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Dynamic Pressure Management

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Abstract
In order to reduce natural gas leakage from the gas network and to prioritize biomethane over natural gas dynamic pressure management is required. A system has been developed to dynamically manage the pressure in the distribution grid. By combining field measurements with weather forecasts and historical data, the system will be able to predict future gas demands and act accordingly. The functioning of this system has been proven by extensive testing in a natural gas testing facility. Technical details and test results are still confidential. Details including test results will be available for the paper submission in July 2014.

Introduction
The Dutch natural gas grid is one of the most robust and reliable gas grids in the world. Customers on average experienced a downtime of only 64 seconds in 2013 (in the Liander service area the downtime was just 34 seconds). The grids main strengths are its many interconnections, the total independence of the electric grid (No electricity is required for the transport and distribution of natural gas) and the fact that the grid continuously operates at maximum design capacity. This means that the pressure level in the gas transportation grids is constantly kept at 8 bar(g) and our distribution grids are operated at 100 mbar(g). These are static values, which currently only can be changed manually. Although the relatively high values aid in the reliability of the grid, they also pose some challenges.

Gas leakages

Gas grids, especially older ones, are susceptible to leakages. In particular during summertime, the high pressure causes problems because of the high effusion of methane. The leakages not only lead to potential hazards but also cause environmental damage.

It is estimated that annually about 6 million Nm^3 of natural gas is leaking out of Liander's natural gas grid. This represents an economic loss of € 3.1 million but also corresponds to an equivalent of 90.000 tonnes of CO_2. Methane has a ±25 times stronger contribution to the greenhouse effect than CO_2 and is therefore marked as a high environmental risk.

Since the effusion of natural gas is related to pressure, reduction of the standard pressure level would directly reduce gas losses. Such a measure therefore not only improves the integrity of the grid but will also lead to reduction of grid management costs and more sustainable gas consumption.

Restriction for bio methane insertion

By 2020, the Dutch government aims to cover 14% of total energy consumption with renewable energy sources. To reach this goal a stimulant package has been created for subsidising sustainable energy production initiatives. This package makes it interesting for companies and farmers to produce Biomethane or Green Gas. Liander consequently is faced with an exponential growth in demand for the injection of Green gas into the grid.

Due to the fact the grid continuously operates at maximum pressure levels, there is only limited room available for insertion of Green Gas. Especially in the summer period, when gas consumption is almost zero, many demands have to be rejected for this reason. This conflicts with Lianders aims of becoming a sustainable gas grid operator.

Current law does not yet force grid owners to facilitate the injection of biomethane. Additional costs for insertion of green gas therefore are to be paid by the biomethane producer. This however may very well change in the near future, causing high costs for grid owners related to implementation of solutions and distribution of surpluses of (bio)gas.

By reducing the pressure in the summer to minimum allowable levels, more "buffer" would be available for the insertion of bio methane, leading to a more sustainable gas grid. A possible answer to abovementioned challenges was therefore found with the introduction of Dynamic pressure management.

Dynamic pressure management (DPM)

Dynamic pressure management is based on the idea that the overall pressure in a gas grid can become fully controllable. It is build upon different levels of control, in all of which the pressure in the gas grid can be more or less independently managed.

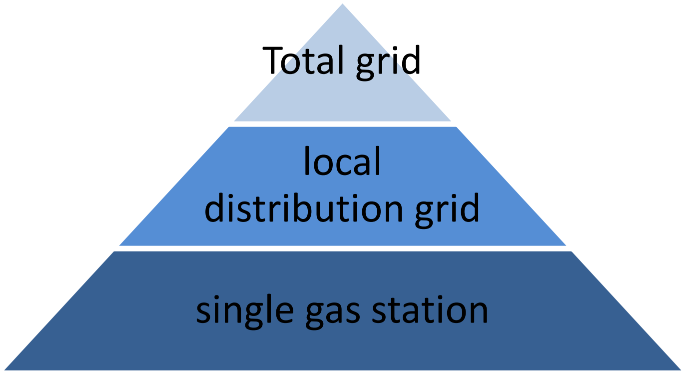

Figure 1 The three stages of dynamic pressure management

Stage one

The first stage of DPM is finding means to centrally managing the outlet pressure of a single gas station. By introducing electronic control equipment, this gas station is capable of self-regulating its output pressure. A local remote terminal unit RTU continuously calculates the necessary control parameters to maintain the chosen set point, which is transmitted to the RTU from Liander's Central Control Room (CCR). During this stage no interaction with other gas stations takes place yet and the set point used will have a fixed value. For that reason the station will not act dynamically yet. Nevertheless the introduced components are needed as a base for Stage two.

