Is the gas N-1 standard of the EU Regulation a good indicator of the security of gas supply of a country?

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ABSTRACT

The EU Regulation No. 994/2010 on security of gas supply requires Member States to comply with the infrastructure standard or so called N-1 standard. The Regulation provides the N-1 formula which should give a result equal or greater than 100% to ensure the compliance with the standard. The N-1 formula is used to estimate whether the gas infrastructure of the country or area of study has enough technical capacity as to satisfy the total gas demand in the event of disruption of the single largest gas infrastructure during a day of exceptionally high gas demand occurring with a statistical probability of once in 20 years.

In this paper the N-1 standard as defined in the EU Regulation has been compared with the simulation of the N-1 scenario with a hydraulic model. A hydraulic model of two designed countries has been developed and scenarios of disruption of the largest gas infrastructure of each country have been simulated in steady state under the same conditions. The N-1 formula and the N-1 scenario results have been compared for the two countries and for the case that the two countries operate as a region that shares their gas resources. The difference between considering a single country or a region and between estimating the standard with the N-1 formula or with the N-1 scenario will be shown.

1. INTRODUCTION

Regulation (EU) No 994/2010[(1)] has been a piece of legislation enacting rules and standards to be applied by all Member States (MS) using natural gas in their energy systems. The Regulation has been the first establishing provisions aimed at safeguarding the security of gas supply in MS which must allow for exceptional measures to be implemented when the market can no longer deliver the required gas supplies.

Recently Regulation (EU) No. 994/2010 has been repealed by the Regulation (EU) No.

([1]) European Union (EU), Regulation (EU) 994/2010 of the European Parliament and of the Council of 20 October 2010, concerning measures to safeguard security of gas supply and repealing Council Directive 2004/67/EC, L 295/1. No longer in force.

2017/1938(2) concerning measures to safeguard the security of gas supply. The new Regulation came into force on the 1st November 2017 and entails an update and improvements of the previous one. Both, the old and the new Regulation, oblige Competent Authorities of MS to prepare and notify periodically to the European Commission their Risk Assessment (RA), Preventive Action Plan (PAP) and Emergency Plan (EP). The provisions of the RA include a full assessment of the risks affecting the security of gas supply of each MS by, among other things, running various scenarios of exceptionally high gas demand and supply disruption and assessing the Country compliance to the infrastructure standard (see article 5) and supply standards (see article 6). Both the PAP and the EP should be based on the results of the Risk Assessment.

The infrastructure standard is an indicator developed to describe the ability of the technical capacity of a gas infrastructure to satisfy the total gas demand, in a certain identified area, in the event of the disruption of the single largest gas infrastructure during a day of exceptionally high gas demand occurring with a statistical probability of once in 20 years (also called “1-in-20 daily peak demand”). The standard is calculated using the so-called N-1 formula (see Annex II of Reg. (EU) 2017/1938):

$$\mathrm{N-1\ (formula)[\%]} = \frac{\mathrm{EP_m + S_m + P_m + LNG_m - I_m}}{\mathrm{D_{max}}} \times 100 \qquad \text{Eq. 1}$$

Where ‘EP_m’ is the technical capacity of all entry points (in mcm/d) capable of supplying gas to the identified area during the reference period; ‘S_m’ is the sum of the maximum technical daily withdrawal capacity of all storage facilities which can be delivered to the system of the identified area (in mcm/d); ‘P_m’ is the maximal technical production capability (in mcm/d) of all gas production facilities which can be delivered to the identified area; ‘LNG_m’ is the maximal technical send-out capacity at all LNG facilities in the identified area (in mcm/d); ‘I_m’ is the technical capacity of the single largest gas infrastructure (in mcm/d) with the highest capacity to supply the identified area; ‘D_{max}’ is the 1-in-20 daily peak demand.

A MS is compliant with the infrastructure standard when the result of the N – 1 formula, as calculated using Eq. 1, is at least equal 100%.

Throughout the period of application of the Regulation (EU) No. 994/2010, from 2010 to 2017, it has been observed a high degree of reliance by many MS on the N-1 formula, which was used not only to discuss the infrastructure standard but also to inform supply interruption scenarios or the impact of the future evolution of supply and demand.

