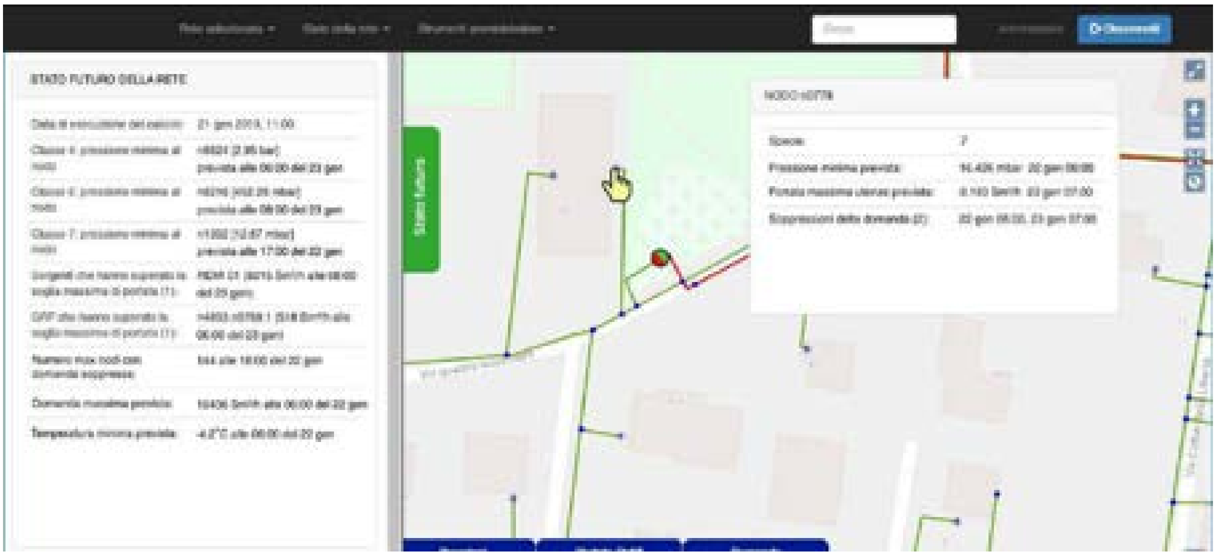

Figure 4: An example of a type 2 simulation result with an indication of the date/time of maximum stress

Type 3 simulations: tests simulations

Test simulations can be run on request by an enabled user. The purpose of this type of simulation is to verify the effect of disturbance conditions on the gas distribution system which may derive from operational needs dictated by scheduled maintenance operations or unexpected incidents. Field data from the SCADA system is managed in a similar way to that already described for type 2 simulations.

Test simulations are launched with reference to a user-defined future time frame within which the operation is expected to be carried out, specifying its start and end time. The end date and time cannot extend beyond the period of time for which the consumption forecast is considered sufficiently reliable (which is a maximum of five days). The conditions which could enable a change in the operating state included in Sim-On Gas tests simulations are a combination of one or more of the following events:

- closure of one or more valves;
- flow interruption in one or more pipes;
- exclusion from the system of one or more MRSs;
- exclusion from the system of one or more GPRs;
- creation of one or more by-passes in the network, whose nominal length and diameter are indicated;
- the intervention of a mobile gas cylinders truck;
- a change in pressure settings of one or more MRSs;
- a change in pressure settings of one or more GPRs.

A test simulation is started by the user by including some of these conditions of disturbance in the model. Once the effect of the test has been observed, the user can discard the test in progress, thus eliminating any modification of the simulated network and leaving unchanged the main network, or they can approve the test. If the test is approved, the modified conditions of the network operation are considered effective in the time frame defined for this test and then applied to the main network, thus determining substantial implications on all three types of simulations mentioned:

- Type 1 simulations, which represent the current state, consider as effective the temporary operating conditions approved in type 3 simulations, thus defining a state of the network which includes the temporary changes made to the base model, and apply them to all the current state simulations carried out within the time frame defined for the same modification. In fact, we must not forget that type 1 simulations represent the current moment, while type 3 simulations describe changes to the network operation in future time frames and therefore, when type 1 simulations temporarily overlap the type 3 operational tests carried out beforehand, they take into account the approved changes.
- Similarly, type 2 simulations, representing the future state, shall automatically consider as effective the temporary operational conditions approved in type 3 simulations. In this case, both type 2 and type 3 simulations concern future time frames; Sim-On Gas verifies the temporal overlap of the two intervals and applies to each hourly simulation of future calculations the indicated conditions from previously approved tests, but just for calculation times which are relevant to type 2 simulations.
- The already approved type 3 simulations may interfere with further type 3 simulations (new tests simulations) which will be later defined. When starting a new test, the user wishing to verify the effect of operations in a future time frame is notified if there are already approved tests for the same time frame. If this new test is approved, Sim-On Gas will consider all these special operating conditions in subsequent simulations for the established time intervals.