Stage two

A local distribution grid is fed with two or more gas stations. Via a communication network, all stations are interlinked with each other through the CCR. This grants the possibility to change the pressure in the whole outgoing distribution grid centrally.

By using pressure sensors in the periphery and/or weather forecasts, the grid can be programmed to operate on minimal pressure levels while still ensuring gas supply to all clients connected to the grid. When the connection to one of the stations is cut off, all other stations automatically return to their original set point, thereby preventing a possible shortage of gas supply.

Stage three

The highest stage within DPM is controlling the whole transportation and distribution grid simultaneously. This makes it possible to use weather forecasts or historical data to manage the pressure within whole regions. It also grants operators options to remotely turn specific gas stations on or off during maintenance or calamities.

Proof of Principle phase one

To determine the feasibility and to prove the principle of DPM in a single gas station, a multidisciplinary research team was assembled. The team consisted of consultants and engineers with various backgrounds, active in diverse divisions within Liandon.

Criteria

At the beginning of the project a list of criteria was drafted which served as a guideline for finding the right solution. The main criteria were:

- The solution must be able to manipulate the exiting pressure.
- The solution must be easily integrated into existing gas stations.
- The solution must not have a negative effect on the availability of supply.

One of the advantages of the Dutch natural gas grid is its independence of the electric grid. As mentioned earlier, no electricity is needed for the transportation and distribution of natural gas through the grid. Introduction of electronic components therefore have long been opposed for fears of losing this advantage. The biggest challenge thus would be to convince the grid operator that dynamic manipulation of the outlet pressure of gas regulators is possible without creating negative impact on security of supply.

First attempts

First attempts to finding a solution were focused on changing the set point of the pilot regulator (PSR). Using an ATEX proof electric motor it was possible to lower and raise the outlet pressure. The biggest problem with this solution was that during a power or communication loss the system could not return to its original set point, creating a risk to the security of supply. Another problem was the size and weight of these actuators, originating from the explosion safety requirements.

Chosen solution

After failing to resolve the problem using conventional methods, a new approach was taken. This approach was based on the idea of reducing outlet pressures by direct manipulation of the loading pressure, instead of manipulation of the PSR set point.

The solution found during this approach takes over the functionality of the pilot entirely by reducing the pilot inlet pressure, and thereby the loading pressure, to the main regulator. This was achieved by means of an electronic pressure controller (ESR) (see figure 2).

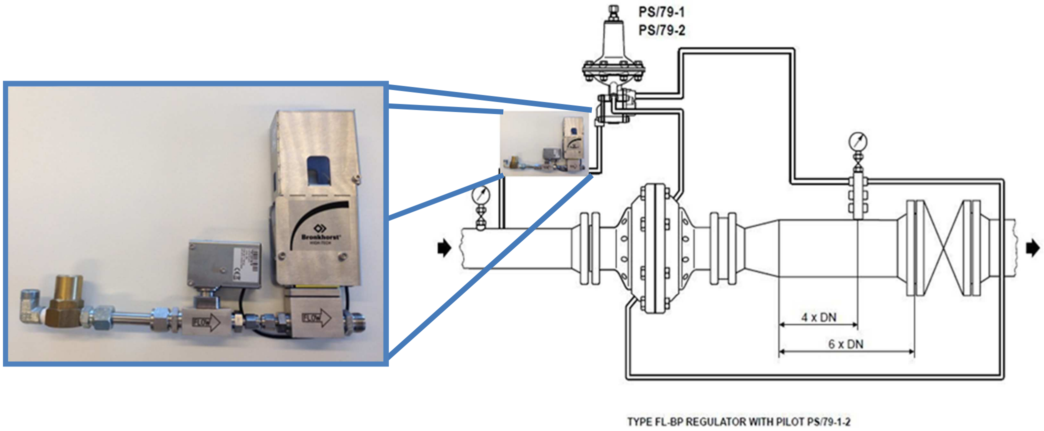

Figure 2 detail ESR (left) and gas regulator configuration with ESR (right)

Configuration

The whole setup consists of an ESR, a pressure transmitter and a RTU unit with PLC functionality.

The pressure transmitter is used to measure the outlet pressure. The RTU is the central control centre of the ESR configuration. By comparing information from the pressure transmitter with the given set point value, the RTU continuously calculates the necessary valve position of the ESR.