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(2) European Union (EU), Regulation (EU) 2017/1938 of the European Parliament and of the Council of 25 October 2017 concerning measures to safeguard the security of gas supply and repealing Regulation (EU) No 994/2010, L 280/1.

However the N-1 formula lacks in details and can drive to misleading conclusions when taking it as the main security of supply indicator. One limitation of the N-1 formula is that it describes the “maximum technical capacity” (i.e., maximum firm capacity) of the gas demand in the identified area, but fails to recognize the distinction between capacity and the physical availability of supply. The formula assumes that the gas flow entering at the entry points is able to reach all demand points regardless the pressure constrains associated to the supply and/or the demand points. Therefore the formula does not consider flows or contractual quantities of gas or internal bottlenecks. A second limitation is in the lack of consideration of the gas in transit. The Regulation does not specify if the transiting gas should be deducted and different approaches were adopted by the MS when assessing their compliance with the standard. A third limitation is linked to the term S_m, which represents the maximum withdrawal capacity of all UGS facilities. The formula completely ignores the changes of the maximum withdrawal capacity with the inventory level of the gas reservoir. Assuming that gas flows from the UGS facilities at maximum capacity implies that the gas inventory is full or almost full. This situation, if it happens, will be possible only at the beginning of the gas year when the injection season finishes and it will rarely happen at the time of D_{max}.

In order to overcome some of the limitations of the N-1 formula, Regulation (EU) No. 2017/1938 proposes to complete the analysis of the N-1 formula with the use of a hydraulic model to evaluate the consequences of the scenario of disruption of the largest gas infrastructure. A hydraulic model reproduces the topology of a gas network including all elements relevant for the transportation of gas, and includes all physical equations needed to correctly simulate the transport of gas (conservation of mass, of energy and of momentum and the equation of state).The assessment of the scenario N-1 with a hydraulic model shows if the gas system is really and physically able to cope with the disruption of the largest gas infrastructure, i.e. if the gas flow is able to reach all points where it is demanded at the right pressure. The parameters considered in the equation N-1 (scenario) represent actual gas flows within the limits of contracted capacity and agreed delivery pressures.

In this paper, we use a hydraulic model for a simulated gas grid comprised of two countries to study the infrastructure standard. In the first part, the N-1 formula is used to calculate the compliance of the two countries and the region with the provisions of the EU Regulation. In the second part, a steady state analysis of the gas network of the two countries has been carried out to simulate the disruption of the largest gas infrastructure in both countries and for the region (i.e., the N-1 scenario). Results obtained from the analysis of the N-1 scenario are compared with the results obtained with the N-1 formula in the last part of the paper.

2. EXAMPLE OF A GAS GRID TO EVALUATE THE N-1 FORMULA AND N-1 SCENARIO

In order to compare the results obtained with the N-1 formula and the N-1 scenario, the gas network of a region comprised of two neighbouring countries has been simulated (see Figure 1).

The largest gas infrastructure of Country 1 (C1) is an underground storage (UGS) facility located in a depleted gas field which has a maximum withdrawal capacity of 26 mcm/d (all volume values are considered at 0°C and 1 bar) when the inventory of the reservoir is full. Close by the UGS there is a production well with a maximum production capacity of 0.8 mcm/d. Country 1 has four entry points from third countries that are not part of the region. The entry point number one (EP1) has a maximum entry capacity of 25 mcm/d at normal conditions. The EP2 introduces a maximum technical capacity of 6 mcm/d and 4 mcm/d of entry capacity is associated to EP3. The fourth entry point of C1 can operate providing gas to C1 - the node is called EP4 - or sending gas to the neighbour– named EX1 in this case. The maximum technical capacity of EP4 (10 mcm/d) differs of the maximum technical capacity of EX1 (6 mcm/d), although gas is flowing in one or another direction through the same physical point. This particularity is due to the fact that the node EP4/EX1 brings gas from a third neighbouring country into Country 1 to be injected in the UGS facility during the summer season. In winter, the same point sends gas from Country 1 with a firm capacity agreed of 6 mcm/d maximum. Country 2 (C2) has two entry points, EP5 and EP6, with a maximum technical capacity of 24 mcm/d and 6 mcm/d respectively. In addition, a LNG terminal with a maximum send out capacity of 12 mcm/d completes the gas sources of the country. C1 and C2 share a cross-border point (CBP) that could work in reverse mode sending up to 5 mcm/d in either direction. Country 2 has a contractual agreement with a third neighbouring country to provide a maximum capacity of 10 mcm/d via the point named EX2.