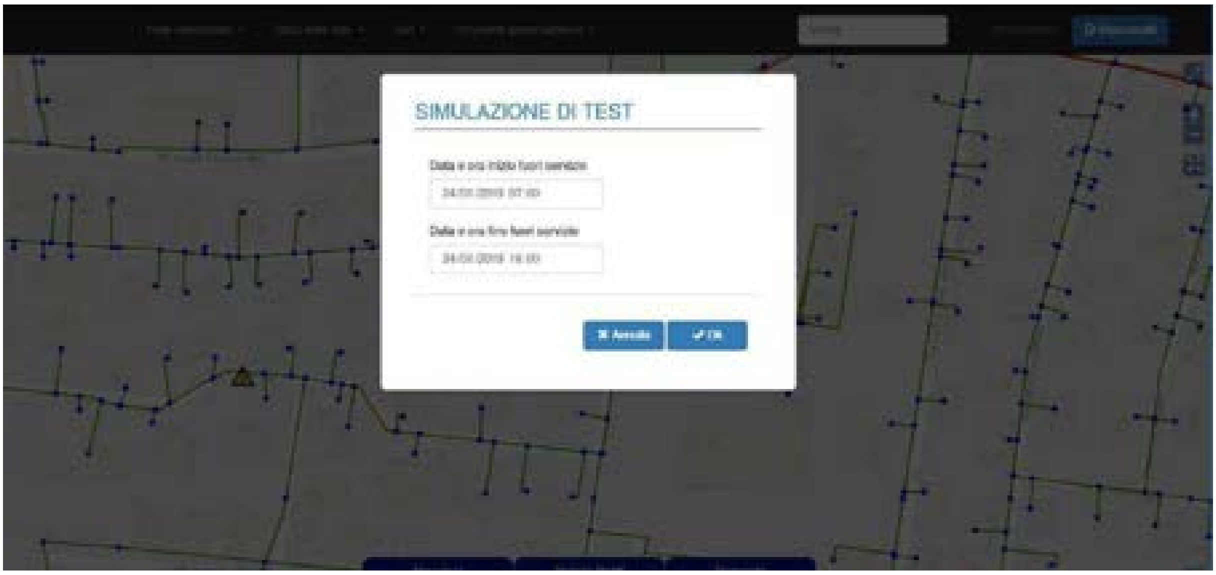

Figure 5: Definition window for start and end date/time of the test

As for type 2 simulations, the result of type 3 simulation shows the envelope of the extreme conditions of the variables, so:

- minimum pressure at each node;
- maximum flow and speed for each trunk pipe;
- maximum capacity at MRSs and GPRs.

For each variable, the date/time that it occurs within the analysed time period is indicated.

It should also be noted that type 2 simulations (future state) become immediately obsolete when a test on a network is approved. Sim-On Gas will then immediately regenerate the results of this type of simulation whenever a user approves a test or if already approved tests are deleted.

Further information on how to identify the moment of maximum stress for each variable is shown later in this document.

Consumption forecast

Future state simulations and test simulations (type 2 and type 3 simulations, described previously) refer to future time frames, so it is essential that the software system can predict the trend of the total future consumption of the network; the total gas demand for all users has to be considered.

It is well known that gas consumption is strongly influenced by conditions such as:

- external temperature trend;
- day of the week;
- public holidays;
- seasonal fluctuations (in the middle of summer consumption levels depend very weakly on outside temperatures, vice versa in winter).

In the literature there are other variables which affect the consumption such as wind, cloud cover or any snowfall. However, during our tests and research carried out on real data available to us (in Italian contexts), these connections were found to be insignificant if compared to those indicated and therefore they were not included in the development of the correlation algorithm currently used for internal consumption forecasts in Sim-On Gas.

The Sim-On Gas consumption forecast algorithm is based on a future extrapolation derived from a multi-parameter linear regression. Weekdays, Saturdays and public holiday forecasts are each treated separately.

The algorithm also treats winter forecasts separately from mid-season and summer forecasts.

In order to predict an estimated consumption value hour by hour for the following 5 days, the algorithm interrogates an online meteorological data forecast service every 6 hours. The forecast service we use and which has proven to be reliable (based on our tests on available sample data) is provided by Meteosolutions. The query takes place every 6 hours, following the update frequency of our chosen forecast service; a forecast processing with a higher frequency would not bring any added value.

Based on the available temperatures forecasts, the algorithm produces a future extrapolation of consumption up to a maximum of 5 consecutive days. The general principles on which this forecast is based are as follows:

- The overall consumption of the network is based on the measurements of the total inflow rates from MRS (algebraic sum of the flow rates supplied by all the MRS).
- Identification of the reference season: winter, mid-season or summer regimes; the algorithm applies different numerical schemes for different regimes.
- The extrapolation of future consumption levels is based on consumption variations already recorded on previous days, resulting in an increase or decrease in consumption compared to similar days

recently recorded (these are differential forecasts that are related to the amount of consumption increase or decrease, and not referring to absolute consumption value per se). For example, to predict consumption on the following Sunday, you have to start from the consumption recorded on the most recent Sunday of the year, and the possible variation in consumption levels compared to the reference day is estimated on the basis of climatic, seasonal or calendar conditions. Obviously, if the forecast weather for the following Sunday is colder than the one recently recorded, the forecast estimates an increase in gas consumption for that day. Working on differential consumption forecasts returns more precise results and mitigates the impact of the continuous changes in the network, which could result in new users being connected or disconnected.

- The hourly consumption forecast in the following 5 days is carried out by the calculation algorithm in two steps: first, the average daily consumption of the network is forecasted for each of the next 5 days, then the consumption trend is forecast hour by hour by applying consumption curves measured in similar days.
- Finally, before proceeding to the future state simulation or test simulations (type 2 or 3), a safety coefficient is applied to the forecast consumption value by the internal forecast algorithm. This determines an increase of the consumption values used in the simulation. This coefficient is used to compensate for the overall approximation of the consumption forecast levels which actually derives from the sum of two factors, in favour of safety. The first is intrinsic in the calculation method itself, the second derives from the temperature forecast on which the calculation method is based, having its own margins of uncertainty. The overestimation of consumption levels appears justified by the operating purpose of the Sim-On Gas system.

