BENEFITS OF GAHP TECHNOLOGY APPLIED TO NATURAL GAS GRIDS: RESULTS FROM REAL CASE APLICATIONS

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Regas srl is a leading company operating as supplier of Italian natural gas distributors. In particular, Regas srl produces gas stations, odorants injection systems, operates services directed to gas systems (pressure regulation, metering, odorization), distributes odorants and gas pressure devices according to contracts that link the company to multinational companies such as Arkema and Itron.

Founded in 1956, today Robur spa is a leading manufacturer whose mission is to offer energy-efficient, gas-fired heating and air conditioning solutions capable of significant energy saving and reducing environmental impact. Robur's extensive experience in climate control, in particular through the manufacturing of Gas Absorption chillers and the new Gas Absorption Heat Pumps, has allowed it to develop heating and cooling solutions for a broad range of sectors ranging from industry, housing, hotels, tertiary like malls and fitness centers.

Background

The pressure on environmental and socio political aspects is driving increasing attention on reduction of CO2 emissions by means of augmented efficiency and increased use of renewable energy across the entire range of energy uses.
On a worldwide basis several attempts are made to improve also the efficiency of the distribution of the gas grid.

Natural gas market in Italy is roughly described by one figure: 83.32 billion cubic meter (Eni, 2010) shipped in the high pressure transportation network, mainly managed by Snam Rete Gas.
On the distribution side, in Italy there are around 200 companies delivering natural gas with local networks. The number of distributors is strongly decreased from the more of 700 subjects (before the liberalization and unbundling process that started in early 2,000) and is forecasted to decrease further to create very large entities, often participated by investment funds.

Most of this gas is decompressed in pressure regulating stations (approximately 9,000) that, in order to safely distribute it, need to proceed with various processes: filtering, pre-heating, measurement and odorization.
Regarding the pre-heating of natural gas, one should consider that in the process of decompressing natural gas, for a physical effect, gas reduces its temperature.
As normally gas distributed in Italy contains hydrates, the decrease of temperature could lead to freezing of hydrates that could cause malfunctioning or even failures of pressure regulating devices as well as of safety devices.

For this reason, in every station with an inlet pressure of at least 12 bar, there is a pre-heating system that is intended to add thermal energy to natural gas before decompression. The system is normally made of heat generators, heat vector (commonly water), a piping system, circulating pumps and heat exchangers.
Normally, heat generators are controlled via thermostats installed on the outlet side of the gas line. Generators are usually set with a certain water temperature and controlled with an "on-off" mode via those thermostats.
There is a large number of stations without any kind of thermal insulation of pipes and with no thermostat on the gas line (thus heaters are controlled just via water temperature).

Aims

In terms of potential market, the largest majority of the nearly 9,000 stations existing in Italy are connected to pipelines with operating pressure higher than 12 bar.
We consider that roughly 8,000 stations are equipped with preheating systems and therefore are eligible for the application of the technology described later on in this paper.
It's quite tricky to determine the potential impact in terms of CO_2 (carbon dioxide) emission. We can only make some estimates based on assumptions that we're going to describe in the next lines.
We assume that around 88% of the gas distributed is treated in stations equipped with pre-heating system. Furthermore, we assume that on a national level, on the basis of actual average consumption data we have collected, the amount of gas used as "process gas" in order to heat up 1,000 scm (standard cubic meters) distributed via the network is nearly 2 smc.
On the basis of the previous assumptions, we estimate that around 146 Mln smc (million of standard cubic meters) are used in pre-heating systems as process consumption.
This in turn, generates emission of CO_2 of approximately 278,622 ton of CO_2 emission.
Please note that natural gas used for pre-heating is a cost for gas distributors that weigh around 0,6 €/smc, that results, nationwide, in 87.60 Million Euros.

On the basis of the above assumptions and considerations, we see that a large amount of natural gas burnt in process lines connected to the distribution of natural gas.
This process has never really gone under the magnifier of the energy efficiency office of a system integrator.

When we started to study the issue, we tried to determine which drivers we had to follow to cope with the need of increasing the energy efficiency of the pre-heating process.

We understood that mainly there were two fundamental issues: the *obsolescence of the technology applied in boilers* and the *type of control*, very primitive, that is regulating the whole system.