Other facilities in the region are compressor stations. Country 1 has three – named as CS1, CS2 and CS3 - and Country 2 has two– CS5 and CS6.

The gas demand in both countries is mainly for households, commerce and industry. Nevertheless, Country 1 devotes 30% of the considered daily peak demand to feed four gas fired power plants (PP1, PP2, PP3 and PP4 in Figure 1) meanwhile Country 2 allocates 10% of the daily peak demand to two gas fired power plants (PP6 and PP5). It has been assumed that the gas flow needs to be delivered above a minimum pressure of 30 bar for the safe operation of all power plants.

Table 1 provides an overview of all parameters and technical requirements.

The demand considered in the analyses is D_{max} assumed to be equal to 39.8 mcm/d for Country 1 and 24.4 mcm/d for Country 2.

Figure 1. Map of the gas network of country 1 and 2 with the maximum technical capacity specified for each gas source and cross border point.

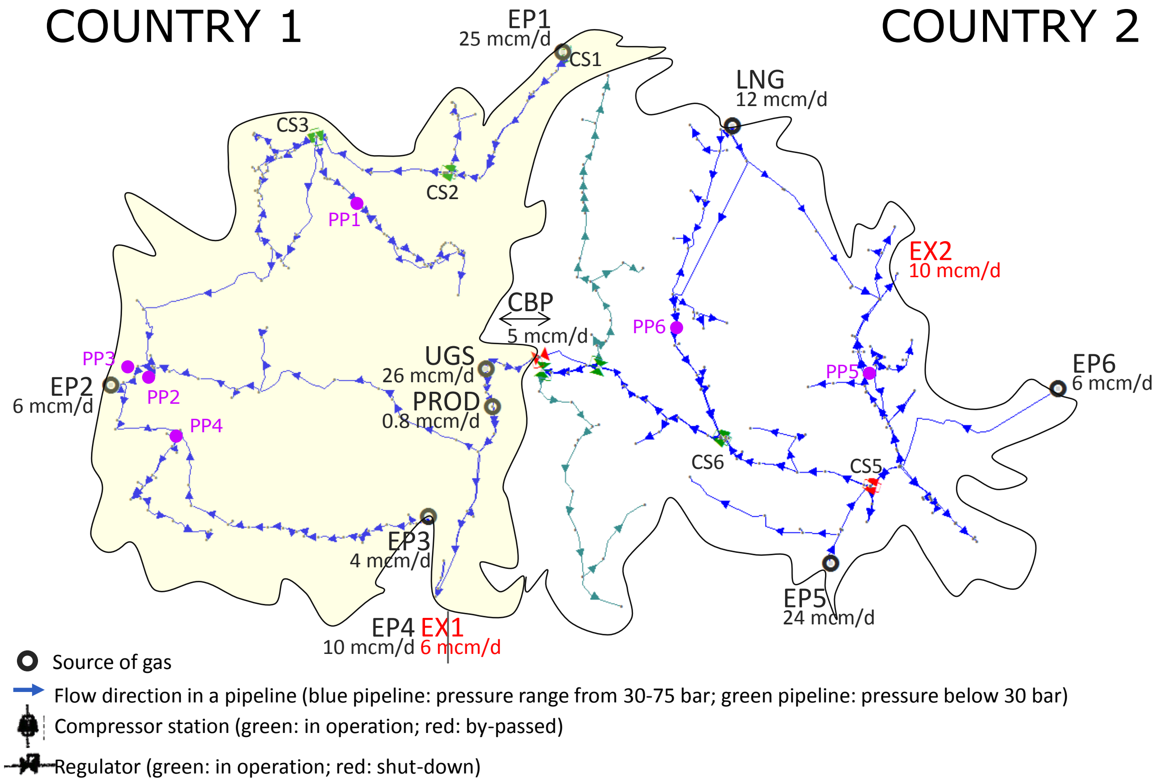

Table 1. Operational pressure ranges and maximum capacity at cross border points of Country 1and Country 2

