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Dynamic pressure control in gas grids for better integration of green gases – a potential analysis in the North of Germany

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ABSTRACT

The integration of green gases e.g. biogas, hydrogen or synthetic natural gas is an important task and precondition for a successful energy transition. It is especially challenging to inject green gases into the grid at the point of their production as this is often in rural areas with less sophisticated infrastructures. There are technical measures as recompression to higher-pressure tiers enabling the gas injection almost into every grid section but this solution demands both high technical and financial efforts. A very promising approach is the strategic use the existing grid buffer (storage capacity of a gas network and the use of the difference between upper and lower pressure limits).

In distribution and regional transportation grids with maximum operational pressures above 1 bar, a strategic pressure driven operation may allow green gas injection without any additional measures also in challenging situation as summertime nights were the load is in most areas exceptionally low. This could be achieved by a pressure reduction preferably in the evening hours, when the load is high, to enable an uninterrupted green gas injection overnight accompanied with a pressure build up, when the load is low. In order to assess the opportunities of this approach properly, it is also important to understand the preconditions (as needed pressure swing, geometric grid volume, customer distribution etc.) which have to be fulfilled. These questions have been answered by a R&D project supported by a following up pilot application that is carried out for EWE Netz GmbH by DBI GUT. The R&D project shows the potential of the dynamic pressure control exemplarily for selected gas grids in the North of Germany.

Within the project several lower and upper pressures limits for have been considered. Furthermore, distribution grids with different load situations (based on the connected customers e.g. domestic or industrial character) were selected to enable future extrapolation to larger areas.

The pressure driven operation of gas networks is subject of a European R&D project of GERG, which is called “Dynamic Pressure Control”. The kick-off took place in March 2014 under participation of EWE Netz and DBI GUT.

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1 INTRODUCTION

The rising constraints by the regulator to improve the general efficiency of gas grids as well as the challenge to integrate green gases such as biogas, SNG or hydrogen request, in a smart way new solutions and make the use of potentials mandatory which were not in focus up to now.

A very promising approach is the dynamic use of the existing grid buffer (differences between upper and lower pressure limits) also called dynamic pressure control (DPC) of gas grids. The DPC has been developed to deploy the gas grid as gas storage (grid buffer) by using the pressure range limits of the gas grid. This results, depending on the intended effect, either in an increased capacity for the feed-in of renewable gases or in a smoothing of gas demand peaks, which determine the volume of the internal order from the upstream network operator and may therefore be reduced.

The results for the analysed rural area suggest that compressor expenses could be reduced (operating expenses and for newly-build stations as well capital expenses), and for the urban area a decreasing need for transport capacity and thus declining expenses for the internal order.

The conducted research analyses the effects of the DPC using two different gas networks in Germany – a rural and an urban one [DBI 2014].

To increase the grid capacity for the feed-in of biogas in the rural area, three representative scenarios were analysed (weak, heavy, and intermediate load) by comparing the DPC with the current situation. In the urban area, the smoothing of the daily load curve of the natural gas procurement under a heavy load scenario has been compared with the current situation to display the influence of the DPC. Additionally, the expenses for the necessary adjustments of the gas pressure regulation stations (GPRS) were compared with the savings achieved by the DPC.

Key figures were developed to enable an approximate transfer of the findings to other distribution networks. Thus, the potentials of the DPC can be assessed by evaluating the effects.

Considered cases to evaluate the potential of dynamic pressure control:

First case: Feed-in of biogas and renewable gas to increase the transport capacity of the gas network (rural area).

In rural areas, mismatches between gas demand and biogas feed-in occur more often, especially during the summer period. The feed-in of biogas happens throughout the whole year and temporarily exceeds the gas demand, so that the excess gas has to be fed into the upstream transmission network. Due to the different pressure levels between the gas transmission network and the downstream distribution network, the gas has to be compressed. The energy required for compression and the installation of the stations cause further expenses, which eventually lead to increased network charges for consumers. Upon application of the DPC, the network capacity of the distribution grid may be enhanced, which considerably reduces the feed-in to the upstream transmission network. Thus, the operating expenses are reduced and moreover, future installation of compressor stations may either be avoided or realised with a smaller power layout.