Therefore our target has become to find a solution for each case: one solution conceived for applications where the amount of gas shipped via the station is limited (only a smarter control is affordable/justifiable) and, for larger stations, a second solution that integrates the new control system together with a much more efficient heater.

Method

According to the history of laying gas networks in Italy, we had to face an existing infrastructure of thousands of city gates of small to medium size. Many of these stations are delivering natural gas to, mainly, domestic to small industrial and commercial use. In those cases, flow rates are variable according to gas demand during the year and within days, according to gas consumption, creating a highly fluctuating demand. This situation, coupled with small amount of gas distributed, makes it difficult to always justify from the economical point of view an important intervention such as the substitution of gas boilers. So, we decided to develop a control that increases the efficiency of the heating function by controlling the required gas temperature with minimum possible water temperature.

We developed specific software dedicated to this function. It only requires few elements to operate that are: presence of heat generators, pumps and heat exchangers. In order to be a viable solution, that system needs to be very cost effective and universal to install. The control unit developed by Regas is called EMMA (Energy Multivariable MAster) and has been patented in Italy.

Then, we have coupled this “heating control logic” with the state of the art technology of heat generators. The choice has been directed toward the GAHP (Gas Absorption Heat Pump) technology that is considered nowadays the best and most promising heating technology to increase energy efficiency to the highest possible levels. GAHP have already demonstrated that efficiency on primary energy in excess of 165% (EN12309) can be achieved by air sourced appliances and that these performances do not deteriorate even when used with high thermal lifts (low ambient temperatures and high output temperatures).

In fact, Gas Absorption Technology Heat Pump (see picture) is a technology that can drastically reduce the consumption of gas in those decompression stations where regular boilers are used. Current boilers cannot deliver efficiency or renewable energy content while solar systems do not offer the continuity of service required. Last, but not least, existing electrical heat pumps (EHPs) rely on electricity supply that is not commonly spread, with the power needed, in all the gas stations and cannot offer energy efficiency performance when needed. Indeed when natural gas is most needed, at winter time, air sourced EHPs’ performance deteriorate severely, in particular in supplying hot water at the temperatures needed for this specific application.

The benefits of the application of GAHP technology are not only economic, but also environmental, given the reduced use of primary energy and the simultaneous exploitation of renewable energy. The reliability, the ease of installation, the short payback times and the prompt availability make this technology extremely attractive for mass deployment on existing gas grids.

To maximize the economic performance of the installation an appropriate “load matching” need to occurs. In fact, the GAHP technology will deliver its benefit only if… it is used.

The load of the decompression stations depends on several variables that we have to take into account when selecting the solution and performing the “load matching”:

- Inlet pressure: the higher the inlet pressure is, the higher the load of the system. In fact, the amount of thermal energy that has to be given to natural gas before

decompression increases on the basis of the differential pressure to be reached after decompression. The higher the load the highest will be the return on investment.
- Fluctuations of the flow rates: stations with important components of stable flow rates, typical of industrial process use, bring the best opportunity to reach high yield for the investments. These cases make even more attractive the deployment of a GAHP.

Field testing has been conducted on different stations, some equipped just with the control unit, some others with the complete system including the highly efficient GAHPs.

In order to choose where to install the GAHP units, we only had to check the following elements:

- Existence of Heat Load (as discussed previously)
- Availability of space (less than a couple of square meters) in the area surrounding the gas station in order to minimize heat losses, cabling and piping. Please take into account that the installation can occur only in "non classified area" regarding the explosion danger regulation applicable in this kind of installation.
- Availability of electricity supply of adequate power (approx $1kW_{el}$)

The application we want to present in the next lines, is called "OPPEANO" according to the name of the village nearby Verona where the first installation has happened. The city gate chosen is also supplying a manufacturing company that gives to the station a pretty stable behavior all year round.

CITY GATE "OPPEANO"	
Inlet pressure [bar]	70
Outlet pressure [bar]	4,5
Maximum nominal flow rate [Smc/h]	8.000
Annual Flow rate [Mln x Smc/year]	25
Insulation of overheated water circuit	Yes
Nominal thermal power installed [kW]	288
Annual consumption of natural gas for pre-heating purpose [Smc]	36.950

Before the installation, the control function was performed inside each heater (4 x 77 kW = 288 kW) by a thermostat. Under a functional viewpoint, the cabling was a series connection between a general thermostat installed on the gas stream and the equivalent device built in the heaters controlling water temperature.

