DESIGN OF THE LATEST GASUNIE COMPRESSORSTATIONS IN A CROSS BORDER ENVIRONMENT IS A CHALLENGING BUSINESS

By

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1. BACKGROUND

Gasunie operates a relatively long (11.600 km) and complex pipeline network in a highly densely populated small country, the Netherlands, and a comparable network in Germany. Recently new projects have been initiated in order to realize a Gas Round About in the Netherlands, meaning that predominately 48" / 80 bar pipelines have been laid and 2 new compressor stations have been realized in order to be able to flow gas from and towards cross border exit and entry points. Gas coming from Norway / Russia is flowing through the Netherlands to the neighbouring countries like Germany, Belgium France, Italy and also to the United Kingdom through an offshore pipeline. Also liquefied natural gas (LNG) delivered by boat at the Gate terminal of Rotterdam is transported as gas through the western part of Holland and will also be compressed by the newly build compressor station CS Wijngaarden in **any** by the dispatching centre desired direction.

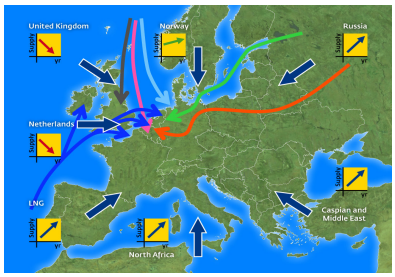

Figure 1 : cross border gastransportation

Figure 2 : gas roundabout in the Netherlands

In January 2007 the Department Large Projects of NV Nederlandse Gasunie has developed, as a dedicated project team, a very large project consisting of the engineering, procurement and construction of different, in the Netherlands situated, new 48", 80 bar pipelines with a length of approximately 500 km and 2 new greenfield compressor stations with a total power of respectively 63 MW and 42 MW. The scope was established after the open season of 2005 and is in line with the aim of Gasunie's management to realize the gas round-about of Europe, see figure 2, in the Netherlands as one of the pillars of the operational excellence challenges. Since shippers have nominated in several open seasons an increasing amount of gas that should be transported through the Netherlands, the network department of Gas Transportation division of Gasunie has calculated the necessity of the enhancement of the existing gas transportation network resulting in the mentioned new pipelines and compressor stations. The projects with a total budget of 1,5 billion Euro's started in 2007 and were

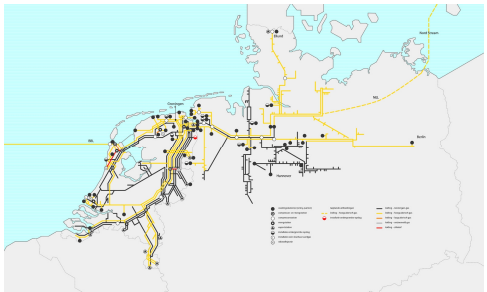

Figure 3 : Gasunie's network

successfully delivered to the Operational and Gas Transportation department by October 2011, after an overall construction period of 2.5 years. Due to the fact that the project team has received a lot of resistance from the local citizens the planned permitting period for the compressor station Wijngaarden has been extended with about a year in order to deal with 27 unexpected, official notices of objections, 11 law suits where 5 were escalated up to the "Raad van State", being the highest court in the Netherlands. Anyway since this is the right of the citizens in the Netherlands, the Gasunie project team has been able to collect all the necessary permits within the extra year and started the construction of the Wijngaarden compressor station at the 8th of April 2009. After a very fast, but successful commissioning and start-up, the station has been in operation since the 1st of October 2011.