During current state simulations (type 1) no safety factor is applied, but the real recorded demand (not generated by the forecasting algorithm) is imposed instead.

In short, Sim-On Gas is able to automatically produce a demand forecast (hour by hour and for a maximum of 5 future days) with a reasonable safety factor, thanks to its connection to the remote monitoring system and to a weather forecasting service. We must not forget that demand is the fundamental variable for a careful real-time use of the system in future time frames.

The graph in Figure 6 shows an example of a consumption forecast produced by the internal Sim-On Gas algorithm. On the left side the line shows the observed gas demand level (measured by the remote monitoring system) in the recent past, while on the right side you can see the demand levels expected by the algorithm and those adjusted through the application of the safety coefficient.

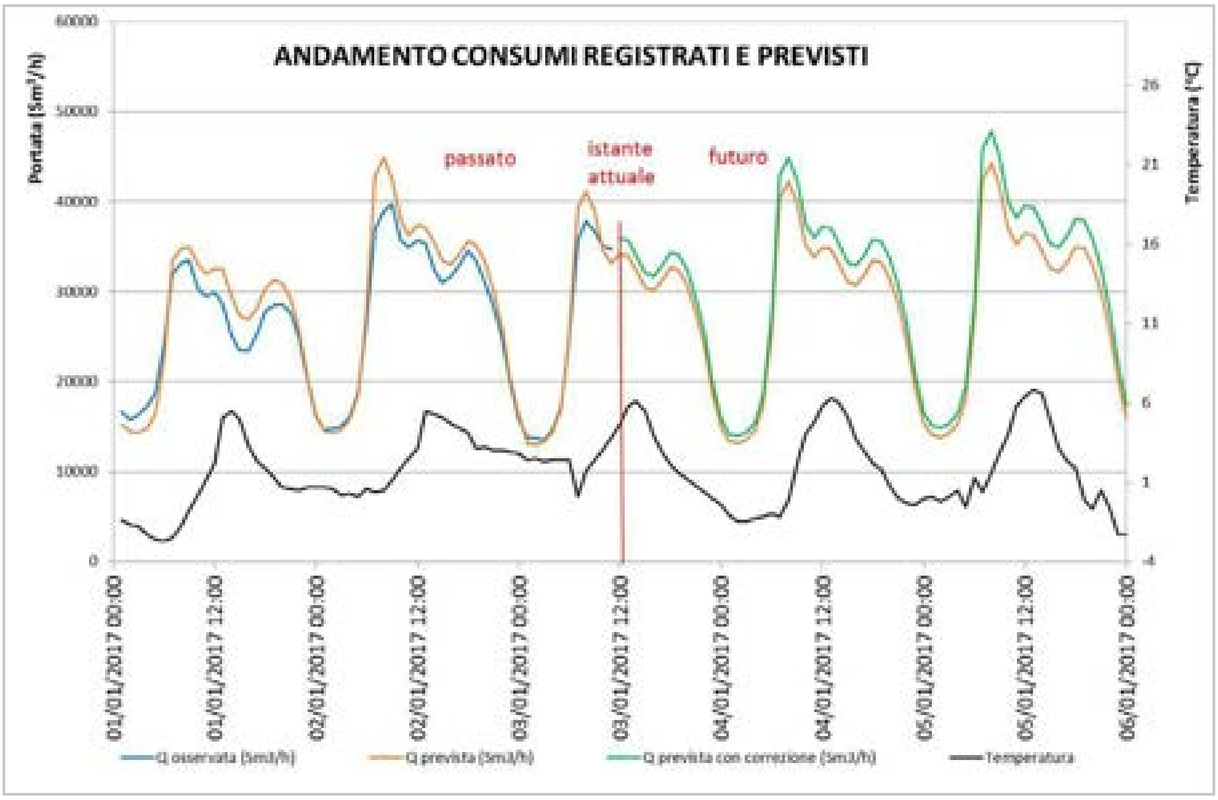

Figure 7: Trend in recorded and predicted demand as a function of temperature

Maximum network stress

The current state simulation (type 1) automatically takes place at regular intervals and refers to a single well-defined time instant. Forecast future state and test simulations (type 2 and 3) refer instead to a series of time instants contained in future time frames, i.e. having a start and end date and time. For the latter two types of simulation Sim-On Gas returns a predicted result representing the maximum stress on the network during the entire time period, also taking into account the safety coefficient introduced in the consumption forecast. It is therefore important to define in detail the way in which the maximum stress on the network is evaluated within the defined time frame.

Some examples will be used to illustrate how to evaluate the maximum stress level.

Example no. 1

Let's assume that it is 01/01/2019 at 00:00 and an updated weather forecast has just become available. The Sim-On Gas algorithm immediately produces a forecast of the total demand pattern for the next 5 days applying an additional safety coefficient in the forecasts, as described.

Let's also assume that the automatic simulation of future state (type 2) is configured to predict the maximum stress level in a future time frame of 3 days (please note that the extension of the consumption forecast is made over a 5 day-period while the simulations of future state have an extension that can be configured by the user and must be of 5 days at most).

Sim-On Gas starts 72 independent simulations, each one producing a distinct result for a certain date/time.

