Capacity Calculation

1. On Open Grid Europe

Open Grid Europe operates the largest and most complex natural gas transmission network in Germany. The current length of this up to 80 years old network is about 11.000 km with over 30, mostly cross-border, entry points and over 1,000 exit points inside and outside Germany. These various international and national natural gas sources make Open Grid Europe to a gas wheel for the European energy market by providing transport between the major gas hubs in this market.

In accordance with the European Regulation EC 715/2009, Open Grid Europe would like to introduce the internally applied the calculation methodology of the technically available capacities to a broad audience. Due to the complexity of the issue, the following text is a simplified description of the key assumptions. This text is aimed at a general understanding and shall not be perceived as scientifically exact representation of the matter.

For more information about the natural gas transmission network of Open Grid Europe, please visit our website http://www.open-grid-europe.com.
On top of numerous information about our network, you will find a network data dashboard there, also information on all network points and data requests and downloads, as well; but you will also find the products and services we do offer as well as the current network access conditions.

2. Calculation of firm, freely allocable capacity

The goal of such an analysis and subsequent calculation is to determine the maximum amount of technically available, freely allocable capacities in the network operated and marketed by Open Grid Europe. In the German network access regulation (‘Gasnetzzugangsverordnung’) it is stated in § 8, paragraph 2, that Open Grid Europe, as transmission system operator, has to offer freely allocable capacities that enable the shipper to use any booked entry and exit without specifying a transport path.

2.1. Gas flow simulations and scenarios

To determine the maximum bookable entry and exit capacity at a network point, there are two examinations possible: on one hand, the possible distributions of the exit flow from the network of Open Grid Europe (OGE); on the other hand, using a framework of fluid dynamics simulations, it will be observed with which combination of entry flows and exit flows a supply without any bottleneck could be achieved. Available capacity increasing instruments, e.g. flow commitments, will be considered, as it is the goal of the subsequent presented capacity model to calculate and market the maximum of freely allocable firm capacity for all entry and exit points in the operated gas transmission network of OGE and in the market area of Net Connect Germany (NCG). For such a complex and intermeshed gas transmission network like the OGE, the legal obligation of the free allocation of firm capacities poses a special challenge.

To achieve a free allocation of the entry and exit capacity, several flow simulations, so called scenarios, will be observed. There is a distinction made between peak flow scenarios (focus is to test the maximum exit capacity) and interflow scenarios (focus is to test the maximum entry capacity). The selection of scenarios ensures the consideration of bottlenecks, which may occur in variety of situations.

The statistical data of the flows, used for the scenarios, is enhanced with historical temperatures and then used in the specially programmed software named SIMONE, to determine that the assumed flow of this scenario would be physically possible and therefore realizable.

In peak flow scenarios the exit flow will be maximized with an exception made on storage exit points. To ensure such a maximization of the exits (especially of those temperature related) the peak flow scenario will be modeled after DIN EN 12831, i.e. the lowest ever observed temperatures will be applied. In this peak flow scenario, a small capacity surplus will be observed when compared to the exit side. This higher demand on the exit side will lower the shipper`s flexibility by restricting the gas injection possibilities on the exit points of the network.

In interflow scenarios (using higher temperatures than the design temperature) not the complete marketed entry is needed to cover the respective exit demand, so that, in consequence, a high entry capacity surplus will be observed. As the exit flow will decrease with increasing temperature, potentially existing price differences in the various natural gas supply points or hubs will lower the shipper`s entry nominations predictability.

Therefore, the two presented scenarios differ in the assumed entry and exit load. The exit load is a nearly constant value in each scenario.

During the simulation, it is checked to which extent the predetermined exit flow can be supplied by the, for this scenario, selected entry points. The selection of scenarios (e.g. at different temperatures and different distribution of the load on the exit points) shall ensure that all transport bottlenecks, that can occur in various situations, could be identified and considered during the capacity calculation. Since the free allocation dictates a complete decoupling of the entry and exit point (with the Virtual Trading Point

(VTP) as a centerpiece), this reality has to be considered as well in the model used in the capacity calculation.

There are several hundreds of scenarios for the total capacity calculation of the OGE H-and L-gas network, with the consideration of 40 entry points and over 1,000 exit points.