2. AIMS

This paper will give an overview of the design criteria of the latest electrical driven compressor stations with magnetic bearing systems and low or even no emitting seal gas flow. Since gas transportation is nowadays completely different and much more complex than in the past, the design criteria are really challenging. The design criteria are among many others the availability, flexibility, safety, controllability, operability and maintainability of the total station, but also for all the specific apparatus within the station. Furthermore the compressor station must have an operational excellence, must fulfil all the criteria related to the permits and licenses to operate, must be very safe and highly available at the same time and above all cost-efficient and market driven. The compressor stations are pumping gas from and towards cross border exit/entry points, meaning that the operational availability for gas transportation is very important due to the firm contracts that have been negotiated by the gas transport department with the shippers. One of the latest designed, constructed and operational compressor station is CS Wijngaarden. CS Wijngaarden is located in the western part of Holland, see figure 4A and figure 4B. In order to fulfil local legislation the realization of the compressor station at 9 hectares had to be compensated by a landscaping of about 12 hectares, with ditches, frog ponds and a lot of trees, working as curtains to prevent that neighbouring citizens have an open view at the station, as one can see by the artist impression in figure 4B. The station is build in the so called green hart of Holland, the neighbouring citizens are situated at about 700 meters, meaning that noise and external zoning contours were not directly a problem. It has been a challenge to discuss all the non technical issues with the legislator(s) and to receive the permits in time, although there has been an extra permitting period of one year. The compressor station is situated at a crossing of pipelines and is receiving gas from the 4 wind directions, as shown in figure 5. Gas from the North is coming from CS Beverwijk, which is the gas from the North sea suppliers and an increasing amount of Russian gas and

Figure 4A : new pipelines in the Netherlands

figure 4B : artist impression of CS Wijngaarden

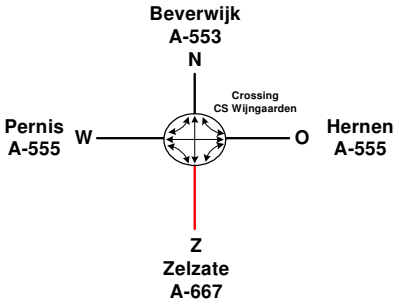

Figure 5 : CS Wijngaarden at a pipelines crossing

Norwegian gas from the east-west pipeline GWWL. Gas coming from the Western part is gasified gas coming from LNG delivered at the Gate terminal and storage gas from Gasunie's LNG-plant at the Maasvlakte. Gas from the Eastern part is coming from Hernen being the backbone of H-gas network in the Eastern part of Holland. At the new compressor station Scheemda, gas from Norway and part of the gas coming from Russia through Oudestatenzijl, being the cross border facility between Germany and the Netherlands, is compressed towards Ommen and Hernen. The gas flowing towards or coming from the Southern part of Holland is received at Zelzate, being the cross border facility between Belgium and the Netherlands. One of the basic starting points of the gas transportation department related to design criteria of this compressor station was that flow and pressure must be controlled into any direction, see adjacent figure 6. Anyway the influence of the overall performance of the gas compressor station at the cross border gas flows and pressures is very large. This is among others one of the reasons that the design criteria about the availability, flexibility and operability have been very high compared to previous designed compressor stations. At first the compressor station is designed with double suction lines, a filter separation module, a compressor module, a cooling module and double discharge manifold according to figure 7. Taken into account the rangeability per item of each module and the desired flexibility of the compressor station there were an enormous amount of valves necessary. Of course one of the challenges of the project management is to deliver according the desired scope and design criteria, but also at the lowest possible costs. So one of the cost reduction measures that have been taken during the engineering phase, after evaluating advantages and disadvantages, is that the after coolers have been replaced by one recycle cooler and that filter separator, the compressor and associating surge line per compressor have been placed in-line, as is schematically indicated in figure 8. Meaning that the module configuration was replaced by an inline configuration. The costs, but also availability and operability have been calculated to be able to take a quantified decision. It goes beyond the aim of this paper to go in to more detail, but the project team was able to reduce the number of (manifold) valves with 30, to reduce the size of the manifolds (mostly diameter) and to reduce the associating costs with about 7,5 M€. In order to have a gas flow over the compressor station when the compressor units are not online two check valves across the station have been added as can be seen in figure 8. The recycle cooler has been used during (hot) commissioning, because it has been designed to be able to recycle the maximum flow of one compressor. As a result thereof every compressor has been commissioned without any interference or determined time frames enforced by the gas transport dispatchers, because the total flow was recycled over the cooler bank, resulting in a zero disturbance in gas transport flows, consequently realizing a very fast commissioning period. Since no communications with CCP (Central Command Post, situated in Groningen) about availability of the required / desired flows and pressures in the gas transport network were necessary, the commissioning of the compressors did not cause extra time delays. However later all the specific gas transport modes have been thoroughly tested by dispatchers, local operators, project team engineers and specific commissioning engineers, knowing that the compressor sequences and controls have already been commissioned .

