DECISION MAKING SOFTWARE FOR GAZ DE FRANCE
DISTRIBUTION NETWORK OPERATORS: CARPATHE

C. Chauvelier-Alario
B. Mathieu

Gaz de France
Direction de la Recherche
France

C. Toussaint
Gaz de France
Gaz de France Réseau Distribution
France
ABSTRACT

Gaz de France distribution networks are highly meshed and made of large numbers of equipment, which renders their behavior difficult to anticipate intuitively. In order to assist the operators to make decisions on maneuvers to be carried out in the field depending on their consequences on the network (consequences such as the number of customers set out of gas), Gaz de France has been using for the past ten years, a software: CARPATHE to assist the piloting of networks, software developed by the R&D Division (Direction de la Recherche) of the Group Gaz de France. The new version of CARPATHE (V5), presented in this paper, covers a much larger spectrum of functionalities than its predecessor which was limited to one pressure level and design network functionalities. CARPATHE V5 simulates the behavior of multi-pressure networks and includes functionalities for both network design and network operation.

The purpose for network operators of such a software is twofold: anticipating the consequences of maintenance work to be done on the network (gas supply interruption for maintenance for example), and being able to set the network in security in order to avoid damages to people and assets in case anything should happen. The stakes for the software to be operational lie in its user-friendliness and its efficiency to bring answers allowing the operator to make the most appropriate decisions on what to operate in the field while bringing him awareness on all the consequences.

The specific functionalities for network operators implemented in CARPATHE correspond to actions the network operators face in their function:

- Search for specific points to intervene (valves, regulators), equipment that can allow to isolate parts of the network,
- Operating some equipments and evaluate the impact on the rest of the network gas supply,
- Take into account in network calculations real temperature conditions,
- Evaluate the survival time of the network in case of decrease in gas supply and deduce the associated reduction supply plan.

CARPATHE, thru these functionalities, is a decision making software essential for network operators who need to optimize security and economical aspects for every situations faced in their function.
TABLE OF CONTENT

Decision making software for Gaz de France Distribution network operators: CARPATHE ............ 1
Abstract................................................................................................................................. 2
Table of content.................................................................................................................. 3
Context ................................................................................................................................ 4
Software requirements ....................................................................................................... 4
Added value of the software for decision making.............................................................. 5
   Graphical representation.................................................................................................. 6
   Isolate part of the network .............................................................................................. 6
   Anticipate actions on the network .................................................................................. 6
   Estimated survival time of the network ......................................................................... 6
Conclusion............................................................................................................................ 7
List of figures ....................................................................................................................... 8
   Figure 1: CARPATHE interface : simulation results .................................................... 8
   Figure 2: Isolate a part of the network with CARPATHE ............................................ 9
   Figure 3: Impact of a maneuver on the entire network ................................................ 10
   Figure 4: Setting up for survival time .......................................................................... 11
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CONTEXT

Gaz de France distribution networks are defined and operated as entities named ‘exploitations’ which start with the transmission delivery pressure reducer to the final individual customers. These ‘exploitations’ include pressure levels ranging from Medium Pressure (MP) at 16bar\(^1\) down to Low Pressure (LP) at 21mbar. They are highly meshed and vary in size from several hundreds pipes to several ten-thousands of pipes depending on the size of the city the distribution network covers. The increasing size and complexity of the networks, lead Gaz de France to set at the operators disposal a software to help the decision process. This tool, CARPATHE, addresses specific requirements tied to the public service obligation of Gaz de France as well as security of people and equipment.

For the last 10 years, Gaz de France provides its distribution network operators with tools able to assist them in piloting networks. The software assists the operators to make the most appropriate decisions on maneuvers to be carried out in the field depending on their consequences on the network (consequences such as the number of customers put out of gas). In order to provide the operators with a software that is both easy to use and fast in giving results, CARPATHE does network simulation in steady state conditions.

The entire software CARPATHE, in its version presented in this paper, covers a much larger spectrum of functionalities than its predecessor. While its predecessor only dealt with one pressure level networks and provided only network design functionalities, CARPATHE V5 simulates the behavior of multi-pressure networks and includes functionalities for both network design and network operation. Only the functionalities specific to network operators will be addressed in the present paper.

SOFTWARE REQUIREMENTS

The largest part of the distribution network managed by Gaz de France Réseau Distribution runs at middle pressure levels. This requires to make decisions on how best to operate the network (what equipment to maneuver for example) as fast as possible. The speed of the software, its ease to use and to interpret its results are very strong requirements for Gaz de France.

