Calculating Technical Capacity

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Contents

List of figures

I Introduction

Because of statutory regulations (EnWG Section 20, (1b)) pipeline system operators must determine entry and exit capacities "that enable network access without the definition of a transaction-related transport path and that can be used and traded independently of each other." These freely assignable capacities entitle the transport customers to connect from or to the virtual trading point of the respective market area. In accordance with Section 9 GasNZV, the freely assignable capacities are calculated "on the basis of state of the art load flow simulation." Among other things, pipeline system operators take account of historical and forecast capacity utilization.
To date, there has been no standardized method used throughout the industry to carry out such a calculation that would ensure discrimination-free access to gas networks. Accordingly, it is up to the individual pipeline system operators to develop the state of the art for these calculations. The method used by GASCADE Gastransport GmbH is described below.
Reference is made to the situation in the gas market to provide an idea of the challenges of the method used here. Historically, the gas networks in Germany have grown with the volumes of gas to be transported. Gas networks never had to represent a single unit or larger balancing zones (like market access is now structured through recent market area cooperation agreements) but had to ensure point-to-point transportation. In other words, the determination of transport capacities against the background of the market access model of the gas transport market decoupled from trading is not based on free gas networks without reservations but on an existing gas flow or an existing supply configuration. This situation must be considered anew each time gas market areas are merged. On the one hand, this circumstance offers the possibility of analyzing historical flows in the network and making forecasts against the background of relatively constant end customer behavior. On the other hand, it raises the challenge of being able to continue to supply end customers (e.g. via "downstream network operators") in the future. This means that determining freely assignable capacity not only concerns increasing capacities but primarily concerns maintaining capacities, whose quality is increased as a result of the free assignability.

Below are some basic definitions and determinations. This is followed by a detailed description of the problems involved in determining freely assignable capacities.

I.1 Basic Definitions

The following definitions are based on legal regulations and the General Terms and Conditions of GASCADE Gastransport GmbH (hereinafter referred to as "GASCADE"). Because of the current room for interpretation, they are not yet universally valid. This should especially be considered when publications on this subject are being read.

I.1.a) Terms to describe the natural gas network

Network point: A network point is an entry or exit point in the pipeline system of GASCADE that can be reserved. This includes points to downstream network operators that place internal orders.

Capacity-limiting element: A capacity-limiting element is an element with clearly assignable and adjustable boundary conditions and a resistance characteristic that allows the clear definition of a capacity limit.

- For example, a filter is a capacity-limiting element, since at the minimum (design) pressure the manufacturer specifies the maximum permitted pressure loss (maximum flow).
- The boundary conditions are based on the recognized rules of engineering.

Pipeline system: A pipeline system is a system that is define by capacity-limiting elements (compressors, controllers, etc.) or by its first aggregation stage (= station). (see Figure 1)

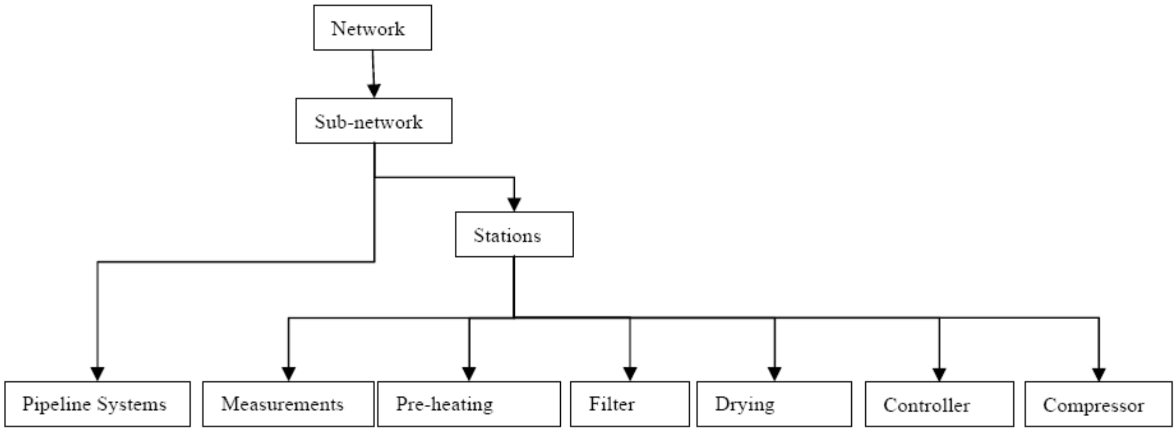

Figure 1: Diagram of the network components to describe a natural gas network

I.1.b) Capacity terms

Requested capacity: Binding or non-binding reservation request from a transport customer or a downstream network operator.