Figure 8 below shows the general consumption trend expected (blue line) for each hour, for an overall time frame of 72 hours (vertical lines are drawn at hourly intervals).

Then, let's suppose that in the network there is also a large industrial consumer who has an intermittent consumption level active between 17:00 and 22:00 every day, and that this consumer has a regular behaviour (red line in the graph). It should be noted that the blue line represents the total demand of the network, including the industrial consumption mentioned above. The rest of the demand amount (difference between total demand (blue line) and industrial consumption (red line) can be classified as "ordinary", which is the category of demand prevailing in the network.

By analysing the data in this example, the moment of maximum demand level is expected at 08:00 on 03/01/2019, but the numerical analysis produced by Sim-On Gas does not consider this as the only moment of maximum network stress just the one for which the maximum consumption level in the system is expected. To be rigorous, it is also necessary to include in the simulation the time instants corresponding to the maximum industrial consumption level, when heavier fluid-dynamic pressure drops can be generated at a local level in the industrial area, which may not have the same significant consequences at a general network level. So, especially when the base model includes substantial industrial users, we should consider that in some areas of the network the conditions of biggest stress could occur as a result of a localised activation of industrial consumption and not necessarily at the time of maximum overall consumption of the whole system.

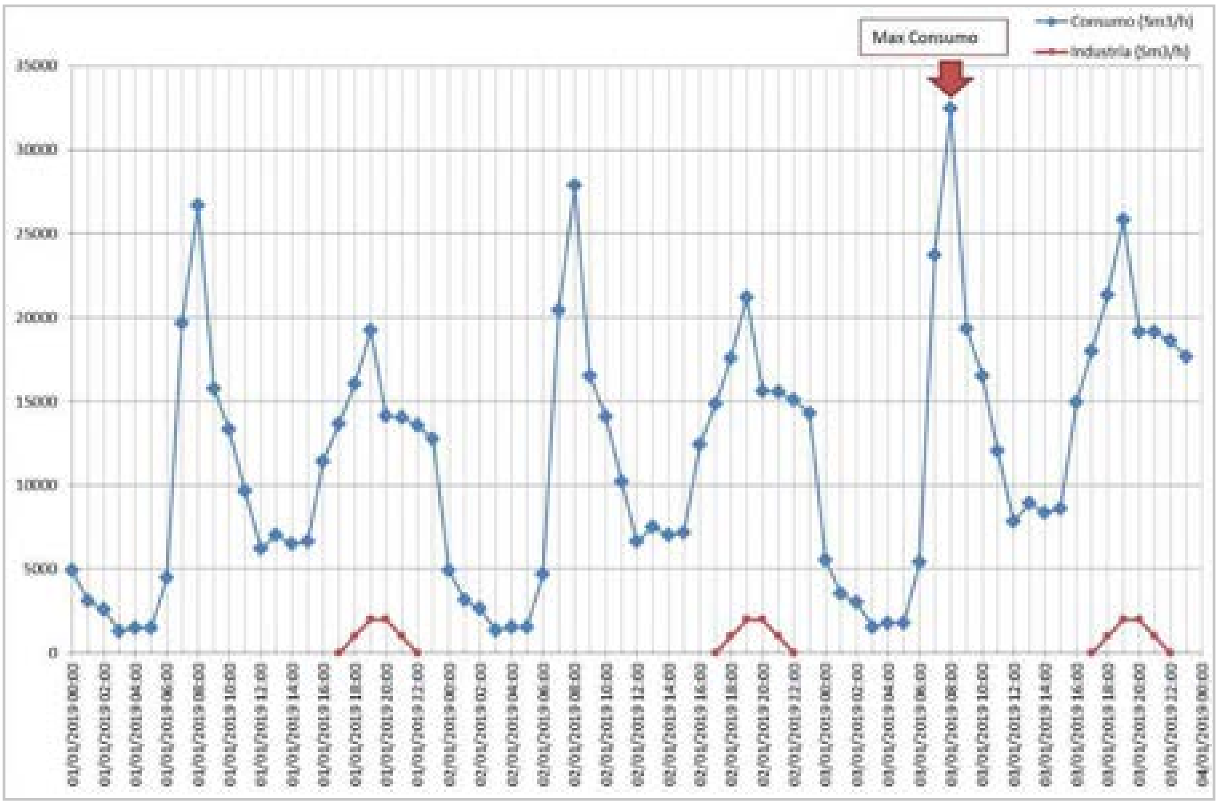

Figure 8: Demand trend as illustrated in example no. 1

The general approach used by the Sim-On Gas calculation algorithm consists of analysing all the conditions that may occur. In this case, the results of 72 simulations, one for each hour of the period under consideration, so as to include all the possible combinations of local industrial demand that may generate more unfavourable expected pressures at different times of the interval being analysed in some areas of the network.

In all probability, the moment of maximum stress for most elements of the network corresponds to the moment of maximum total flow (in this example, 03/01 at 08:00); however, it may happen that in some zones closer to industrial areas, the moment of maximum stress is reported, for example, at 19:00 on 03/01.

As mentioned above, the Sim-On Gas user interface reports a single plan result, which shows the envelope of the maximum stress levels, and so:

- for each node, the minimum pressures with their expected dates and times;
- for each pipe, flow rates and maximum speeds with their expected dates and times;
- for each MRS and GPR, the maximum flow rates delivered with their expected dates and times.