wind direction	place	cross border	gas to / from	
N	Beverwijk	BBL	United Kingdom	Transco
W	Pernis	LNG	several	
O	Hernen	Rysum	Norway	Gasco
		Oude statenzijl	Germany/ Russia	Wingas / Gazprom
Z	Zelzate	Zelzate	Belgium	Fluxys
				Wingas

Figure 6 : gas flows from and to CS Wijngaarden

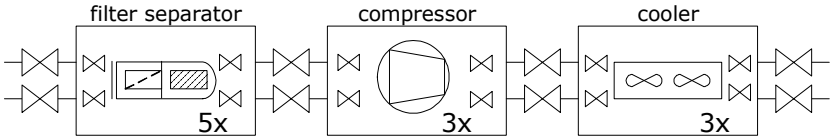

Figure 7 : module configuration CS Wijngaarden

One of the other advantages of the cooler bank is that it also can be used during operational period of time to keep the flow setpoint per compressor at the most efficient working point within the compressor envelop. In order to allow for an undisturbed and continuous recycle flow, the recycle cooler bank is flow and temperature controlled by the Station Control System. In the schematic representation of the compressor station, see figure 8, most of the manifold valves are not shown to keep it simple. As one can understand there are indeed a lot of valves to be controlled in an open or closed position in order to be able to switch compressed gas flow from one to another desired flow direction and vice versa. Moreover to switch the compressed gas transportation direction from West to South in another desired direction without stopping the gas flow at the entry / exit points, is also one of the major challenging issues for this compressor station. Not necessary to mention that it must be possible to switch automatically all the gas transportation modes from one desired mode to another. Since the gas transportation department is most willing to sell firm gas transport contracts rather than interruptible gas transportation contracts, especially the timely start-up after construction and fast commissioning period has been a hot issue.
The paper will get more in detail about the technical possibilities and transport modes that have been introduced during the design and the organisational matters that have been arranged in order to guarantee a timely delivery and hand-over of the station to the asset owner organisation, the operational department and of course the dispatching centre as part of the gas transportation department.

3. METHODS

The new compressor station in the western part of Holland that is part of the Gas Roundabout must be able to transport and compress the gas in **any** desired direction. In order to be able to transport the maximum station flow the process engineer has calculated that the compressor station should consist of at least 3 compressors of 10,5 MW each. Due to the maintenance policy laid down in the Gasunie Technical Standards (GTS) the design criteria is N+1, whereas N is the number of compressors for the nominal flow and 1 is the hot spare unit which is fully configured into the station manifold and utilities. The compressor unit consists out of two compressors and one motor at the same rotor. The motor is electrically powered with a variable speed drive. The compressor unit is completely sealed, not emitting seal gas and equipped with magnetic bearings and per compressor unit installed in an enclosure with a dedicated crane to lift only valves and other equipment, but not the compressor unit. The station consists of 4 identical compressor lines. Each compressor line has its own filter separator with surge line, check valves and utilities as shown in the adjacent figure 8. One of the major reasons to design this in this matter has to do with the desired gas transport availability. The 4 compressor also have double suction and double discharge manifolds so that the gas can independently flow from North to South ***and*** East to West or in any other combination at the same time with different flow and/or pressure settings. This means that the compressor station Wijngaarden actually consists of two fully independent compressor