In addition to these general conditions, features and principles in the preparation of capacity model or scenario selection and modeling are described in detail in the following sections,

2.2. Classification of the entry points in a scenario: minimal and maximal entry points

In scenarios where the focus is on reviewing the entry capacity, usually an unspecified flexibility in the employment of entry capacity by the shipper will be assumed. For each entry point, therefore, there is a range of scenarios to test which is the maximum capacity that can be marketed on the selected entry point. In these scenarios, the selected entry point is hereinafter referred to as the ‘maximum entry point’ (or abbreviated *maxEntry*).

Since the level of employment of *maxEntry* will be varied in such a scenario, at least one additional entry point can be determined as a “balance point” - to make a flow balance possible - hereinafter called "minimum entry point" (or abbreviated *minEntry*).

To determine the maximum bookable entry capacity at one point, those scenarios, where this entry point is defined as *maxEntry*, are relevant. Crucial for the publication as the maximum of firm freely allocable entry capacity will be the minimum of the values resulting from these scenarios on this selected entry point.

2.3 Classification of exit points in a scenario: strained and relieved exit points

To use a so-called real fluidic, restrictive flow situation for capacity calculation of *maxEntries,* the off take, under its statistical reference (depending on the temperature), will be minimized for relieving exit points (i.e., exit points, which are located between the *maxEntries* and the bottleneck in the system); strained exit points (i.e., exits that are beyond the bottleneck) will be maximized.

Minimizing the exit capacity at the relieving exit points will cause that the natural gas, having entered at *maxEntries,* will take the maximum transport route. Thus, the load on the network of OGE is increased and simulates therefore that one bottleneck that limits the entry capacity at the *maxEntries*. To calculate the capacity of *maxEntries* without considering off takes at relieving exits would however lead to significant decreases on the firm, free allocable entry capacity as compared to a model with statistically assumed off takes.

3. Temperature-dependent load and flow modeling

The, considered in its entirety, gas transport system indicates, generally, at colder temperatures a higher overall off take. As low interflow off takes near the observed entry point are influencing the amount of the later marketed firm entry capacity, the scenarios for determining the maximum entry capacity will be defined not only for extremely cold temperatures but also for offtakes with varying temperatures. This allows a realistic observation of the interflow off takes.

The off-take behavior in the distribution system area is usually highly dependent on temperature, while other types of exit points may show an off-take behavior that regularly fluctuates between zero and the contracted capacity value. At a fixed temperature, fluctuations in DSO off take will be rather low, as their customers behave reliably in sum, predictably dependent on temperature. On the off-take side, several degrees of freedom exist in the employment of the exit contracts for the supply of industrial customers and cross-border/cross-market area points (with no temperature-dependence). This disparity is considered when modeling the off-take scenarios see Figure 1).

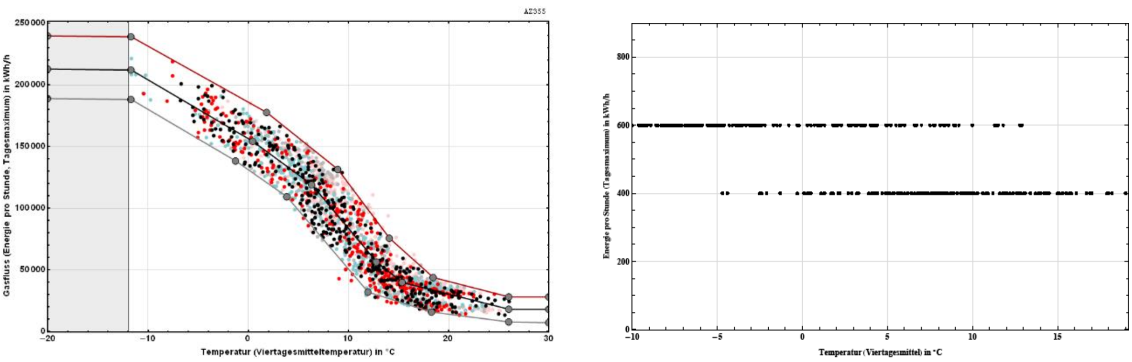

Figure 1: Left: Temperature-driven offtake (e.g. regional supplier); Right: Temperature-independent offtake (e. g. industrial customer)

4. Modeling of 'Entry Groups' within interflow scenarios

For a given off take, the number of possible injection variations grows exponentially with the number of entry points. For the OGE network, this means that the simulation of all theoretically occurring load flow situations is not manageable in practice, only because of the high number of entry points. To reduce the number of the scenarios for the calculation, it is necessary, from the set of all possible scenarios, to identify and select those which reflect the congestions in the gas transmission network. Therefore, several entry points, related to each other in the fluid mechanical sense, and between which show no transport bottlenecks in restrictive scenarios, will be summarized in so-called "Entry Group".