Interruptible capacity: Interruptible capacity in [kWh/h] is the possibility of fulfilling transport performance to the best of one's ability. Transports based on interruptible capacities can be interrupted. Accordingly, interruptible capacity is not considered in the determination of fixed capacities.

Fixed capacity: Fixed capacity is capacity that cannot be interrupted. Synonym: Firm capacity.

Exit capacity: Exit capacity is the maximum volume per hour in standard cubic meters that can be withdrawn and reserved from a network or a sub-network at an exit point. (EnWG)

Entry capacity Entry capacity is the maximum volume per hour in standard cubic meters that can be fed in at an entry point in a network or a sub-network of a network operator. (EnWG)

Technical capacity: Maximum fixed capacity that the network operator can offer to transport customers at a network point with consideration of the system integrity and the requirements of the network operation (GasNZV). Technical capacity is the total freely assignable capacity (reserved and still able to be reserved) and the additional limited assignable capacity of this that can be marketed.
Bottleneck: A transport restriction that has or can have limiting effects on the technical capacity of one or more network points.

Technical station capacity: Maximum fixed capacity that could be offered at a station without consideration of the system integrity.

Reserved capacity: Reserved capacity is the real-time determined total of reserved capacity rights and/or internal orders at one or more network points. It can be split into different classes of capacity products (e.g. fixed and interruptible reserved capacity). Synonym: Marketed capacity.

Available capacity: Available capacity is the technical capacity under the respective boundary conditions. The available capacity corresponds to the technical capacity if the assumptions that were made to determine the technical capacity actually occur.

- Possible effects: Maintenance, weather conditions, interruptions to operation
- It is dynamic in relation to the boundary conditions

Free capacity: Free capacity is the capacity at a network point that is calculated from the technical capacity of the network point minus the reserved capacity.

- It is specific to the respective network point.
- It is dynamic in relation to the respective boundary conditions (incl. contractual restrictions) and the capacity rights.
- free capacity = technical capacity – reserved capacity

Freely assignable capacity: Freely assignable capacity is a capacity for which a customer

a) can connect a capacity right at an entry point with a capacity right at any exit point of the market area for a specific transport service **or**

b) can connect a capacity right at an exit point with a capacity right at any entry point of the market area for a specific transport service.

- In principle, it is network point-specific, although several network points can compete for the same capacity.
- It is connected to the system definition. (see Figure 1).

Limited assignable capacity: Limited assignable capacity is a capacity for which a customer can connect a capacity right at a network point only in a defined manner with one or more capacity rights at certain network points to a specific transport service. The nature and extent of the restriction are specified in the respective capacity right.

- It is network point-specific and is in connection with certain entry and exit points.

Capacity bottleneck: A capacity bottleneck exists if: requested capacity > technical capacity minus reservations.
Capacity restriction: A capacity restriction exists if the available capacity of a network point is less than the technical capacity of a network point (e.g. due to the breakdown of system components or because of maintenance)