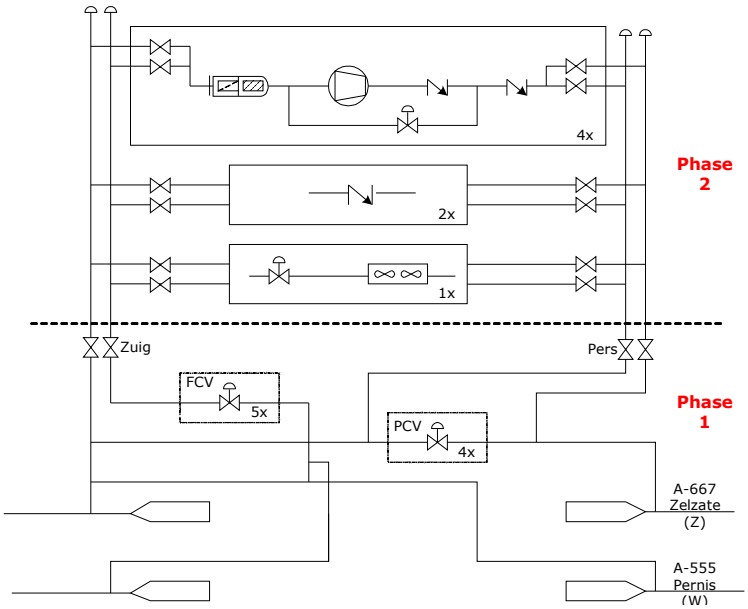

figure 8 : inline configuration CS Wijngaarden

stations, see figure 9. The compressor stations called C-018 and C-118 normally consists of 2 compressors per station, with a maximum of 4 compressors per station. Since the operator can select per compressor to which compressor station a specific compressor belongs, all the selections of valves are included into the control software of an Unit Control Panel (UCP) per compressor. This also implies that not only the main valves for the gas flow are switched from one station to another, but also all the other valves in the anti surge control lines, other utility valves and of course the control instruments. The safety instruments (1 out of 3) are not switched and are directly positioned nearby the compressor unit. The possibilities to switch a specific compressor into a compressor transport mode are 6. These are as indicated in figure 11.

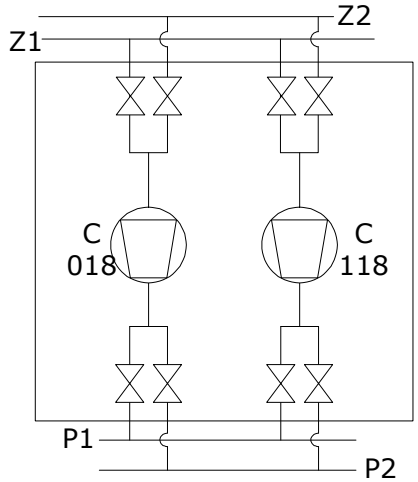

Figure 9 : 2 compressor stations

During the design phase 4 special gas transport modes have been elaborated and agreed upon. Especially challenging is that during the construction phase, 4 more gas transport modes have been developed by the gas transportation department. Although there was a zero change policy ordered by the project manager, due to the strict RFO-date (Ready For Operation), the project team has successfully implemented the extra desired transport modes into the software of the Station Control System right after SAT (Site Acceptance Test). The local Station Control System can automatically switch over from one gas transportation mode to another by local operator or CCP (Central Command Post)-operator command. It is not the intention that compressors are switched off and must be restarted as a consequence of such a switch over. Also it is not the intention to wait for the gas transport system to have balanced the flow in a natural way by the market demand. Due to the large buffering of the different pipelines (caused by large diameter and length) the switching over by automatic bypass valves will, without any doubt, take too much time, consequently causing an undesired flow stop down- or upwards the compressor station. To be more flexible there are 2 reducing stations included in the (overall) compressor station design. The reducing stations can be switched into a mode that they either work as a flow- or pressure reducing station. Each reducing station has been implemented to control the differential pressure over the compressor station when switching from one gas transport mode to another, consisting of a number of control valves in accordance with the rangeability of that station. And of course the operation of these reducing stations can be controlled locally, but also from the CCP in Groningen. Both systems can be controlled in a local way meaning that the local operator or the dispatcher from Groningen can give a setpoint. The system however can also be controlled in an automatic way, meaning that the new chosen gas transport scenario determines whether or not flow or pressure must be reduced in order to be able to switch over from the current to the desired gas transport mode. Moreover the station recycle flow loop, with or without