The final users of the software are highly trained professionals in gas network operation and have a very good knowledge of the nominal behavior of the network they are in charge of. However, in case of temporary configuration of the network such as maintenance act requiring gas interruption on the distribution network, incident caused by a third party, or decrease in gas supply due to maintenance acts on the upstream transmission network, the operators in charge need an ergonomic tool. CARPATHE was designed to meet this ergonomic requirement as well as the functionalities needed in such circumstances, and of course with response time as short as possible.

To be effective, such a software needs to provide robust results in a very short time on highly meshed networks, in real field conditions (temperature, day type, ...) within a mouse click. Most of the time, the final decision needs several successive hypothesis, which need to be evaluated in terms of impact on the network operation (number of clients put out of gas, for example).

In order to run such a software, the following data need to be available:

- description of all the equipments in the field that are pertinent to model (pipes, valves, pressure reducers, ...) ;
- gas properties;
- consumption data.

Gaz de France Réseau de Distribution (GRD), the entity in charge of the distribution network management and EDF Gaz de France Distribution (EGD), the entity in charge of operating the electric and gas distribution networks are in the process of rolling out their new geographical information system (GIS) which includes all these data. The model within the GIS was designed so that once exported from the system, the data did not need any additional work to be used by a network simulation software. Along with the equipment description such as diameter, length, material for pipes, the information on the network topology is present in the GIS model. Also, the consumption data are

\(^1\)1bar = 100kPa
related to the network data. Consumers are divided into two types: large customers and current customers. Depending on their type, their representation in the GIS model differs. Large customers are singularized as a specific object, they can have very specific consumption profiles and they may have specific requirements in terms of gas interruption for example. The category of current customers groups both tertiary customers and individual customers. Their consumptions are aggregated by pipes without creating an object for each of these customers.

For all these customers, their gas consumptions available in the GIS contain enough information so that the gas consumption on the network can be evaluated at any temperature, any day of the year. This is a strong requirement for the software to be a valuable assistant to decision making for the operator in charge of the network, allowing him to assess the consequences of any maneuver on his network any day of the year.

There are two essential pre-requisites for such a tool to be appropriate and well accepted for the network operators:
- the quality of the data: the up-to-date and proper description of the equipments in the GIS are essential;
- the appropriate behavior simulation of complex equipments such as the pressure reducers

Without these two requirements, the operators tend to be very reluctant to trust the results obtained by the software as its results are not coherent with the nominal behavior of their networks.

**ADDED VALUE OF THE SOFTWARE FOR DECISION MAKING**

Even though, the operators in charge of the distribution networks are highly trained professionals, the increasing size of the networks they are in charge of and the increased complexity of the networks, require to assist them in operating the network when facing non nominal configurations. Moreover, the simulation tool is a very good training tool to thoroughly understand and determine the behavior of a network when not familiar with it. As such, CARPATHE is used by the future network operators to practice on how to operate the networks.

Within the new configuration of the distribution GIS, CARPATHE receives updated data directly from the GIS, which corresponds to the network that is actually in gas in the field. As the data model in the GIS is ready to describe computable models, no configuration work needs to be done on the data once exported from the GIS.

The ergonomics of CARPATHE is strongly based on graphical restitutions even though specific and local information can be obtained on any equipment. In particular, it allows the users to identify very rapidly:
- the parts of the network where gas supply is insufficient;
- the parts of the network where the pressure level is insufficient, with respect to a fixed value called the Minimum Pressure of Service$^2$;
- the number of large customers as well as the number of regular customers who have their gas supply stopped.

The networks are properly designed by the design offices so that they can hold properly to very low temperatures (the designed temperatures used in Gaz de France correspond to the lowest temperatures that occurred twice in the last 100 years)

In the network operation context, the elements easily identified on the graphical user interface$^3$ are used when simulating non nominal configurations of the networks. This can occur when:
- gas supply decreases due to maintenance acts on the upstream transmission network;
- maintenance act requiring gas interruption on the distribution network,
- incident on the distribution network caused by a third party, for example.

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$^2$ Minimum Pressure of Service : PmS
$^3$ Graphical User Interface : GUI
When simulating the behavior of a network under specific circumstances, the obtained results are compared with the PmS values fixed for each pressure level on the pipes and nodes within that pressure level. Any pipe or node that has a pressure below the PmS will appear colored in red in the results restitution, while the others will remain colored as defined by the user (see Fig. 1). In the case presented on the figure, the simulation in the appropriate specific temperature conditions showed that a part of the network was not sufficiently supplied in gas.