Second case: Optimisation of gas procurement (urban area)

The downstream network operator is obliged to sign up for a maximum available exit capacity to the upstream network operator (also called internal order). The daily peaks of gas demand determine the capacity. The DPC optimises the gas procurement by smoothing the daily load curve, in the sense of a reduction of the load peaks. This results in a lower reserved capacity for the internal order, which again leads to reduced expenses for the internal order.

The DPC deploys the upper and lower pressure limits and thus the gas network is not only used to transport gas but also to store gas. Gas is stored by feeding-in gas in times of low gas demand until the upper pressure level has been reached and is fed-out at times of higher gas demand. The amount of gas fed-out falls behind the gas demand and the network storage is hereby emptied.

The feed-in pressure of the GPRS and the biogas grid injection stations as well as the upper and lower pressure limits of the network may require revision to fully use the advantages of the DPC.

This article will, after explanation of the research methodology, describe the results first for the rural area and then for the urban one. Technical requirements for the DPC are considered afterwards to finally refer to the conditions how the findings may be transferred to other gas networks.

2 RESEARCH METHODOLOGY

This study analyses the gas flow of a rural and an urban network to understand the impact of the DPC. The gas flow in both networks was simulated using the program STANET®. The current demand-orientated operation mode of the gas network has been compared with different scenarios of the DPC. According to the intended effect, three different scenario were differentiated: heavy, weak, and medium gas demand. By variation of the research conditions as for instance:

- upper and lower pressure limits of the gas network,
- feed-in pressure of GPRS, and
- feed-in pressure of the biogas grid injection station

a network operation mode for the rural area has been identified which combines a maximised biogas feed-in with little adaption effort for the gas network. In urban areas, it is intended to minimise the daily load peaks to decrease the capacity for the internal order.

The simulations results were used to develop and review key figures, based on mathematic algorithms. The key figures can help to estimate the effects of the DPC in other network areas.

3 Results

3.1 Results – rural area

In the considered rural area, a seasonal dynamic adoption of pressure in all scenarios (heavy, medium and weak load) is sufficient. A daily adaption is not necessary. The results suggest that the pressure-orientated operation mode enhances the capacity of the distribution network for biogas feed-in and at the same time markedly reduces the compression energy.

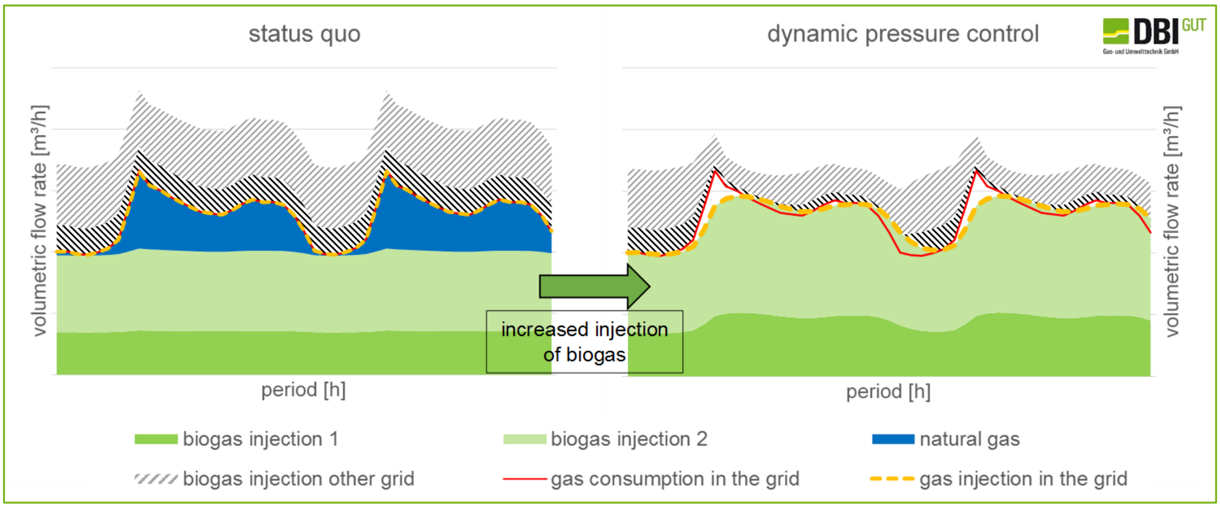
Biogas could be completely injected into the analysed distribution network, without being compressed and transported into the upstream transmission network if the operation mode was altered from a demand-orientated towards a pressure-orientated. This would generally require a revision of the lower pressure limit and an adaption from 0.5 bar to 0.3 bar combined with an adaption of the pressure of the GPRS. Furthermore, an extension of the gas network would be needed in times of weak and medium load (>16 °C).