Example no. 2

Let's now assume that during the 3 days under examination, from 00:00 on 01/01/2019 to 23:00 on 03/01/2019, the effect of a closed valve for 12 hours, from 08:00 to 20:00 on 01/01/2019, has been forecast in a previous approved tests simulation (test 1). Figure 9 helps you to see the situation described here.

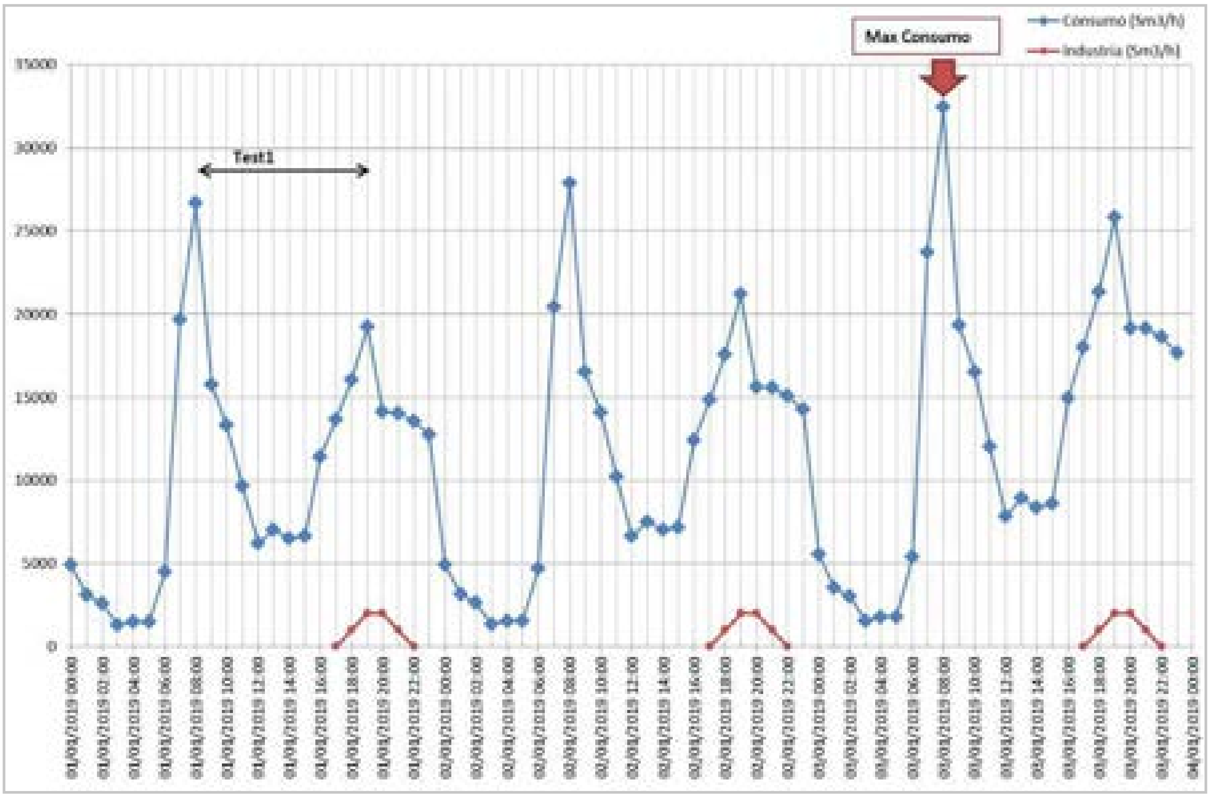

Figure 9: Consumption trend as illustrated in example no. 2

In this case, being able to define in advance what the moment of maximum stress on the network could be is even more complex, and we need to perform all the 72 simulations to determine the most critical conditions for each element of the network.

The 72 simulations are launched by taking into account the overall trend expected for consumption, the presence of localised industrial consumption levels and the presence of the closed valve during the expected period of closure.

The maximum stress conditions represented in the Sim-On Gas plan view as a result of the simulation in the future time frame do not refer to any of the individual simulations performed, but return a combination of all the performed simulations. In some areas of the network, presumably next to the closed valve, we can expect that the maximum stress occurs in the simulation of 08:00 hours on 01/01, while in other areas it is likely that the biggest stress level occurs at 08:00 hours on 03/01.

Example no. 3

Finally, let's assume that during the 3 days under consideration, from 00:00 on 01/01/2019 to 23:00 on 03/01/2019, different conditions are forecast in two previous approved test simulations (see Figure 10):

- the presence of a closed valve for 12 hours, from 08:00 to 20:00 on 01/01/2019 (test 1) as in the previous example;
- the presence of a by-pass for 24 hours, from 14:00 on 01/01/2019 to 14:00 on 02/01/2019 (test 2).