One of the most frequently used functionality of the software is the search for equipments such as valves or pressure reducers needed to be operated in order to set a part of the network out of gas. The circumstances of this type of search can be the need to maintain a piece of equipment in a given street, or an incident caused by a third party on some equipment. Figure 2 shows the behavior of the software in such a case. The part of the network to isolate is circled in orange. CARPATHE is used to identify the equipments that needs to be operated in order to get the pipe in this street to be isolated. The valves to close are identified on the window on the left hand side of the figure, and are represented on the network in dark. The user can then run a simulation and determine the impact of these maneuvers on the rest of the network under the real conditions (temperature and day). Figure 3 shows the result of this simulation on the entire network. As shown in figure 1, CARPATHE shows the part of the network that is below the PmS and where gas supply is going to be interrupted if these maneuvers are actually realized in the field. The entire northern part of the network is not properly supplied in gas, which is a behavior fairly difficult to anticipate without a simulation tool.

CARPATHE provides the operator in charge of the network not only with the pipes that are out of gas (in red on the graphical restitution), but also a list of the streets (information carried by the object pipe) and the number of clients affected by this operation.

In the case shown, as such a large part of the network is under the PmS, the network operator may have tried another hypothesis for calculation: squeezing the PE tube in order to decrease significantly the number of customers not supplied of gas. This is just an observation, as squeezing a tube may not be the first choice action in the field as it requires to dig in order to intervene directly on a pipe.

The software is currently used when planning maintenance or specific acts on the networks. Most of the acts on the network are performed with the network under pressure. For example, when installing a new customer connection, the network remains under pressure. However, before performing this type of installation, the network operator runs the software in order to identify the valves to operate in case the network has to be put out of gas. This approach reinforces the security of all actions performed on the networks.

Another functionality that is currently used by the network operators relies on the type of contract Gaz de France established with some of its large customers. Some gas customers own other means of energy production and even though their primary energy supply is gas, in case of shortage in gas supply on the network, they can be set out after being informed. Such customers are clearly identified in the GIS system and this information is exported along with all the other characteristics of the network to simulate. CARPATHE can simulate the shortage of gas supply (maintenance on the upstream transmission network, for example) by letting the operator setting the flow at the available value (Figure 4 (a)). Using this information and approximating a pseudo-dynamic behavior (the difference between transient simulation and static simulation was evaluated to be less than 20%), CARPATHE evaluates an approximate survival time of the network (time during which the network can sustain its load with the decrease gas inlet. On the given example (Figure 4 (b)), this time is 2 hours and 28 minutes. If the maintenance act on the transmission network requires 3 hours, this time can be set up. CARPATHE will then provide the operator with a list of large customers who can be put out of gas in order to keep the rest of the customers with the proper level of gas pressure and flow (Figure 4 (c)).
CONCLUSION

As shown in this paper, CARPATHE is an efficient tool for network operators in assisting them in the decision making processes they face in operating their networks. Even though, they are highly trained professionals in gas network operation and have a very good knowledge of the nominal behavior of their networks, the complexity of the latter does not allow them to anticipate its behavior in cases of temporary configurations. The strong pre-requisites for the operators to trust such a software are the data quality and the appropriate model of the equipments.

Moreover, the software is a very good training tool for new network operators to acquire a good knowledge of the network and its behavior once they will be in charge. They practice operating the network using the software.

Finally, some of the functionalities included in CARPATHE for network operators turned out to be used to plan network reinforcements as it helps anticipate and identify weak parts of the network.
LIST OF FIGURES

FIGURE 1: CARPATHE INTERFACE : SIMULATION RESULTS

Results of a network calculation: the part colored in red shows the network that is not properly supplied in gas, the rest of the network (green for LP and blue for MP) is properly supplied.
**FIGURE 2: ISOLATE A PART OF THE NETWORK WITH CARPATHE**

The part of the network to isolate is circled in orange. The valves to close are identified on the window on the left hand side and represented on the network in dark.
FIGURE 3: IMPACT OF A MANEUVER ON THE ENTIRE NETWORK
After closing the valves identified previously, and running a simulation in the real condition (temperature and day), the network operator gets the behavior of the entire network.
FIGURE 4: SETTING UP FOR SURVIVAL TIME

(a) Set up the available gas flow: 100 m$^3$/h instead of the required 272.626 m$^3$/h

(b) network survival time. CARPATHE evaluates the time the network can sustain its load with the decreased gas inlet: 2h 28min 40s. If the maintenance on the transmission network requires 3 hours, the user can set up that required time.

(c) the list of customers who can be put out of gas is provided in order to keep the rest of the customers with the proper level of gas pressure and flow.