Via an internet connection the RTU communicates with the central control room of Liander. This makes it possible to change the set point of one or more stations remotely.

By choosing an ESR with an open default configuration, the system is able to return to the original static pressure set point of the pilot in case of a power or communication loss. The RTU's in the affected stations are programmed to automatically shut down when communication with the CCR is lost. The CCR automatically reacts to this loss of communication by shutting down the remainder of the RTU's in the affected grid. This action guarantees the supply of gas through the gas station, without creating an overpressure in the outlet side of the station.

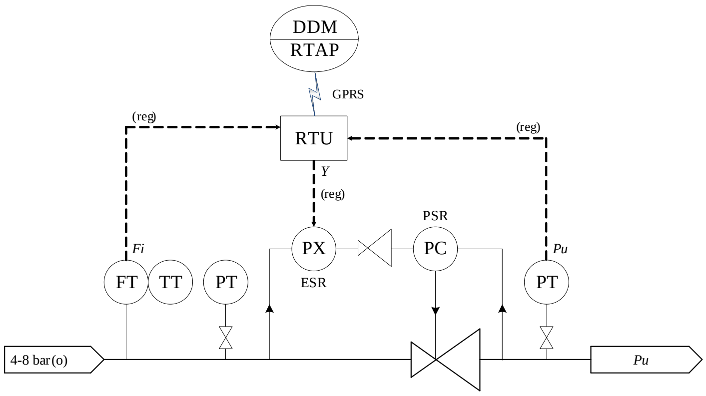

Figure 3 Schematic view of total smart gas station concept consisting of flow, temperature and pressure measurements as well as dynamic pressure control

The found solution can be extended with pressure, flow and temperature transmitters, turning the gas station into a so called smart gas station.

Working modes

The ESR configuration can operate in three different modes, depicted in Figure 5Figure 4.

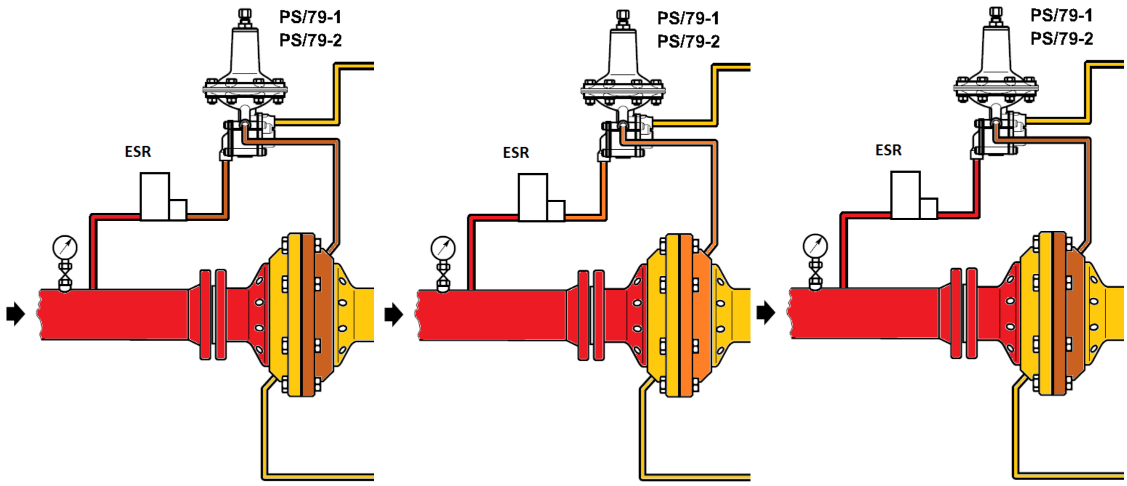

Figure 4 Left ESR is in standby mode ; middle ESR is operational ; Right ESR is in failsafe mode

Standby mode

The ESR is powered but is set in its maximum regulating range (100%). The ESR lowers the loading pressure just above the set point of the pilot. The static set point of the pilot therefore is leading.

Operational mode

When a lower outlet pressure set point is sent to the RTU, the ESR will reduce the loading pressure, and therefore take over the role of the Pilot. The Pilot itself is fully opened, trying to reach its static set point.

Failsafe mode

During power loss the ESR will place itself in its fail safe position, i.e. fully opened. The conventional Pilot takes over and the outlet pressure is returned to its original static value.

Results lab testing

To proof the solution found during the first part of the project, a series of lab tests were performed at Liandon's own Test Facility Gas in Amsterdam.