Country 1	Pressure Range (bar)	Max. Capacity (mcm/d)
EP1	50-60	25
EP2	45-55	6
EP3	40-60	4
EP4/EX1	45-60	10/-6
UGS	50-60	26
PROD	60	0.8
CBP	40-60	5
Country 2	Pressure Range (bar)	Max. Capacity (mcm/d)
EP5	48-60	24
EP6	50-55	6
LNG	50-75	12
CBP	40-60	5
EX2	40-50	-10

3. N-1 FORMULA

The calculation of the N-1 formula has been carried out for C1, C2 and the region comprised of C1 and C2. If the identified area of analysis is C1, the maximum capacity of the underground storage facility – the largest gas infrastructure (I_m in Equation 1) – has to be discounted from all the other capacities. The N-1 formula gives a result of 128% (see Table 2), meaning that in case the largest gas infrastructure is not available during a 1-in-20 peak demand day, the capacity of the other sources of gas is high enough as to satisfy the demand. C1 counts as entry capacity the capacity from EP4 which, as it has been already explained, is reserved from a neighbour country to store gas in the UGS facility of C1. This fact could be leading to wrong conclusions since the capacity taken into account in the N-1 formula is higher than real.

The same calculation was carried out for Country 2. In this case, the largest gas infrastructure is the entry point named EP5 that has a capacity of 24 mcm/d. In this case, when the capacity of the largest facility of the country is discounted the result of the N-1 formula is 94% (Table 2) and it falls below 100% meaning that the remaining sources of gas are not able to satisfy D_{max}.

It has to be noted that both countries considered as entry capacity of themselves the capacity of the cross border point between countries. The point name CBP in Figure 1 is bidirectional and could flow gas in one or another direction depending on the scenario. For the calculation of the N-1 formula, both C1 and C2, consider available the capacity of CBP to mitigate the consequences of their N-1 situations.

The regional calculation of the infrastructure standard considers inoperative the largest gas infrastructure of the region, this is the UGS facility. The effect of the CBP capacity is disregarded since it does not count as a source of gas for the region. The calculation of the N-1 formula for the region shows a considerable improvement of the result obtained respect to the result obtained for Country 1 and Country 2 separately. The regional N-1 is equal to 137%.

Table 2. N-1 formula calculation for Country 1, Country 2 and the region comprised of Countries 1 and 2

N-1 formula as in Regulation (EC) 994/2010	Country 1	Country 2	Region
EPm (mcm/d)	50	35	75
Pm (mcm/d)	0.8	0	0.8
Sm (mcm/d)	26	0	26
LNGm (mcm/d)	0	12	12
Im (mcm/d)	26	24	26
Dmax (mcm/d)	39.8	24.4	64.3
N-1 Result	**128%**	**94%**	**137%**

3. N-1 SCENARIO EVALUATED WITH A HYDRAULIC MODEL

The hydraulic model developed for the simulated gas network has been used to evaluate the consequences of the N-1 scenario of Country 1, Country 2 and the region. The model is solved in steady state conditions, i.e. the variable time is not taken into consideration. For this reason the dynamics of the linepack([3]), and its contribution to mitigate the impact during the first hours of a crisis, is not accurately captured.

A specific strategy has been implemented for all the simulated N-1 scenarios to take into account the impact of the use of linepack. The approach consists in starting with a solution, which represents the operation of the system the day before the N-1 scenario happens. This state is called “reference scenario”. A reference scenario shows the normal operation of the gas grid when no disruption of supply occurs and defines the level of the linepack in the system assuming a daily demand equal to the peak day demand associated to the N-1 scenario. Once a solution is obtained, the linepack is noted for the reference scenario and later compared with the linepack observed for the N-1 scenarios once the disruption of the largest gas infrastructure happens.