The above described scenarios occur only if the necessary flexibility is offered by a selection of employing entry points. Restrictive for the firm entry capacity calculation are therefore generally scenarios with not maximized gas supply, i.e. in temperatures above the design temperature.

5. Interaction of peak flow scenarios and interflow scenarios

To determine the maximum marketable entry capacity, interflow scenarios are more significant than peak load scenarios, as the injection capacity, as presented in the above calculation, is limited by the interflow scenario. The historical booking situation of interruptible capacity is considered as well to balance certain scenarios where the assumed off take would exceed the sum of injections.

In the peak load scenarios, usually the highest gas flow will be accompanied by the by the greatest load in the distribution systems; therefore, these scenarios are often restrictive for the maximum of marketable exit capacity. However, even an interflow scenario can appear to be restrictive. The maximum of marketable exit capacity is therefore determined by the values of the peak load scenarios and those interflow scenarios where the considered exit point is modeled as a maximally employed.

6. Inclusion of simultaneity effects: notional entries and exits

Additionally, to the statistical analysis of the flows on single entry points, a statistical analysis of the simultaneous off take of exit point groups which are fluidically related (named fields) ensues during the capacity calculation.

Due to simultaneity effects, the maximal concurrent off take of a group of exit points is usually less than the sum of the individual maximal off take of each single exit point. Analogically, the minimal simultaneous off take of a group of exit points is usually higher than the sum of its individual minimal off take of each single exit point.

To generate a realistic pressure drop calculation in the network, only the value of the maximum and minimum simultaneously flowed amount should be used in the simulation and not the sum of the individual maximum and minimum off takes of the via this pipeline supplied exit points. This realistic restrictive system load allows for the realization of a higher amount of firm marketable capacities as if in a pessimistic addition of all single off takes of the then supplied exit points. Furthermore, due to security of supply, an analysis on each single exit point has to ensue if its maximal off take could be transported. Fictitious gas supplies on the junction to the supplied exit points ensure that in a calculation, where simultaneously the maximum flow on the supplying pipeline and the maximal single off takes (of all downstream located exit points) can be simulated in the same scenario. Therefore, the use of fictitious gas supplies helps to avoid a – otherwise necessary – multiplication of scenarios.

Analogically, fictitious gas off takes ensure a realistic view on the network load as the simultaneous minimal off take of a related group of exit points is usually higher than the sum of the single minimal off takes. Considering the simultaneous minimal off take for a modeled group of relieving exit points ensures that the maximum of the firm, freely allocable entry capacity can be calculated.

7. Illustration of hybrid points in the scenarios

It is possible to entry and exit the network at some network points (e.g. storage points), depending on the actual flow at that time. The combination of these two network points, the entry and the exit are summarized as hybrid point. Hybrid points have to be analyzed in two different scenarios; once as an entry, and in a second scenario as an exit point. The number of restrictive scenarios could – in the most unfavorable case- double for each hybrid point but has to be analyzed then anyway. This completes the set of analyzed scenarios and total capacity calculation of the OGE H-and L-gas network is completed circumferentially.

8. Dealing with freely allocable capacities in market area cooperation

If there is a market area with networks of several partners, the flows of the market area points, in coordination with the borders of the market area, will be taken into account, if there is not already a joint capacity calculation 8as with Fluxys TENP and GRTgaz Deutschland). In the first case, capacities at the inner market area points will be considered, similar to the above described method where bookable network points where considered. In the second case, the capacity calculation cooperation together with partner TSO will take place. In a second step, the calculated firm freely allocable capacity will be divided upon the partner TSOs. This ensures that the calculated capacities are always freely allocable in the whole NCG market area.

9. Examples

The previously described capacity calculation method for firm, freely allocable capacities is elaborated by the following examples.

9.1. Example No. 1:

The network consists of two entry points E_1 and $E_{2;}$ and two exit points A_1 and A_2. Furthermore, there is physical congestion, whose maximally possible transport volume is depicted – for better traceability – in square brackets.

Entry and exit bookings are depicted in round brackets in the following examples, and the assumed shipper nomination is depicted without further marking at the entry and exit points in the described scenario. To simplify it all, the off take is assumed to be not dependent on temperature.