These test consisted of:

- Proofing the ESR can be used to stably reach and maintain a desired set point
- Proofing that a signal or power loss does not result in a unstable gas supply

Test one: Stable manipulation of the outlet pressure with the ESR

To proof the ESR can be used to safely manipulate the outlet pressure, a complete gas station was reconstructed using the ESR configuration mentioned earlier. An inlet pressure of 8 barg was introduced to the gas regulator and a continuous gas demand was created behind the gas station. The conventional pilot is set to keep the outlet pressure at 100 mbarg.

During the first series of tests the set point of the ESR is sequentially changed to 80, 60 and 40 mbarg. One of the main requirements during these tests is the absence of undershoot of the outlet pressure. A too low value of the outlet pressure could cause a disruption in the security of supply.

Figure 5 shows the results of these set point changes.

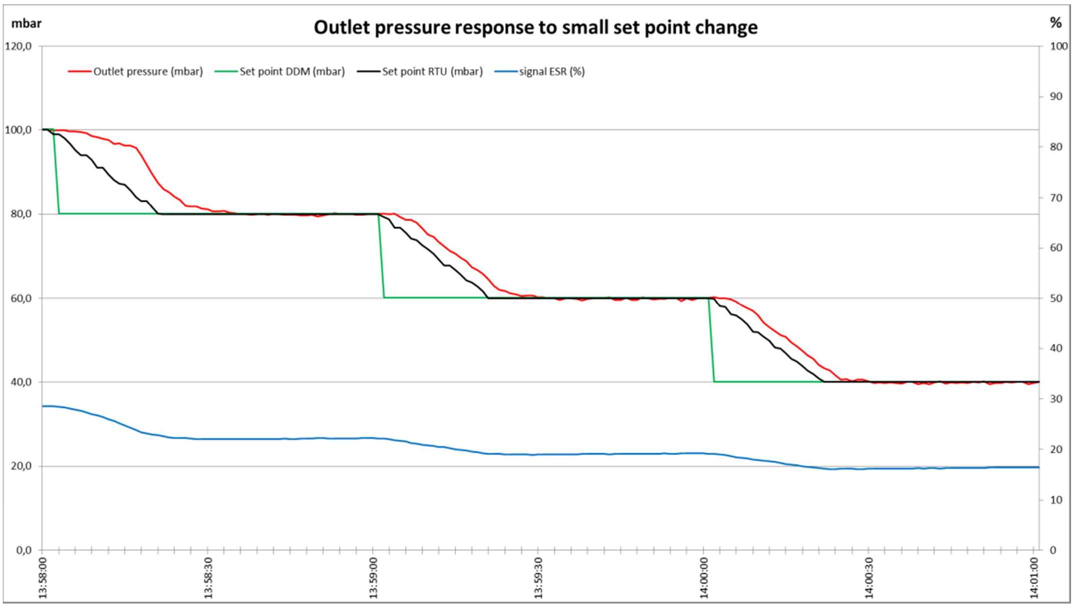

Figure 5 effect of set point changes in ESR on the outlet pressure

The green line in this graph represents the set point value that was sent to the RTU. The black line represents the corrected set point value sent from the RTU to the ESR. The red line represents the outlet pressure. The results show that the outlet pressure follows the change in set point perfectly without showing any signs of instability; no undershoot was detected during these tests. The outlet pressure never drops below the minimum allowed value of 40 mbar(g). Even with larger set point changes, no instability in the outlet pressure occurred. (see figure below)