In most of the scenarios analysed with a hydraulic model in steady state, it is likely to find different possible operating solutions. Each solution will have a value of linepack associated depending on the pressure levels of the system. In order to select the solution that best represents the operating mode for each N-1 scenario two cases have been considered: scenario without gas deficit (i.e., unserved demand to customers) and scenario with gas deficit. When a scenario has no gas deficit, the solution selected is the one that keeps the level of linepack as close as possible to the associated reference scenario. This means that the new operating conditions do not introduce gas to be accumulated in the system (i.e., case of a solution where the linepack increases) and do not consume gas from the system (i.e., case of a solution where the linepack decreases). When a scenario has gas deficit, the solution selected is the one that decreases the level of linepack with respect to the reference scenario the maximum allowed by the pressure constraints of the national system. In these cases, the model seeks for a good use of the available resources. If a country cannot satisfy its demand with the sources of gas available it is expected that some of the gas present in the pipelines is consumed. The volume of gas consumed from the linepack in these cases is the one that allows running the system above the minimum delivery pressure.

The reference scenario reproduces the operating conditions of the gas network of both countries when the demand is representative of the 1-in-20 peak day (D_{max}) and all facilities are working at normal conditions.

The maximum gas entry capacity per country is detailed in Table 1. C1 has an entry

([3]) The linepack represents the volume of gas existing at any time in the pipeline system of a country.

capacity via pipeline (EP_m) of 50.0 mcm/d coming from EP1, EP2, EP3 EP4 and CBP. The maximum withdrawal capacity from UGS (S_m) is 26.0 mcm/d and via production fields is 0.8 mcm/d. In total, C1 has an available capacity of 74.8 mcm/d. C2 has a total entry capacity of 47.0 mcm/d; 35 mcm/d of that capacity is available via pipeline through the two entry points of the country (EP5 and EP6) and the cross border point with C1 (CBP) and 12.0 mcm/d corresponds to the maximum send-out capacity of the LNG facility. In Table 3 the results obtained for gas flows and pressures at each cross-border point are summarized for the reference scenario. In order to satisfy a demand representative of a 1-in-20 peak day in C1 (39.8 mcm/d), a gas flow of 29.3 mcm/d entering via the different entry points of the country is used together with a flow of 14.1 mcm/d of gas coming from the UGS plus 0.5 mcm/d of gas production. It can be appreciated that there are still 30.9 mcm/d of available capacity that it has not been used. In the case of C2, the D_{max} of 24.4 mcm/d is satisfied with 22.8 of gas flow entering via pipeline plus 8.7 mcm/d of gas obtained from the LNG terminal. The spare capacity of C2 for the reference scenario is 13.5 mcm/d.

The solution found for the reference scenario with the hydraulic model in steady state shows the amount of linepack available in the pipelines of each country at that level of pressures. The linepack of C1 is 34.5 mcm and 31.4 mcm in C2.

Table 3. Summary of results obtained with the hydraulic model in steady state conditions for the "Reference Scenario"

	Gas demand (mcm/d)	Gas unserved (mcm/d)	Gas Sources	Flow rate (mcm/d)	Pressure (bar)	Linepack (mcm)
Country 1	39.8	0.0	EP1	23.0	55	34.5
			EP2	4.2	45	
			EP3	2.1	45	
			UGS	14.1	60	
			PROD	0.5	59	
			CBP	0		
			EX1	-4	58	
Country 2	24.4	0.0	EP5	19.9	50	31.4
			EP6	2.9	50	
			LNG	8.6	50	
			CBP	0		
			EX2	-7.0	42	
Region	64.2	0.0				65.9

The simulation of the N-1 scenario involves the inoperability of the largest gas infrastructure of the country, the one that can deliver the highest flow of gas. In the case of the simulation of the N-1 scenario of Country 1, the UGS facility will be unavailable during the day of highest gas demand (D_{max}). To obtain a positive solution for this scenario, it is required to satisfy the full demand with the other sources of gas available. If the UGS is out of service, a maximum flow capacity of 26 mcm/d will be missing. The remaining capacity (48.8 mcm/d) corresponds to the other EP available and a small gas flow coming from the production fields (0.8 mcm/d). Country 2 keeps all the sources of gas in operation and the maximum gas flow capacity is the same than in the reference scenario. The hydraulic solution found to the N-1 scenario of C1 summarized in Table 4 shows the amount of gas unserved in C1 regardless the extra capacity still available. This is due to the pressure constrains imposed in the gas fired power plants of the country which need to receive the gas above 30 bar of pressure. The hydraulic solutions shows that without the UGS facility in operation, the pressure balance cannot be maintained at the level of the reference case and three out of four gas fired power plants must be shut down.