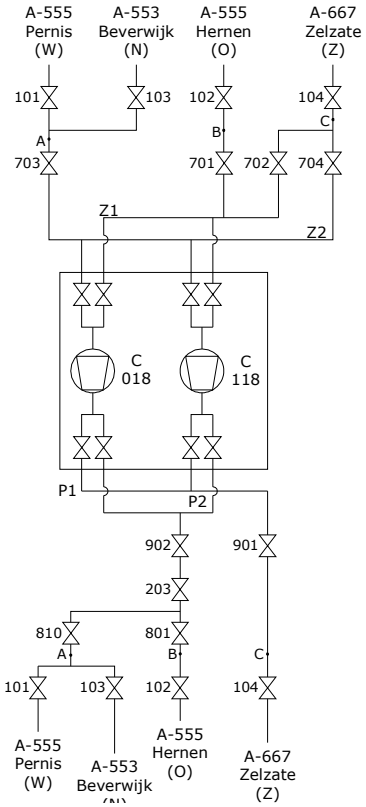

Figure 10 : gas transport configuration

#	C-018	C-118	
1	Z1.P1	Z2.P2	= Z1.P1+Z2.P2
2	Z1.P2	Z2.P1	= Z1.P2+Z2.P1
3	Z1.P1	Z1.P2	= Z1.(P1+.P2)
4	Z2.P1	Z2.P2	= Z2.(P1+.P2)
5	Z1.P1	Z2.P1	= (Z1+Z2).P1
6	Z1.P2	Z2.P2	= (Z1+Z2).P2

Figure 11 : compressor modes

cooling bank, can be used to pressurize the differential pressure across the specific pipelines. Another advantage of the design of this compressor station is that the commissioning and performance verification of each compressor unit can be executed without interference or disturbing the regular gas transportation. By having designed and installed one recycle cooler with a (flow) control valve (see figure 5) the local operators are able to flow the gas from one compressor unit back over the recycle cooler into the suction manifold, without heating up the gas temperature. Therefore this mode can last as long as it is necessary for testing or commissioning and under operational condition to keep the compressor units within the compressor envelop. Even if the rest of the compressor station is in full operational use for gas transport still another compressor unit can be tested as described.

From					CS		Towards			
trans-port mode	dir.	place	pipe line	suction header	C-018	C-118	dis-charge header	place	pipeline	dir.
1	W N O	Pernis Beverwijk Hernen	A-555 A-553 A-555	Z2 Z2 Z1	Z1-P1	Z2-P1	P1	Zelzate	A-667	Z
2	W N Z	Pernis Beverwijk Zelzate	A-555 A-553 A-667	Z2 Z2 Z1	Z1-P2	Z2-P2	P2	Hernen	A-555	O
3	W N	Pernis Beverwijk	A-555 A-553	Z2	Z2-P2	Z2-P1	P1 P2	Zelzate Hernen	A-667 A-555	Z O
4	O	Hernen	A-555	Z1	Z1-P2	Z1-P1	P1 P2	Zelzate Pernis Beverwijk	A-667 A-555 A-553	Z W N
5	O Z	Hernen Zelzate	A-555 A-667	Z1 Z2	Z1-P2	Z2-P2	P2	Pernis Beverwijk	A-555 A-553	W N
6	Z	Zelzate	A-667	Z1 or Z2	Z1-P2		P2	Pernis Beverwijk Hernen	A-555 A-553 A-555	W N O
7	O W	Hernen Pernis	A-555 A-555	Z1 Z2	Z1-P2	Z2-P1	P1 P2	Zelzate Beverwijk	A-667 A-553	Z N
8	O W	Hernen Pernis	A-555 A-555	Z1 Z2	Z1-P1	Z2-P2	P1 P2	Zelzate Beverwijk	A-667 A-553	Z N

Figure 12 : gas transport modi

To switch over from one gas transport mode to another a number of pre-defined steps will take place. The statuses of these steps, as well as the previous transport mode and new selected transport mode are presented to the operator. The operator is allowed to switch valves by himself, but he is also able to control the progress of the different steps in order to be able to look for any “problem” if the execution of a specific step takes too long. Another possibility that have been implemented, because of flexibility reasons for the operator, is gas transport mode 9, which is a totally free mode without any automatic switching or gas route detection and – control. On the other hand since it is a very complex station with enormous amount of possibilities and thus flexibilities one must be very experienced to use this specific transport mode. However, since this mode is implemented in the local station control system, but also in the CCP control system, it increases the availability of the station after an error or failure in a specific gas transport mode.