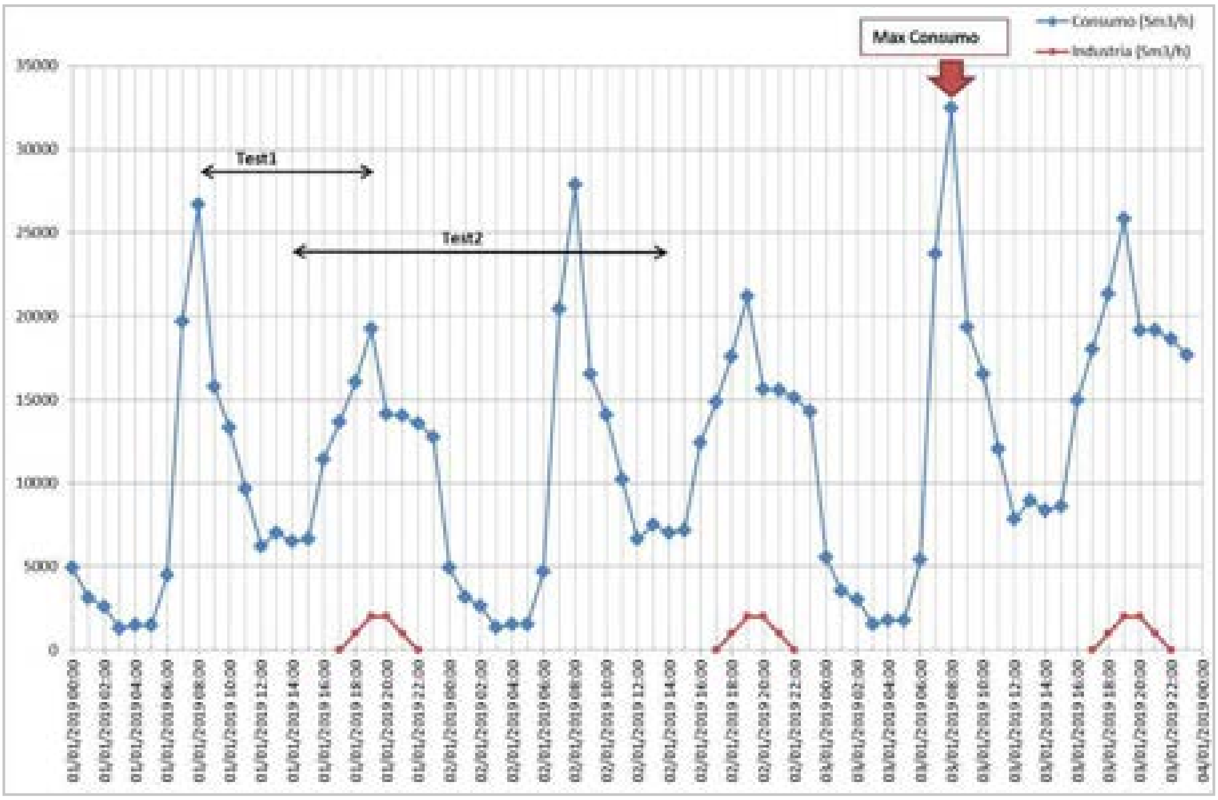

Figure 10: Consumption trend as illustrated in example no. 3

It is not possible to define the moment of maximum stress on the system for the entire network in advance.

The calculation process analyses the results of all 72 simulations and returns a map of the most critical conditions for each network element using the technique already described. It is clear that between 14:00 and 19:00 on 01/01 both the extraordinary state conditions of the network are considered, active and overlapping.

The above examples refer to future state simulations (type 2) which, as described, are automatically started every 6 hours by Sim-On Gas. The simulations launched in series typically take several minutes to complete and make the predicted result available; this mechanism is repeated for each of the networks loaded on the Sim-On Gas platform, and therefore tens or hundreds of simulations could be triggered at the same time.

All future state forecast simulations (type 2), automatically generated every 6 hours, are always saved for future reference. Users can access the previously generated results whilst type 2 simulations (which are updated to the new weather forecasts) are in progress. The new results are likely to be similar to those previously generated as the only variable that has changed is the weather forecast, from which a slightly different condition of expected temperature, and therefore gas consumption levels, could derive.

A test simulation (type 3) is carried out on request, e.g. for a change in conditions for a particular emergency or because the user is working on a tablet in the field, and therefore the user must wait for the overall result of the analysis.

Variations of state in elements not monitored remotely

In some gas distribution networks management changes are planned, normally during seasonal changes, such as the closure of some valves (perhaps to deactivate a MRS) or new pressure settings on GPRs.

The real-time model must obviously reflect these management changes and since this type of information is not normally remotely monitored, a simple mechanism of variation needs to be included in the basic model.

These are not state changes that can be treated as functional tests because:

- they are prolonged for long periods (even months);
- they may require multiple actions, such as adjusting dozens of GPRs, which is impractical in the Sim-On Gas interface.

In this case Sim-On Gas presents a window where you can easily make these state changes at the request of a system administrator. These changes affect the activation date in the future and will trigger an immediate activation of type 2 simulations.

Only valve closures (which must already be present in the basic model) and changes in GPRs or MRSs settings are allowed. Obviously, if pressure settings are available for remote monitoring the system would automatically adjust.

Any other changes to the basic model require the basic model generated by the off-line system to be re-uploaded.

Accessing Sim-On Gas

You can access Sim-On Gas via a web browser by accessing the address of the LAN server hosting the system.

Sim-On Gas requires you to enter your login credentials (username and password). The system administrator can assign users to one of three possible access levels:

- System Administrator: this profile can load new networks to the system, configure system options, access settings and results of automatic simulations of actual and future states (type 1 and 2), start test simulations (type 3) and view the results. The administrator can delete test simulations (type 3) already approved by any user.
- Power User: this profile can access type 1 and 2 simulations and launch type 3 simulations. These users can delete their own tests (type 3 simulations) which have already been approved and previously started. This user cannot delete tests approved by other users.
- Base User: this profile can access type 1 and type 2 simulations and view approved tests. This user cannot perform type 3 simulations.