The gas available in the pipelines can help mitigate the gas deficit during the first hours of the crisis. In Table 4 is seen that the linepack of C1 is 32.7 mcm, 1.8 mcm lower than the previous day when all facilities where operational (see reference scenario). Therefore it can be agreed that the unserved gas of the Scenario N-1 of Country 1 is 4.7 mcm/d, instead of 6.5 mcm/d, thanks to the gas consumption from the linepack.

It has to be noticed that the gas exports of Country 1 (Exit point EX1) are cancelled during this crisis. Country 2 is not affected by the lack of gas from the largest gas infrastructure of C1 and it is supporting C1 by sending up to 5 mcm/d via the bidirectional cross-border point CBP.

Table 4. Summary of results obtained with the hydraulic model in steady state conditions for the "N-1 Scenario of C1"

	Gas demand (mcm/d)	Gas deficit/Gas unserved (mcm/d)	Gas Sources	Flow rate (mcm/d)	Pressure (bar)	Linepack (mcm)
Country 1	39.8	**-6.5*/-4.7**	EP1	19.0	55	32.7**
			EP2	6.0	46	
			EP3	2.5	50	
			UGS	**X**		
			PROD	0.8	44	
			CBP	5.0	44	
			EX1	**0.0**		
Country 2	24.4	0.0	EP5	23.6	48	31.4
			EP6	3.3	52	
			LNG	9.6	50	
			CBP	-5.0	45	
			EX2	-7.0	43	
Region	64.2	**-6.5/-4.7**				64.1

* PP1 (4.2 mcm/d), PP2 (0.9 mcm/d) and PP4 (1.4 mcm/d) are shut down

** Linepack decreases respect to the day of reference in 1.8 mcm.

The scenario N-1 for Country 2 solved with the hydraulic model shows the results obtained for flows and pressures when the largest gas infrastructure of the country (EP5) is disrupted during a day of peak gas demand. Table 5 shows that C1 is unaffected by the disruption in the neighbouring country. C1 is able to satisfy its peak demand and also support C2 by sending 5 mcm/d via the CBP. However C2 is not able to fully satisfy its peak demand. The remaining sources of gas available have not enough capacity as to supply all demand nodes. In the model the disconnection of the largest gas fired power plant (PP6) takes place in order to prioritize gas to other customers. The gas available in the pipelines of C2 can mitigate the effects of the crisis during the first hours. The linepack decreases from 31.4 mcm the day before (reference scenario) to 29.5 mcm, therefore 1.9 mcm of gas could be discounted from the unserved gas. The unserved gas in this case is only 0.2 mcm/d.

Table 5. Summary of results obtained with the hydraulic model in steady state conditions for the "N-1 Scenario of C2"

	Gas demand (mcm/d)	Gas deficit/Gas unserved (mcm/d)	Gas Sources	Flow rate (mcm/d)	Pressure (bar)	Linepack (mcm)
Country 1	39.8	0.0	EP1	23.0	55	34.5
			EP2	4.1	45	
			EP3	2.1	45	
			UGS	19.1	60	
			PROD	0.5	59	
			CBP	-5.0	59	
			EX1	-4.0	58	
Country 2	24.4	**-2.1*/-0.2**	EP5	**X**		29.5**
			EP6	5.9	50	
			LNG	11.4	57	
			CBP	5.0	49	
			EX2	**0.0**		
Region	64.2	**-2.1/-0.2**				64.0

* PP6 (2.1 mcm/d) is shut down

** Linepack decreases respect to the day of reference in 1.9 mcm.

4. COMPARISON OF N-1 FORMULA AND N-1 SCENARIO EVALUATED WITH A HYDRAULIC MODEL

Equation 2 is an adaptation of the N-1 formula of the EU Regulation to be able to compare the results of the N-1 hydraulic scenario with the results of the N-1 formula. The numerator represents the gas demand satisfied, i.e. the gas actually supplied in the scenario once the gas exported (EX) is discounted and the gas consumed from the linepack (LP), if that is the case, is accounted as an extra source of gas.