The enhanced feed-in of biogas is being reached by using the maximum difference in pressure limits within the network area. The feed-in pressure of the GPRS and the biogas injection stations are under current operation conditions similar, so that both stations are injecting gas into the network. Upon raising the feed-in pressure of the biogas injection stations combined with lower pressure of the GPRS, the network would be primarily supplied with biogas.

If the pressure in the network dropped below the feed-in pressure of the GPRS, a supplemental gas supply by the GPRS would be initiated.

As displayed in the figure below, the biogas feed-in could be considerably enhanced if the gas demand was primarily covered by the biogas injection station combined with the adaption of the lower pressure limit.

Figure 1: Effect of the dynamic pressure control on the biogas feed-in (rural area)



The DPC in rural areas leads in the analysed network during weak load to a gas supply solely by biogas. The biogas can be fed-in almost completely throughout the whole year.

The DPC significantly decreases the required compression energy for the feed-in of biogas into the high pressure transmission network, due to the enhanced capacity of the distribution network. The compression energy can be reduced by 42 % to 89 % in times of weak load, depending on the chosen parameters. The maximised reduction requires beside an adaption of the pressure limits as well an extension of the network area.

Biogas can be completely injected into the middle-pressure distribution network in times of heavy load, due to the high gas demand and adjusted pressure levels. The compression and feed-in to the high-pressure transmission network is no longer necessary.

The compression energy can be reduced by introduction of the DPC in both scenarios with weak and heavy load by 89 % to 100 %. The scenario of medium load offers the opportunity to decrease the required compression energy significantly (over 90 %).

Transfer of results and further limitations

The compression energy has only been theoretically calculated in this study, as the actual biogas production and injection remained clearly below the expected amount. Long-term, real, historical load profiles for the injection in the transmission network were not available. The estimation of the impact of the DPC upon the compression energy was derived from the comparison of the theoretically necessary compression with the current demand-orientated operation mode and the pressure-orientated operation mode. The analysis is based on the amount of gas fed in to the transmission network (as simulated in the calculations with STANET®) and the current pressure levels of the medium-pressure network and the high-pressure network

The findings concerning the seasonal adaption of the operation mode might not be fully transferable to other networks with biogas feed-in. In deviation of the results for the rural area, the pressure-orientated operation mode using the grid buffer within one day might be beneficial.