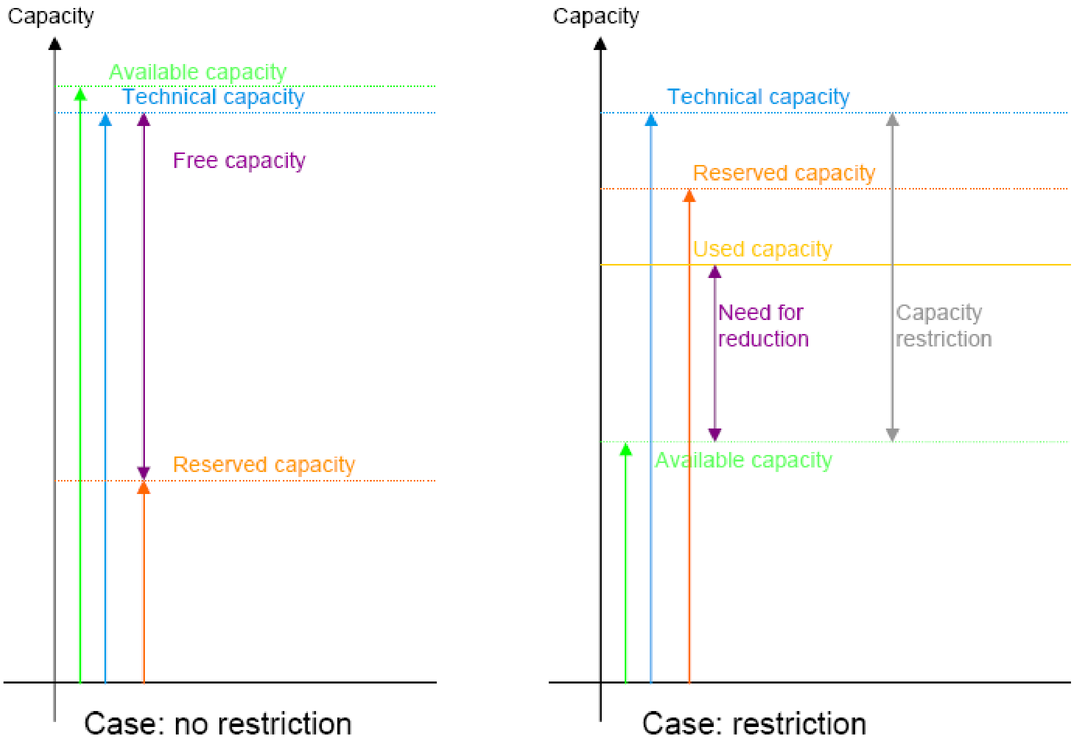

Figure 2: Capacities at stations

Flow commitments: Flow commitments are agreements with third parties that assure specific flows to increase the verifiability of freely assignable entry and exit capacities. (GasNZV)

II Determining Freely Assignable Capacities (FAC)

GASCADE uses a multi-stage process to determine freely assignable capacity. On the one hand, the starting point of this process is a determination of (transport) bottlenecks in the network and, on the other hand, the technical station capacities at the points that can be reserved (= edges) of the network.
The aim of the process to determine FAC at GASCADE is to maximize the marketing of fixed capacities.