The N-1 (scenario) equation has a maximum value of 100%, this means that numerator and denominator are equal when the gas entry flows are able to fully satisfy the demand (D_{max}) without gas deficit.

$$\mathrm{N-1\ (scenario)[\%]} = \frac{\mathrm{EP+S+P+LNG+LP-EX}}{\mathrm{D_{max}}} \times 100 \qquad \text{Eq. 2}$$

Table 6 summarises the results of the N-1 scenario equation. In each scenario the N-1 calculation has been carried out for both countries since the effects of a crisis happening in one country might have also effect in the neighbouring country. It can be seen that the scenario N-1 of C1 gives a result of 88% for C1 and 100% for C2. This means that in the case of disruption of the largest gas infrastructure of C1 during the day of peak demand, C1 could only satisfy 88% of its demand meanwhile that C2 will be unaffected. In the case of scenario N-1 of C2, the result obtained with Eq. 2 gives a 100% for C1 and 99% for C2. This means that C1 will be unaffected by the event happening in C2 and C2 will satisfy only 99% of its demand. If the scenario N-1 is calculated at regional level, by disrupting the largest gas infrastructure of the region (the UGS facility in C1), the result of Eq. 2 shows that 93% of the gas demand will be satisfied.

Table 6. N-1 scenario calculation for Country 1, Country 2 and the region comprised of Countries 1 and 2

N-1 Scenario	for Country 1		for Country 2		for the Region
	Country 1	Country 2	Country 1	Country 2	Region
EP (mcm/d)	32.5	26.8	29.2	10.9	54.3
P (mcm/d)	0.8	-	0.5	-	0.8
S (mcm/d)	0	-	19.1	-	0
LNG (mcm/d)	-	9.6	-	11.4	9.6
LP (mcm)	1.8	0	0	1.9	1.8
EX (mcm/d)	0	12.0	9.0	0	7
Dmax (mcm/d)	39.8	24.4	39.8	24.4	64.2
N-1 Result	**88%**	**100%**	**100%**	**99%**	**93%**

5. CONCLUSIONS

The N-1 formula, introduced by Regulation (EU) No. 994/2010, is an indicator to assess the compliance with the so-called infrastructure standard. It is a minimum requirement of the Regulation on security of gas supply that allows comparing the potential availability of gas in different MS in case the largest gas infrastructure fails during a day of exceptionally high gas demand. However the N-1 formula lacks in details and can drive to misleading conclusions when taking it as the main security of supply indicator. For that reason the new Regulation (EU) No. 2017/1938 adds up the need to back up the N-1 formula with the evaluation of the N-1 scenario developed with a hydraulic model.

By comparing the results obtained for C1 with the N-1 formula and the N-1 scenario it has been shown that the N-1 formula gives a result of 128% when the N-1 scenario gives a result of 88%. In the first case the entry capacity considered is the maximum of all sources of gas regardless the contractual agreements or delivery pressure constrains. However with the hydraulic model the evaluation of the N-1 scenario takes into consideration the pressure limits and bottlenecks of the gas grid and for that reason the result drops to 88% showing the inability of the country to satisfy the full demand.

The results obtained for C2 show a 94% result with the N-1 formula and 99% result with the N-1 scenario. Both methods show the lack of capacity to satisfy the full demand representative of a peak demand day. But the N-1 formula does not consider the ability of the linepack to mitigate the consequences of a disruption during the first hours of the crisis. However the variable linepack is considered in the calculations carried out with the hydraulic model and that is the reason why the N-1 scenario result shows a higher value than the N-1 formula.

The regional calculation of the N-1 formula gives a result of 137%, showing more than enough capacity as to satisfy the peak demand of both countries in case of disruption of the largest gas infrastructure of the region. The N-1 scenario shows however that the available gas is not able to reach all demand points at the right conditions of flow and pressure regardless the spare capacity available in the system. The demand satisfied at regional level is only 93% when evaluating the N-1 hydraulic scenario.

It is therefore proved that the analysis of N-1 scenarios with a hydraulic model complements the results obtained with the N-1 formula and helps to ensure the compliance with the infrastructure standard of the EU Regulation.