4. RESULTS

At August 2011 the pre-commissioning of the compressor station was almost finished. Two of the four compressors have already run at 60 bar and 3500 rpm. The construction of process related items were finished and handed-over from the contractor to the commissioning organisation, which was a separate group within the project team added with 4 local operators. At the current time of writing this paper the construction contractor is still working at some not process related items like landscaping, the fences and security system and the paving of the roads etc. By the time the author is presenting the paper at the WGC 2012 in Kuala Lumpur, Malaysia, the contractor will have finished all the remaining items and the project team has left the CS Wijngaarden premises.

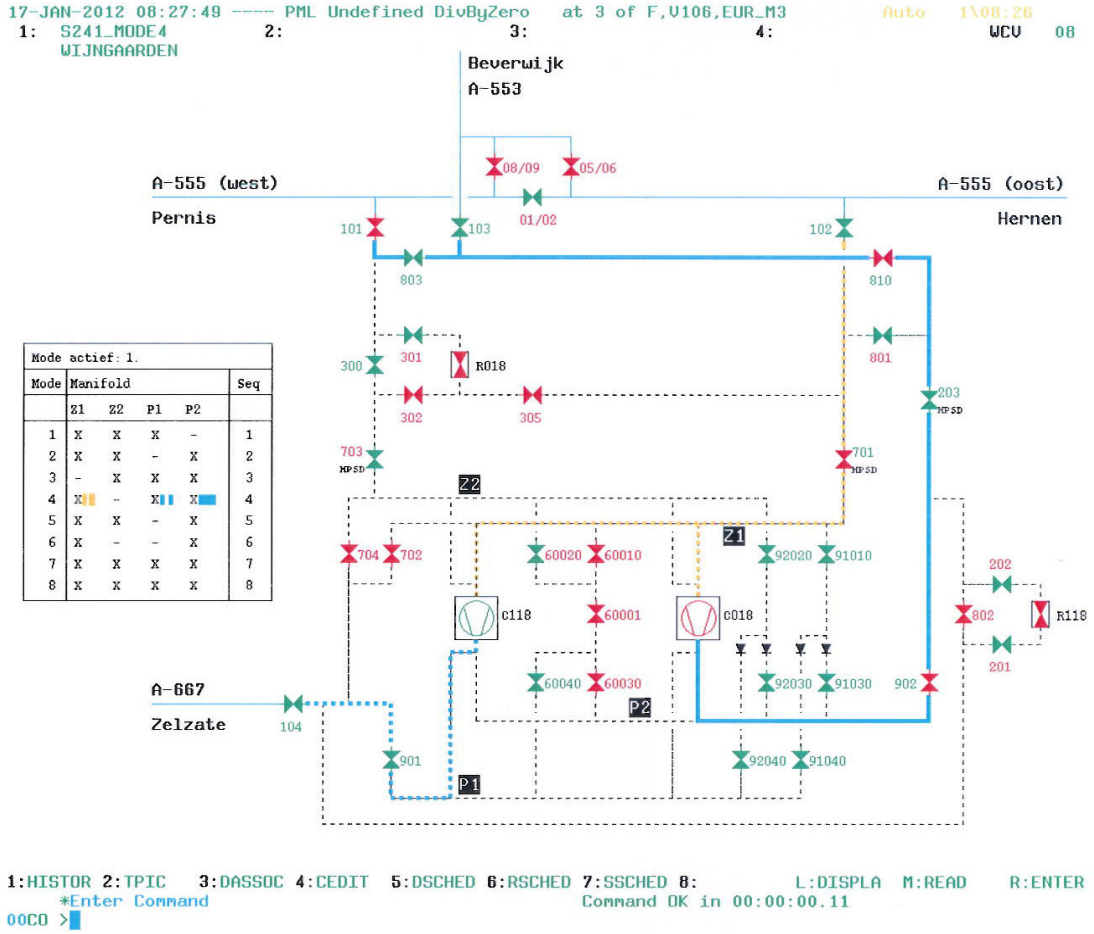

figure 13 : display of local operators and CCP-dispatchers

The local operator and CCP dispatcher are making use of the same displays see figure 13 above, so that communications between the two parties is at least not hampered by differences in the actual measurements and or statuses of the operational equipment. Of course all the measurements and statuses have been thoroughly tested and measures have been taken to mitigate the differences. Also a few learning sessions have been held to get awareness of special market situations. Those session were executed with local operators, CCP-dispatchers, project - and commissioning engineers to retrieve as much information and knowledge as possible. At those displays the actual pressures