Connection to the remote monitoring system

The connection of Sim-On Gas to the remote monitoring system is customised by evaluating the technical characteristics of the software solutions used in the company's system. For example, some formats that are likely to be accessible are:

- text files (CSV, txt or others);
- DB, SQL Server-type;
- DB, Oracle-type.

For any case, the best data acquisition strategies will be evaluated by the software supplier.

It should be remembered that the fundamental data for real-time simulations is the MRSs inflows (measured flow rates) trend, since it is on this information that the evaluation of the system's total demand is based. Other useful data, even if not essential, is the outlet pressures of MRSs and GPRs and the pressures measured at representative points on the network. Finally, you can connect the flow rates provided by any remotely readable meter to the system to include in fine detail the most significant consumption values in the simulations.

In order to produce effective and representative real-time simulations, SCADA data has to be available and of good quality and transmitted in a prompt and regular manner.

Sim-On Gas is able to manage any lack of data by extrapolating from previously acquired data.

The possible options for how Sim-On Gas behaves when data is not available are described below.

First of all, the ranges for which the values to be considered as reliable are defined:

- MRSs flow rates cannot be negative (small negative numbers are accepted and treated as zero);
- for some MRSs, maximum values that are considered to be reliable can be set;
- negative numbers are not allowed for pressure measurements, and numbers above a certain value defined by the user are not allowed.

Lack of data for Type 1 simulations

As previously described, in order to have a reliable type 1 simulation you need to have all the remotely monitored variables available. If a variable is not available, Sim-On Gas waits for their complete availability. Request attempts will continue until all the required data has been acquired. If for any reason (e.g. transmission problems for remotely monitored data) it is not possible to acquire information on the flow rates delivered by the MRSs at the programmed time, the simulation is carried out using the total demand provided by the Sim-On Gas system, after informing the user of this approximation. This option only remains valid for a few hours, after which in the absence of the delivered flow rates, the system interrupts the calculation due to lack of data. Any lack of pressure data from the field is reported, but the simulation continues by extending the last recorded value.

Type 2 and 3 Simulations

Type 2 and type 3 simulations take place in future time frames, so measured flow rates and pressures are not known.

The pressures at the definition points of the boundary conditions of the model (controlled MRSs and/or GPRs) are extrapolated from the last available and valid value read by the SCADA.

In order to produce a forecast, it is essential that a reliable weather forecast is available. The weather forecast system is updated every 6 hours and it is very unlikely that the service will be unavailable as long as there is an available Internet connection. Sim-On Gas will always use the latest available consumption forecast derived from the latest available weather forecast and from valid MRSs inflow from previous days.

If the system does not receive this information for several hours, the consumption forecast will no longer be possible and therefore no simulations will be produced.

Sim-On Gas interface

The Sim-On Gas user manual, available separately, is the reference document for all detailed information relating to the use of the software tools. Sim-On Gas has been designed for immediate use from any device connected to the internet (PC, tablet).

Users can select the network to be analysed, automatically accessing the most recent automatic simulation of the current state (type 1) available in the system.

With a simple command, users can switch to the display of the results of the future state conditions (type 2 automatic simulations) of the same network.

An enabled user wishing to carry out a test (type 3 simulations, on request) can quickly select the operation to be tested, choosing it from the options available in the interface (closures, by-passes etc.) for each element of the network.

The following figure shows an example of the user interface.

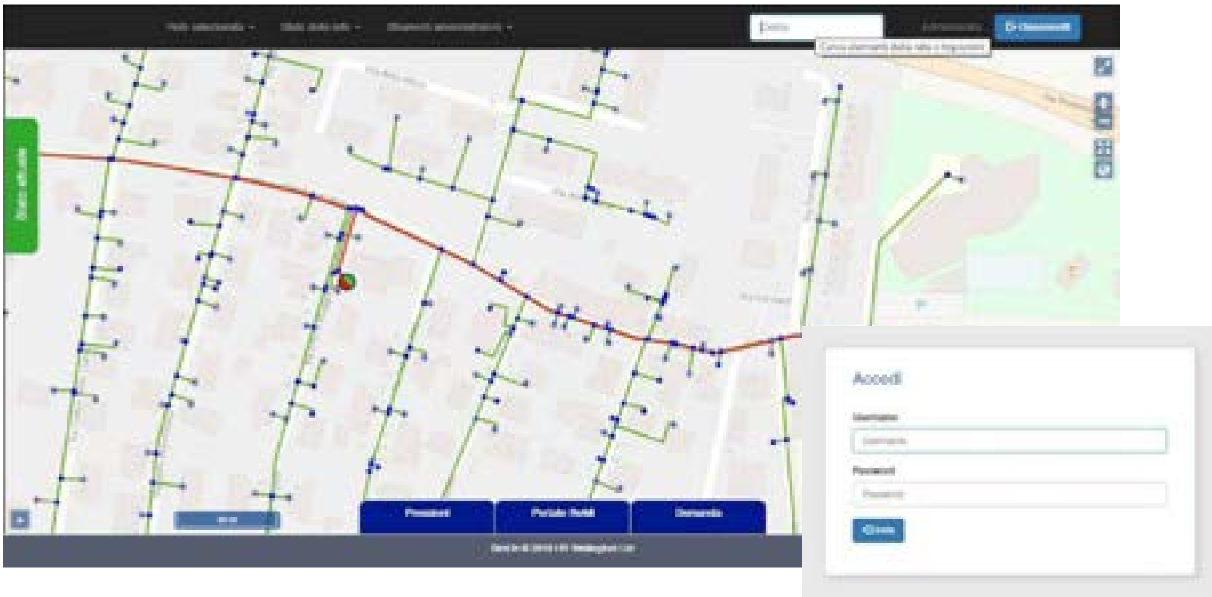

Figure 11: An example of user interface

Graphs

The main view of the Sim-On Gas user interface is the plan view of the results from completed simulations. Various graphs are also available which show the trend of the fluid dynamics variables over time.