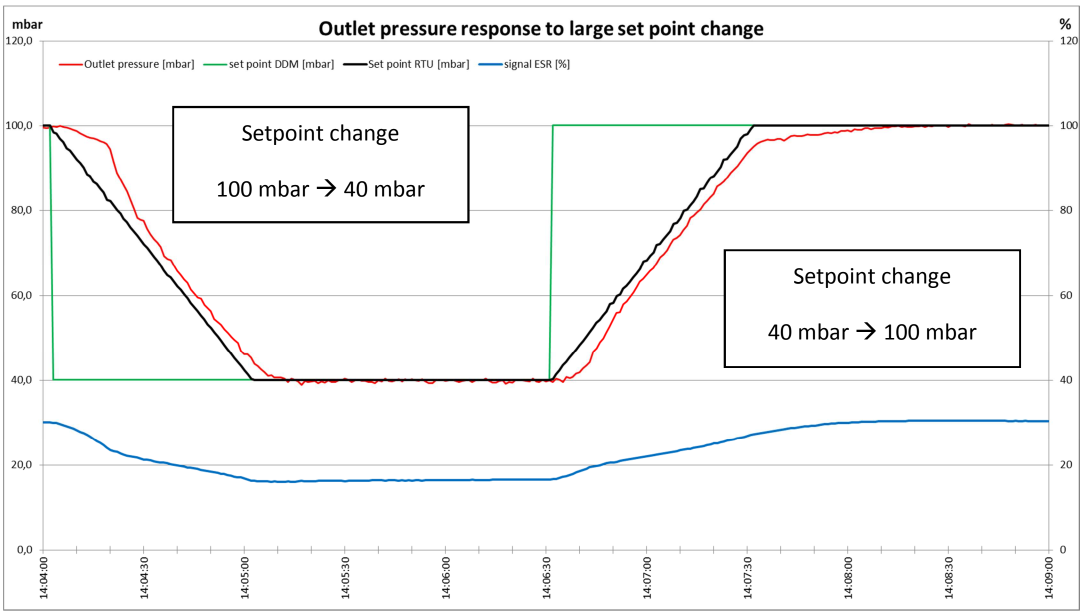

Figure 6 Effect of maximum set point change ESR on outlet pressure (100mbarg --> 40 mbarg and back)

Test two: Response to loss of signal / power

The second test was to proof that a power failure would not result in an instable outlet pressure. In theory the conventional pilot should take over and stabilize the outlet pressure at the pre-set value of 120 mbarg. The outlet pressure must not surpass 140 mbarg due to the triggering of pressure safety devices built into the gas station.

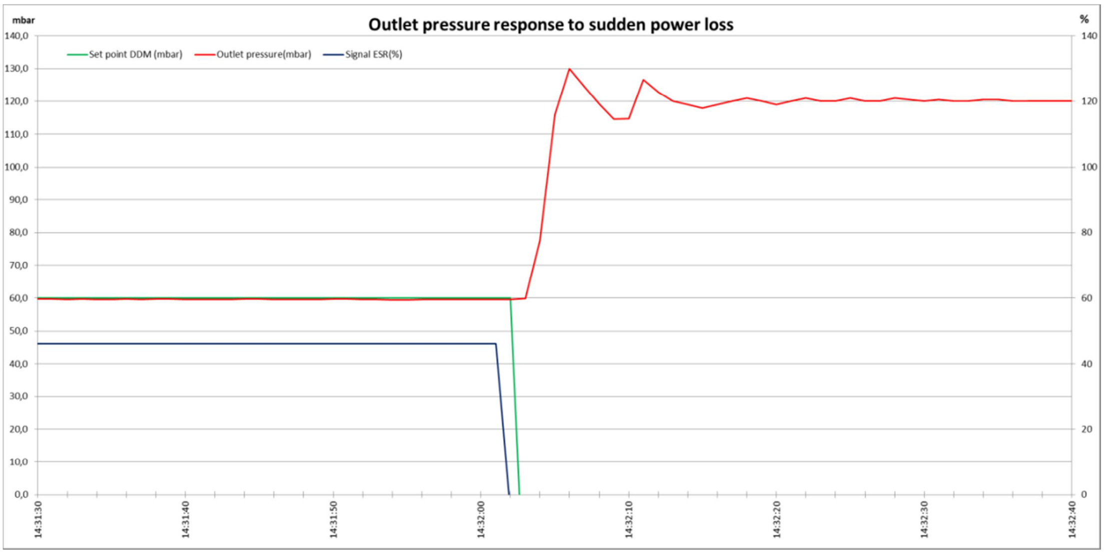

Figure 7 Outlet pressure response to a sudden loss of power to RTU and ESR

The results show that the conventional pilot takes over perfectly without surpassing the boundary value of 140 mbarg. After a few oscillations the outlet pressure stabilizes to its pre-set value of 120 mbarg.

Conclusion phase one

The solution found in phase one is ideal for dynamically changing the outlet pressure in new as well as existing gas stations. Given set points for the outlet pressure are reached fast and remain stable. Also the chosen failsafe configuration works perfectly, preventing unwanted outlet pressure values.

Next phase: Field test of stage two in a local distribution grid

The next step will be to proof that a local distribution grid can be dynamically balanced using the found solution of phase one of the project. A distribution grid connected to multiple gas stations in the city of Zutphen will serve as pilot location for phase two. These gas stations will all be equipped with an ESR and RTU and pressure sensors will be installed in the periphery of the distribution grid.