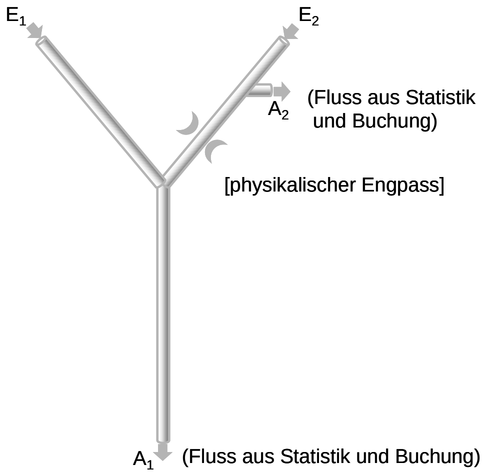

Figure 2: Notation on an example of a Y - network model.

9.2 Example No. 2: Fluid mechanical calculation of the firm free allocable entry capacity for a certain flow situation

For the calculation of the maximum of firm free allocable capacity, the network, as depicted in figure 2 will be assigned with a flow situation, together with booking data and historical (temperature-dependent) flow data of the exit points.

In the current example, the demanded off take on exit point A_1 is between 1000 and 1500 flow units and on exit point A_2 between 100 and 150 flow units.

The firm free allocable capacity at entry point E_1 is determined with an interflow scenario. This method is depicted in the left side of figure 3. The exit point A_1, located between entry point E_1 and the bottleneck will be assigned as a relieving entry point with a minimal off take of 1,000 flow units, while the exit point, located after the bottleneck, will be regarded as a strained exit point with a maximal off take of 150 flow units. The total off take in this scenario would be therefore 1,150 flow units.

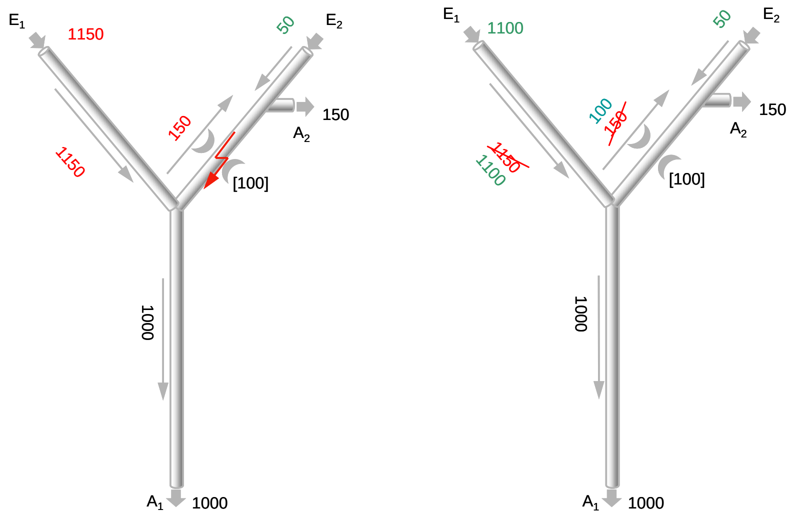

Figure 3: Depiction of a flow situation for determining the technical available capacity of the entry E1

Due to an occurring physical congestion in the observed grid part which allows for the transport of only 100 flow units (in both directions), can be concluded that in this scenario a full supply of the exit flow by entry E_1 will not be possible. To change that and to ensure fully supply is the inclusion of an additional, balancing entry (*minEntry*) with a required flow of 50 flow units (see right part of figure 3).

The calculation of the maximum in the firm freely allocable capacity at entry E_2 is analogous to the procedure described above in a scenario where the exit point A_2 as relieving and exit point A_1 is modeled as straining. In this scenario, it is then checked what capacity can be represented at entry point E_2 without exceeding the maximum flow at the bottleneck. The entry point E_1 is used in this scenario as the balancing entry point *minEntry*.

In summary for this flow situation, a maximum of firm freely allocable capacity at entry point E_1 of 1100 flow units and of 200 flow units at entry point E_2 can be obtained.

At the entry points, interruptible capacity can be booked additionally, as the TSO has the possibility to minimize the flow to the level of booked firm capacity, if needed. The procedure for determining the maximum of firm capacity has been described specifically only for the freely allocable capacities in the network of Open Grid Europe.