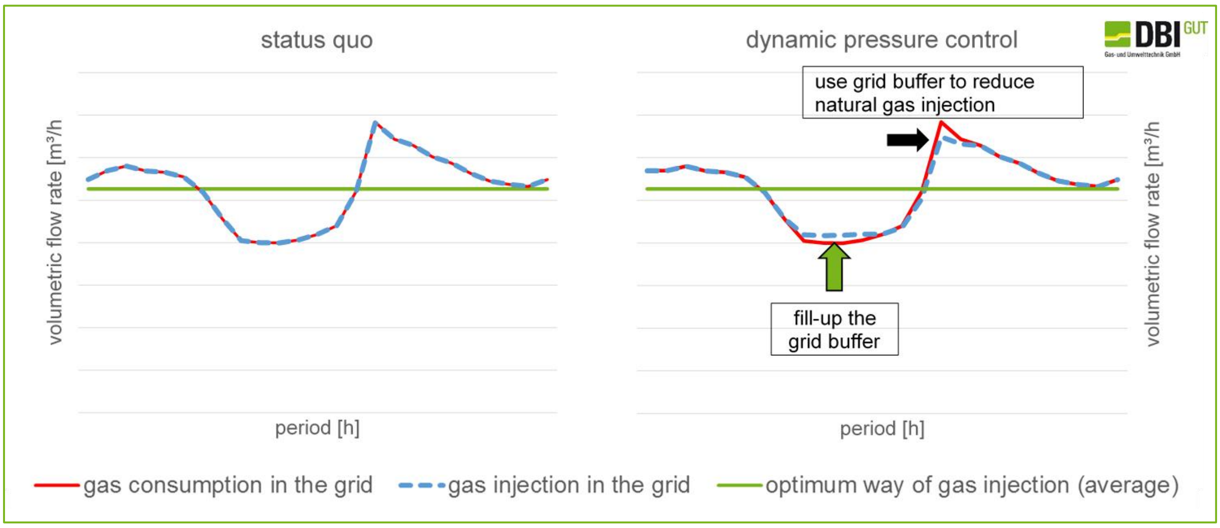
3.2 RESULTS – URBAN AREA

The application of the DPC in the analysed urban network may lead to an optimisation of gas procurement by using the grid buffer. Unlike the above described seasonal balancing of the pressure control, the gas flow has been optimised during the day and thus resulting in condensed daily flow rates during demand peaks.

The current operation mode of the GPRS is demand-orientated, which means that the feed-in of gas directly corresponds to the gas demand on an hourly assessment (see status quo in Figure 2).

To smoothen the demand peak loads it would be necessary to reduce the feed-in of gas during that particular time. The gas, that has been stored in the grid buffer in weak load hours, compensates the difference between gas demand and reduced feed-in. The DPC eventually loosens the correlation between gas feed-in and gas demand and results in a smoothened daily load curve (see blue curve in right diagram in Figure 2).

Figure 2: Effect of the dynamic pressure control on gas procurement optimisation (urban area)



The upper pressure limit has been reached during times of weak load either by raising the set-pressure of the GPRS or by defining an increased quantity for feed-in of gas (quantity-based control). The grid storage is being filled in times of weak gas demand by the increased feed-in (the pressure difference between the GPRS and the downstream network declines) and thus a grid buffer develops.

The gas feed-in by the GPRS during heavy load falls behind the final gas demand of consumers. The gas supply of the network is covered by different GPRS, which are working with gradually varying pressure levels. The GPRS is only feeding-in gas when the pressure level within the network drops below the set pressure of the particular GPRS. This eventually results in a maximised pressure difference between the GPRS and the downstream network. The gas stored in the grid buffer meets the gas demand, and thus the daily load curve is smoothened. In times when the pressure drops below the feed-in pressure of the GPRS, the gas network is supplied by the GPRS.

3.3 Technical requirements for adjustment to the DPC

The technical requirements for adjustment to the DPC, the pressure-orientated operation mode, differ clearly depending on the chosen aim. The capacity for biogas feed-in to the medium-pressure network in rural areas can be enhanced without any technical adjustments of the GPRS, because the seasonal adaptation of the pressure limits of the gas pressure regulator devices and security devices twice a year can be done manually. In the urban network area however, the adjustment of the pressure limits has to be done on a daily basis, which would require both an automatic or remote adaptation and accordingly a refitting of one or more GPRS.

3.4 Transferability of the results to other gas networks

The conclusions derived from the impact of the DPC are primarily valid for the two analysed gas networks. The conclusions may nevertheless be transferred. An accurate assessment would however require a more detailed analysis for example of the network topology, location of the respective GPRS as well as the gas demand by a simulated network calculation.