and flows are presented, but also the setpoints of the 2 compressor stations, the 2 reducing stations and open/close position of main gas transport valves. The active gas transport mode is presented, as well as from where the station is controlled (Groningen or local), if the station is manned or

unmanned, if the station recycle loop is active / in-operation / standby /out of operation and if a compressor is free for start (VVST) or loaded (in Dutch “belast”).

In the underneath showed graph, figure 14, with actual flows and pressures of the different pipelines, made at the control system of the CCP dispatching center in Groningen, there has been a mode change-over from transport mode 4 to transport mode 1. The pressure scale is at the left hand side of the graph, while the flows are presented on the right hand scale.
The current situation at 16-01-2012 was

- Pressures of Zelzate and Beverwijk at the same level {~62 bar(a)};
- Large differential pressure difference between Zelzate/Beverwijk and other pipelines {Pernis / Hernen};
- Reducing station R-118 in operation at flow;
- Reducing station R-018 in operation at flow;

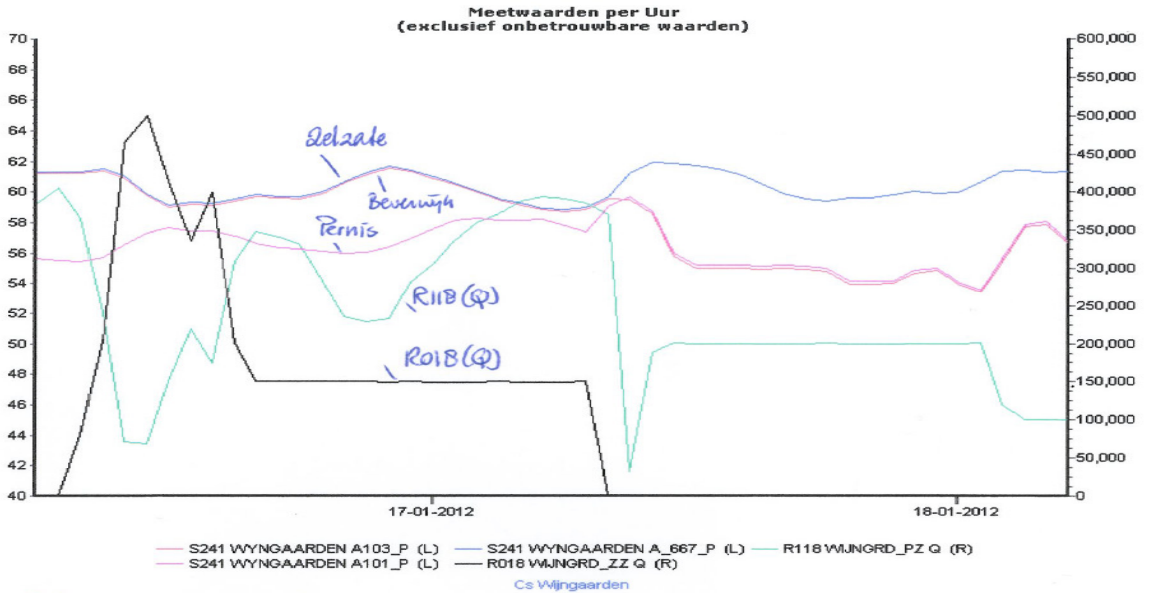

Figure 14 : Dynamic results of a gas transport mode switch

At the morning shift of 17-01-2012 it was decided by the senior dispatcher to switch over from gas transport mode 4 to mode 1, because it was needed to have a compressor to compress the gas flow towards Zelzate according to the changed market situation. The following actions have been taken by the dispatcher on duty:

- The differential pressure between A-555 (Pernis) en A-667 (Zelzate) has been balanced by increasing the flow setpoint of Reducing station R-118;
- The appropriate valves have been manually opened / closed by the dispatching center, see figure 13;
- Gas transport mode 1 has been selected, when the differential pressure has been reduced till ≤ 0,5 bar the mode change is effectuated resulting in the same pressures at A-555 (Pernis) and A-553 (Beverwijk) and a different pressure at A-667 (Zelzate);
- Compressor management system C-118 was started to control the pressure of the Zelzate flow;

The result of the change over was that Pernis and Beverwijk were moved from P1 discharge manifold to the Z2 suction manifold and Zelzate was change from the P1 discharge manifold to the P1 discharge manifold and thus separated from Beverwijk.
As one can see from figure 14 the preparations for the mode change took approximately 8 hours, while the actual step change last almost 30 minutes.

5. SUMMARY / CONCLUSIONS

A new compressor station has been build, constructed in the Netherlands in order to enable the dispatching centre from the gas transportation department to transport gas through the Gas Roundabout in the Netherlands towards several exit / entry points in a cross border situation. This new compressor station is very unique in the world, because it will be able to automatically switch from one gas transportation mode to another by switching valves, flow- and/or pressure reducing stations and 4 compressors such, that all desired criteria from the gas transportation department are met. The compressor units are zero gas emitting units with electrical drives and magnetic bearings. The compressor unit itself consists of 2 compressors and one motor at the same rotor, completely sealed. The compressor station is in operation from the 1st of October 2011 on. Because the station is very complex and flexible, has a lot of possibilities it is very hard for the Local operators but also the CCP-operators in Groningen to learn how to operate the station under all the different market situations. Apparently just one learning session with operators is not enough. The availability of the station is very high. However sometimes it happens that the station and/or compressor unit is switched into a standby, off or even an Emergency Shut Down (ESD) position, but that is merely always caused by a human error. This is one of the reasons that the cause of these errors is discussed with the operators (local as well from CCP) together with the project engineer and responsible staff group employees. Not to punish these people, but to discuss the causes and consequences of the mistakes and to learn from it. Also because the operators are organised in at least 4 shifts it is very hard that every operator will have the same knowledge and experiences at a given date.
Besides all kind of project management challenges like permitting and associating resistance from the public, civil engineering measures to deal with the water household, building in the open green hart of Holland at a very unstable ground situation (building on the yoghurt as a colleague has expressed the sloppy ground situation), the great challenge was without any doubt to fulfil all the desires of the gas transportation department to realize a very flexible compressor station that is able to compress gas into an desired direction. The project team has been very successfully in realizing such a station and is looking very proud back at a smooth and in-time project execution.

6. ACKNOWLEDGEMENT

The author likes to acknowledge the good work of his colleagues of engineering-, permitting, operational-, asset management- and gas transportation departments, whom have been working close and good harmony together in the different project teams in the first place. Secondly all the manufacturers, contractors and their employees that have been working at the construction site in order to allow for a successfully opening of the compressor station just before the aimed and Ready For Operation date of the 1st of October 2011. Only with good cooperation and good understanding it is possible to run a large project as the discussed ones. The management team and especially the responsible project manager is looking back at a very successful project.
All parties worked closely together in order to allow the project team to be successful in delivering the two compressor stations Scheemda and Wijngaarden on time. It has been a great challenge, a lot of work and long hours, but everyone has been working as one **TEAM**, meaning **T**ogether **E**veryone **A**chieves **M**ore.