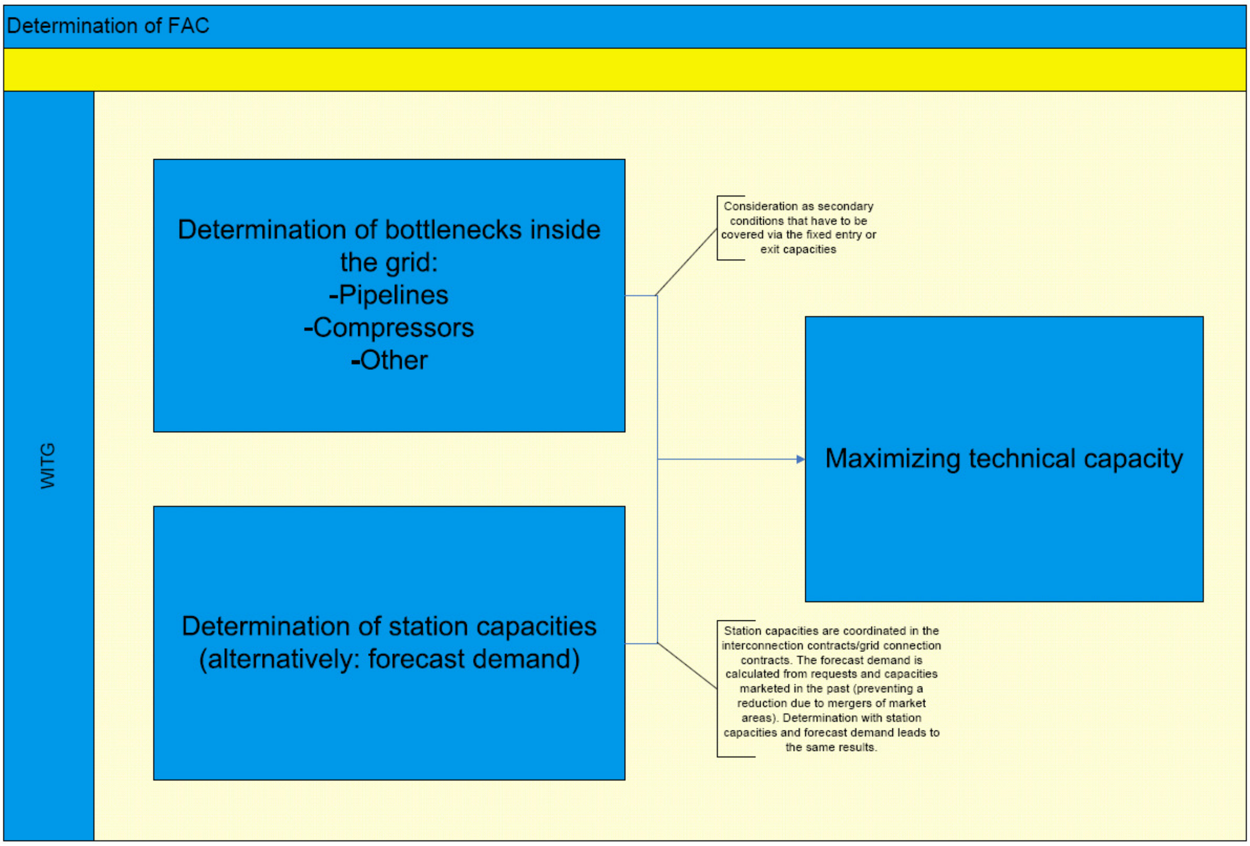

Figure 3: How to determine FAC

II.1 GASCADE pipeline system

The GASCADE pipeline system consists of the MIDAL, WEDAL, RHG, ERM, STEGAL and JAGAL pipelines. Figure 4: GASCADE pipeline system shows the locations of the pipelines. The Weisweiler compressor station splits the WEDAL pipeline system into an eastern and a western part. The Lippe und Reckrod compressor stations split the MIDAL pipeline system into northern, central and southern sections. The Rückersdorf compressor station splits the STEGAL pipeline system into east and west. Because of the location of the Eischleben compressor station, the pipeline system is not split up any further.
In addition to the above pipeline systems GASCADE operates the separate pipeline section Südal.