A more simplified approach has been developed, based on the results of the simulation, which allows the estimation on the effectiveness of the DPC in other networks. The approach is based on two key figures, which may be applied to consider possible capacity gains and/or internal order reductions.

The key figures can be calculated by using an algorithm developed by DBI that is considering the geometric volume of the grid, the manageable pressure swing as well as on the consumer structure.

4 Conclusion

The reduction of expenses and higher efficiency of the network operation, caused by the incentive regulation, are of high importance for the gas network system operators. Additionally, more intelligent solutions are required, due to the increasing feed-in of renewable gases. The DPC can help to achieve this.

The DPC enables the active use of the grid buffer of the gas network through utilisation of both the upper and lower pressure limits as well as pressure-orientated operation mode.

This study explored two network areas under different angles:

- Enhanced biogas feed-in in rural areas
- Optimised procurement of natural gas in urban areas

The seasonal adjustment of the feed-in pressure of GPRS and biogas injection stations has been found sufficient to maximise the feed-in of biogas in rural areas. Moreover, an extension of the area supplied is necessary to increase the gas demand in the network in question.

All of the biogas can be fed-in to the extended network throughout the whole year. This applies to heavy load, weak load, and medium load. In all of the three scenarios a minimisation of the lower pressure limits is necessary; on the other hand the upper pressure does not need to be increased. Depending on the location within the network and the type of load, varied feed-in pressures of the GPRS are necessary to achieve a sufficient pressure difference and thus ensuring the enhanced feed-in of biogas.

In comparison to the current demand-orientated operation mode, in the rural area during weak load the compression energy can be lowered by approximately 90 %. During heavy load, the gas demand is far beyond the feed-in of biogas. This is why there is no need for compression of the gas in the high-pressure network. An annual reduction of 95 % of the cost of compression and feed-in to the upstream network can be achieved.

Concerning optimisation in urban areas, it is only necessary to analyse the scenario of heavy load as the reduction of the internal order can only be achieved by decreasing the maximum capacity.

As opposed to the rural biogas feed-in, the DPC has to accommodate for daily adjustment of the operation mode which can be done by either pressure or volume.

The volume of the available grid buffer is crucial to smoothen the daily load profile of the natural gas procurement. The grid buffer depends on the geometric volume of the network and the maximum differences in pressure limits. To lower the maximum demand, best results are achieved by reducing the lower pressure limit and raising the upper pressure limit.

Furthermore, two specific key figures were identified to transfer the conclusions of the DPC in the analysed areas to others. One of the key figure is aiming to assess the potential to enhance the biogas feed-in. The second key figure measures the optimisation of the gas procurement. Both key figures describe the relationship of the available grid buffer and the best-case scenario, based on the geometric volume and the maximum differences in pressure limits.

Based on the investigations, calculations and evaluation is has been proved that the DPC is an effective measure to increase the biogas injection potential (rural case) respectively to reduce the gas procurement (urban case) in the considered networks. The effort to put this measure in place is very low for the rural case, as the pressure adoption is needed just in seasonal intervals. The installation of ICT (information and communication technology) is necessary for the urban case. It has been found that the DPC is a promising option for both the integration of renewable gases and the optimisation for gas procurement. To better evaluate the potential, key figures has been developed but a detailed calculation remains mandatory before implementing this method.

We want to kindly thank EWE Netz GmbH for their great help, for giving us the opportunity to perform this investigation and for their outstanding, friendly support during the whole time of the project.

5 List of Abbreviations

DPC	Dynamic Pressure Control
GPRS	gas pressure regulation stations
ITC	information and communication technology
R&D	Research and Development
SNG	Synthetic Natural Gas

6 List of References

[DBI 2014] ZÖLLNER, Sylvana; HÜTTENRAUCH, Jens; AHLERS, Manfred; DIESEL, Klaus; MÜLLER-SYRING, Gert: *Final Report Dynamische Druckfahrweise* issued by DBI Gas- und Umwelttechnik GmbH upon order of EWE Netz GmbH, Juli 2014.

7 LIST OF FIGURES

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