- **Calibration graphs**

  For each monitored network point (flow rate or pressure) which is not used as a forced boundary condition of the system, you can produce graphs comparing the values provided by the model (only in current state simulations – type 1) and the measurements acquired by remote monitoring.

  For example, pressure graphs can be produced at upstream points of GPRs or at strategic points in the distribution network where a measurement is available.

  Any anomalies in the modelling results compared to the measured values can be reported in the form of specific alarms to be sent to the person in charge of the modelling system. Figure 12 shows an example.

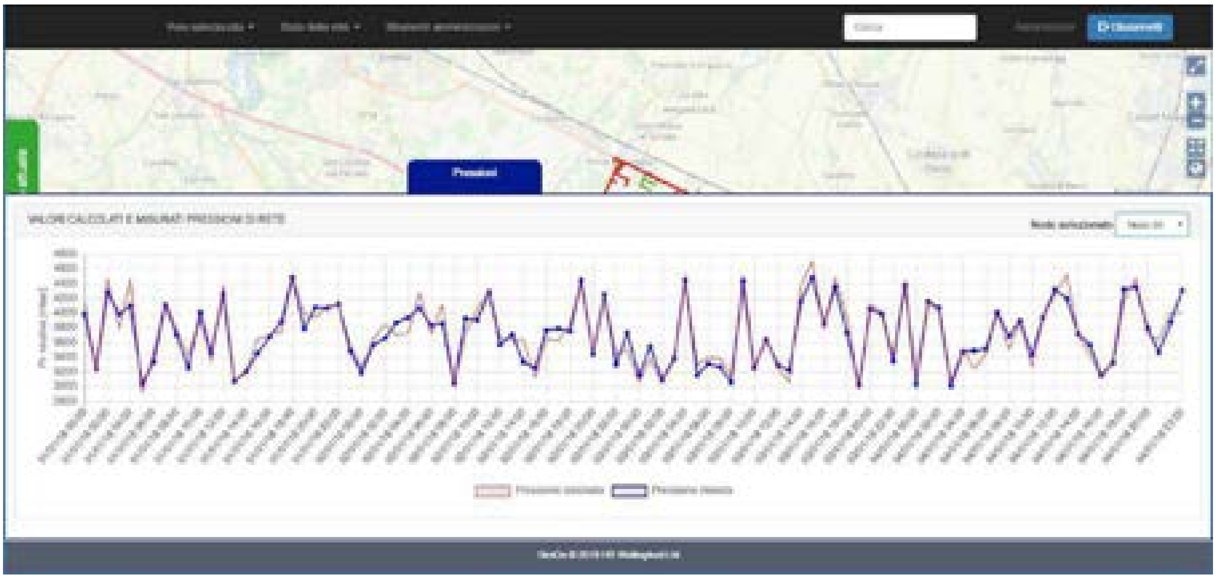

Figure 12: An example of a model calibration graph

- **Demand forecast charts**

  You can view the demand forecasts made by the Sim-On Gas system and compare them to the values actually measured ex-post.

  It is possible that large underestimates generated by the demand forecasting system are considered as alarm signals, to be sent to the person in charge of the modelling system for further investigation.

Base network model

The gas network models which are developed in the InfoWorks off-line calculation system can currently be published immediately on the Sim-On Gas platform. Where basic models produced with other gas calculation software are available, a specific case-by-case evaluation will be carried out, to assess whether these models can also be published on Sim-On Gas.

For InfoWorks users, a script has been set for exporting the model which allows for the immediate and automatic creation of the files required for publication on the online Sim-On Gas system.

All models to be published in the system need to be well-maintained and representative of the modelled system.

We recommend that all the necessary parameters for the evaluation of the network in real-time are included in the base model. For example, it is essential to carefully define the parameters of maximum permissible flow rate values for MRSs and GPRs, as well as the required upstream pressure necessary to the GPRs in order to not trigger a function block.

In the Sim-On Gas system administrator's manual you will find specific details on these topics.

Automatic alarms

The results of the automatic simulations can highlight critical situations for the network, due to predefined alert thresholds being crossed, for which a timely warning system for expected/ongoing problems is available. For each system published on the Sim-On platform you can define the e-mail addresses of the technical managers of that network, to whom alarm e-mails can be sent.

Alarms can be triggered by the following types of events:

- In the current state simulation (type 1) the pressures at one or more nodes of the model result in a minimum admissible threshold value being crossed. The threshold value is predefined by the user in the calculation system for each type of network.
- In the current state simulation (type 1), the maximum flow rates indicated in the basic model for the MRS and for the GPRs are exceeded, or the latter are in functional block due to insufficient upstream supply pressure.
- In the future state simulation (type 2), the pressures at one or more nodes of the model result in a minimum admissible threshold value (defined by the user) being crossed.
- In the future state simulation (type 2), the maximum flow rates indicated in the basic model for the MRS and the GPRs are exceeded, or the latter are in functional block due to insufficient upstream supply pressure.
- Discrepancy of the flow forecasting system, when this discrepancy exceeds a certain average squared deviation or deviations from predefined instantaneous values.

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