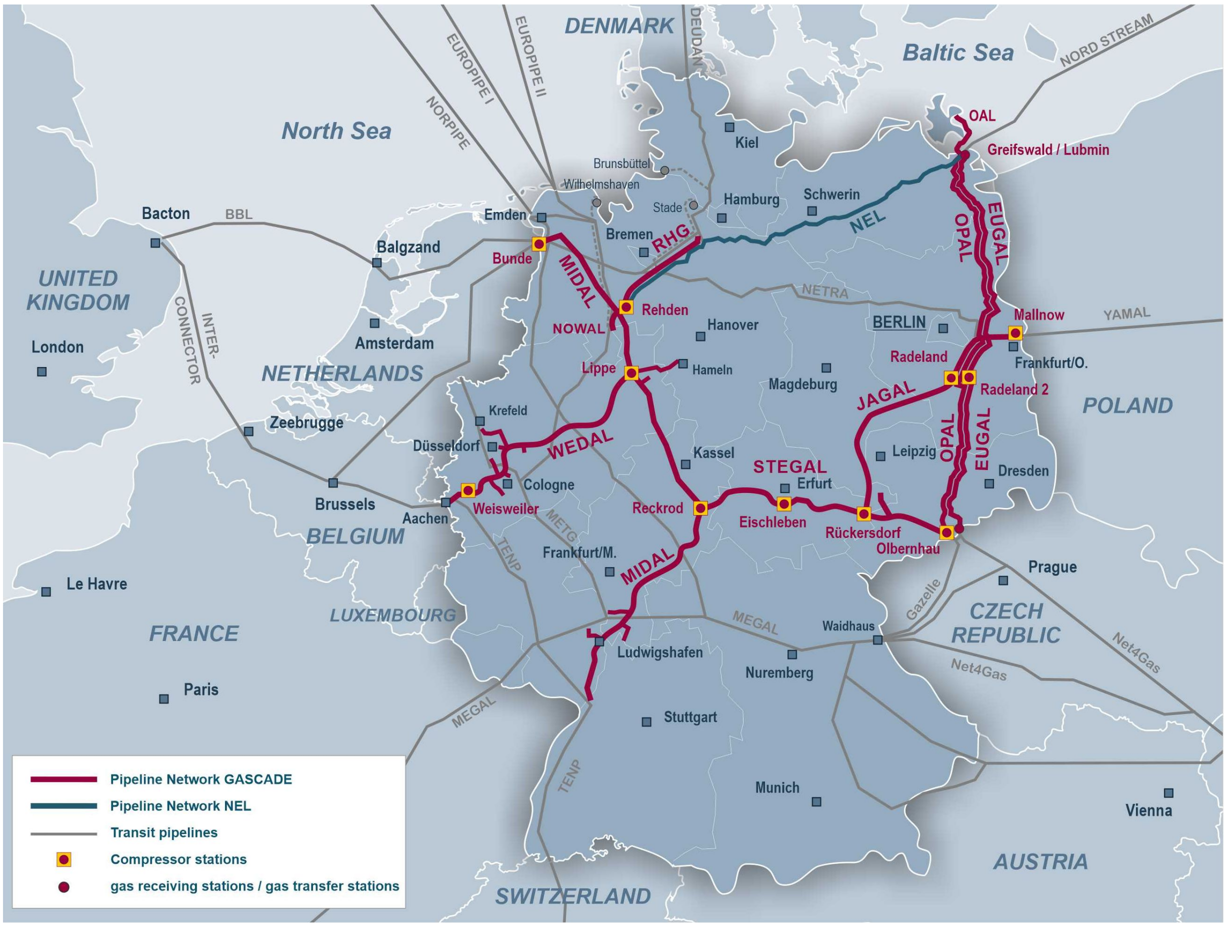

Figure 4: GASCADE pipeline system

II.2 Determining Bottlenecks

Bottlenecks in the pipeline systems have to be identified before the technical capacity can be determined. In some cases these bottlenecks are not relevant in the determination of the technical capacity because it can happen that one bottleneck is balanced out by another. However, in the method described here this can be seen only in later stages. Basically, bottlenecks can be split into the following four categories:

II.2.a) Technical station capacities

See Section I.1.b). The technical station capacity is based on the technical design of the individual components of a station. To a certain degree it can be deduced from the planning and approval documents with consideration of the design pressure or must be agreed in interconnection contracts.

II.2.b) Bottlenecks in the pipeline system

Bottlenecks in the pipeline system occur as a result of the pressure loss during gas transport and due to the associated boundary conditions. Boundary conditions for determining bottlenecks in pipeline systems include contractually agreed handover and acceptance pressures in interconnection contracts with consideration of the use of own compressors at interconnection points. In the GASCADE pipeline system, technical dimensions are used in place of contractually fixed values for the output and input pressures of the compressor stations.
To determine the bottlenecks in the pipeline system the different transport directions must be considered with the assumption of a limiting load scenario. The respective load scenarios were chosen realistically but limiting in that the exit point most distant from the entry point were loaded up to the maximum reserved capacity or the total reserved capacities of the downstream exit points (in the case of compressors) with consideration of the respective

transport direction. The “SIMONE” simulation program – software used throughout the industry – is used to calculate the respective transport capacities of the pipelines. You can find more information about SIMONE on the provider’s website (http://www.simone.eu/simone-simonesoftware-simulation.asp).

Reservations are converted into transport volumes in relation to the geographical location of the network points using a reference calorific value. In the GASCADE system, these values vary between 11.1 and 11.4 kWh/m³.
Determination of bottlenecks in pipeline systems is based on static considerations. It is assumed that entry and exit amounts are the same.

II.2.c) Compressor bottlenecks

The capacities of compressor stations are mainly influenced by the design of the compressor units. This especially concerns the input and output pressure of compressors (compression ratio). Redundant compressors are used as a technical replacement in case of failure and are not factored in to increase marketable capacities. At GASCADE we use only turbo compressors with gas turbine or electric drive systems. Gas inlet temperatures of up to 20℃ and air temperatures of up to 35℃ are assumed for the design of compressors.
Because of the input pressures and the required output pressures compressor capacities in the GASCADE system are dependent on the transport direction and can thus vary for different transport scenarios.

The compressors of GASCADE at entry and exit points are used to represent the technical station capacities.

II.2.d) Other

Other bottlenecks include in particular gas pressure measurement and control plants and gas qualities (e.g. calorific value, Wobbe index, oxygen content, sulfur content,…), since contractual arrangements exist for these (e.g. permissible gas qualities for handover to international interconnection partners).
In the GASCADE system, especially in Bunde (feed-in) consideration of the effect of gas qualities leads to a quarterly profiling of the technical capacities.

II.3 Statistical flows

To be able to consider the restrictions caused by bottlenecks realistically flows are also considered to determine technical capacities. As no knowledge about future flows is available, GASCADE uses historical flows in its forecasts.
For each bottleneck the upstream withdrawals and the downstream feed-ins are considered, since these have a counter-effect on the bottleneck. Feed-ins and withdrawals are considered (accumulated) for all network points that are affected so that concurrency effects can also be taken into account.
A flow is deemed to be statistically reliable if, historically, the flow was below this for less than 24 hours in a row. GASCADE has chosen this method of determination instead of a confidence interval because this form of determination has a substantial relation to gas transport. GASCADE last looked at the 2007-2009 gas economy years to determine the statistical flows.

II.4 Maximizing FAC

The aim of determining the FAC is to maximize the technical capacities; in other words the fixed capacities that can be reserved at entry and exit points. GASCADE resolved an optimization task for this purpose.

As mentioned in the introduction, determination of FAC is based on the assumption that feed-ins and withdrawals are the same in terms of volume. In the gas network access model, this assumption is reflected in the fact that balancing groups must be balanced out. In other words, feed-ins and withdrawals always balance each other out; increased use of feed-in capacities leads to increased withdrawals and vice versa. A reduction in the use of feed-ins (i.e. the respective capacity rights) will lead to increased use of other feed-ins or a reduction in the use of a withdrawal (i.e. the respective marketed capacity rights) if one considers the development of the network conditions.

Accordingly, it is sufficient to map bottlenecks in the pipeline system via feed-ins or withdrawals. Because of the balance between feed-in and withdrawal, the maximum volume of gas at a bottleneck is always the minimum marketed feed-in capacities upstream of the bottleneck and the marketed withdrawal capacities downstream of the bottleneck. If the bottlenecks were to be considered at the same time as the feed-in and withdrawal capacities were being determined, this would lead to excessive restrictions and inappropriate limitations.

When capacities have been marketed, it is no longer possible to change the consideration of a bottleneck from feed-in to withdrawal or vice versa. Consequently, GASCADE has decided to initially map the bottlenecks that maximize the total marketable FAC. No factors were used to weight feed-in and withdrawal capacities at different network points. The capacities were also not evaluated as regards the type of network point (market area-internal network interconnection point, network connection point, border crossing point, market area transfer point).

II.5 Flow commitments

Flow commitments can relieve certain bottlenecks through contracts. For example, at GASCADE the bottleneck in MIDAL South was neutralized for a certain number of years.

II.6 Determining limited assignable capacities

Assignment limitations are possible where volumes of gas cannot be transported via bottlenecks in the pipeline system but where a transport customer is interested in a short transport. Because of an assignment restriction it is possible to utilize the capacity of network sections where the capacity is not fully utilized and, at the same time, take account of the restrictions of the transport system.

II.7 Merging market areas

To date, merging market areas of GASCADE has been resolved by the fact that the full technical capacities of the cooperation partners have been maintained. In addition to existing network points that allow physical exchange, commercial arrangements have also been made to maintain capacities (e.g. flow commitments, local selling and buying of gas).

III Effects of Construction Work

III.1 Network connections

Network connections have the effect that new bottlenecks can be created in certain pipelines; for example, if an end customer connects to a connection line that is exactly dimensioned to supply the gas customers that are already connected.

III.2 Network development measures

Network development measures cause a situation where the extent of bottlenecks can change (e.g. construction of loop lines, new compressor locations, construction of new compressors at existing locations). In the optimum case this can create FAC to the amount of the network expansion on the respective section of pipeline. However, usually the effect of the network expansion is negated by a different bottleneck – at least for a certain time.