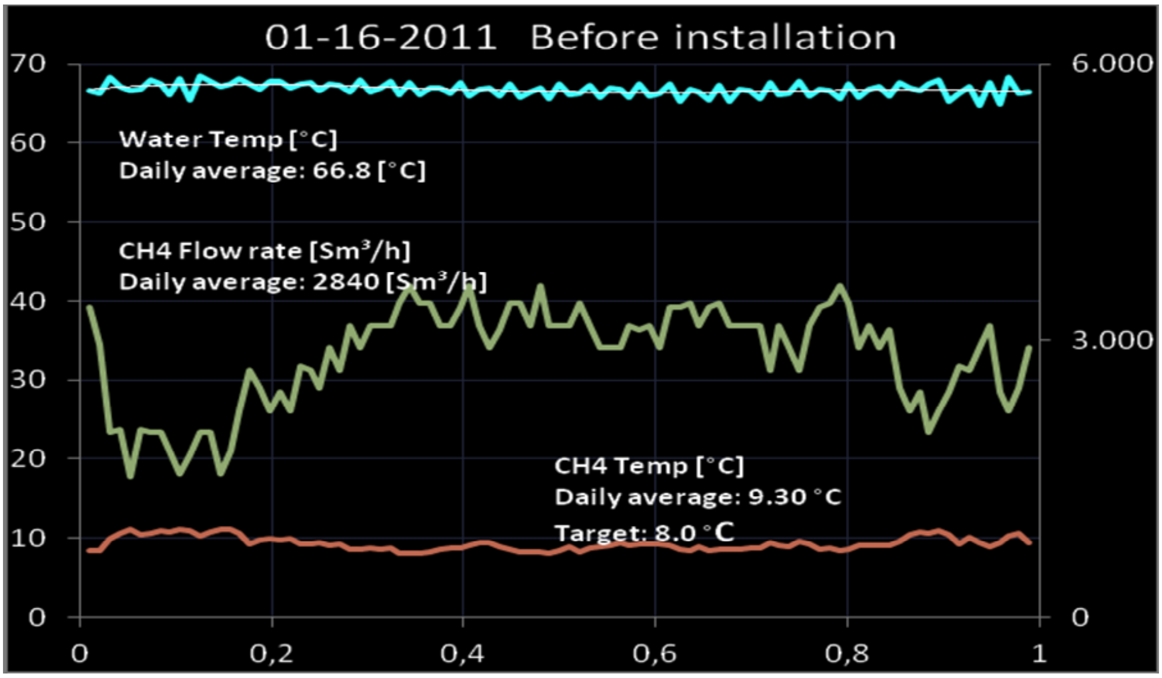
The installation in the Oppeano city gate has included both "Regas EMMA real time control unit" and a "Robur GAHP" (see picture).

After installation, the EMMA device has brought in the control algorithm also the actual flow rate of the station. By this, EMMA determines continuously the amount of energy to be transferred via water to the gas in order to get the required output (a certain temperature of gas). We put particular effort in the robustness of the whole system in order to grant pre-heating requirement also in case of EMMA failure or outage of electrical grid. In order to do so, the traditional heating components are left connected to the system, just with a different set point in order to ensure intervention in case of necessity (back-up solution in case of power outage). Sensors and EMMA control are redundant in respect of the traditional heaters that normally do not require electricity supply in order to work.

The next two graphs show the behavior of the main physical sizes before and after the intervention.
The comparison is related to two days, 16 January 2011 and 2012.
The physical sizes taken into account are:

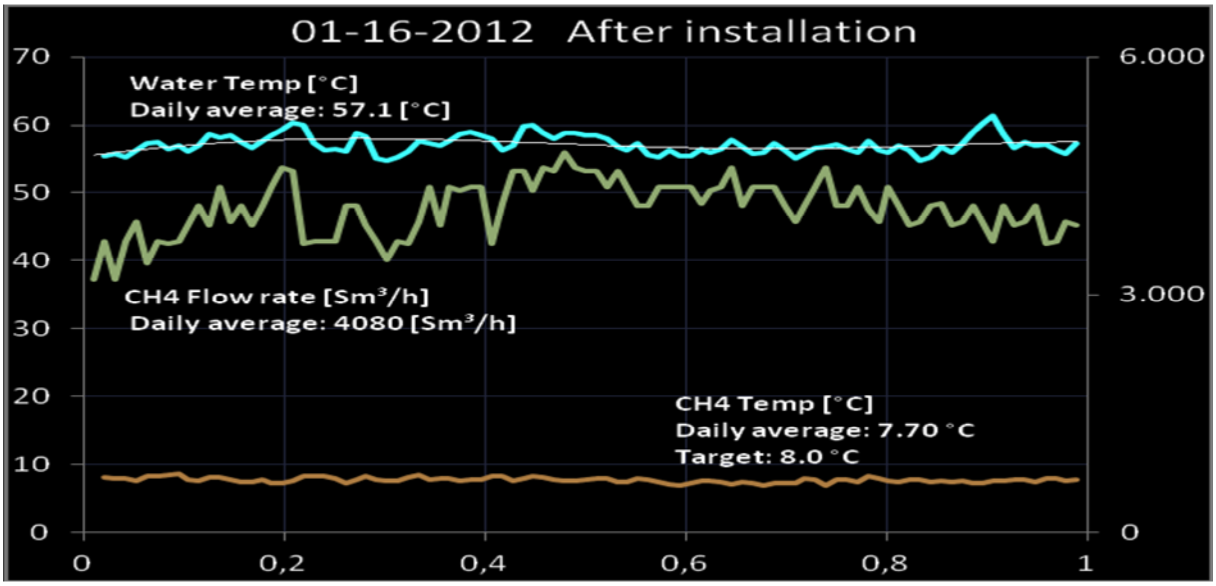
- Instantaneous flow rate (line in violet)
- Temperature of inlet water (red line)
- Outlet gas temperature (blue line)

The first graph shows an average daily flow rate of 2840 smc/h (standard cubic meters per hour). In order to keep the gas temperature at 9.3 °C, the water inlet has been on average at 66.9 °C.



The next graph shows how, **after the installation of Regas control unit and Robur GAHP**, in order to keep gas at an outlet temperature that has been recorded at 7,7 °C, water inlet has been on daily average at 57°C even in a condition of flow rate markedly higher (4080 Smc/h).

We like to stress that water temperature varies more evidently after the installation while gas temperature sticks much closer to the set point (8°C). In addition, please note that no EHPs could efficiently operate at this output temperature and even boilers will not be able to take full advantage of condensation effect. The extraordinary performance of GAHP technology maintained high efficiency even in these demanding operating conditions.



Results

On the longer run, in the next table we show how the system works in term of own energy consumption related to the pre-heating process.

Comparison between before and after use of Regas / Robur GAHP technology	Traditional heaters and temperature control device	After installation of Regas control unit and Robur heater
Period of observation, in days	**184** (from July to December 2010)	**196** (from June 2011 to January 2012)
Amount of gas distributed in the observation period [Scm]	11,893,880	12,827,420
Consumption of natural gas for pre-heating purpose [Scm per 1,000 Scm]	1,299	0.648
Electrical consumption [kWh per 1,000 Scm]	0.00	0.180
Overall cost [€ per 1,000 Sm3] considering €/smc 0.6 for gas and €/kWh 0.12 for electricity	0.780	0.410

In the table shown above, the observation period is slightly more than 6 months, including summer and winter seasons in order to include in the data both high and low domestic consumption. Industrial use remains substantially the same.

The left column where traditional heater is represented shows data before intervention with Regas/Robur highly efficient system. In fact, the specific consumption for pre-heating system (the number summarizing the efficiency) is 1,299 that is in fact roughly twice as much than the value shown in the right column, representing a 0.648 Smc necessary to heat up distributed gas after the Regas control unit and Robur GAHP heater have been installed.

We have also noticed that during summer period, the Robur GAHP heater of 35 kW nominal power has been normally sufficient to face the entire heat need of the gas station while in winter season, the traditional heaters (288 kW) switch-on in order to back up the system and supply the extra thermal need.

From the data shown above it is paramount importance to emphasize that in Oppeano city gate, the reduction in the overall running costs is close **to 50%.**

In the following table, we show how the efficiency achieved is translated in terms of saving on “self consumption”:

Cost saving generated by Regas / Robur GAHP technology	**Traditional heaters and temperature control device**	**After installation of Regas control unit and Robur heater**
Self-consumption of pre-heating gas, normalized on the same amount of gas distributed – period of observation, days	196	196
Amount of gas self consumed by city gate, in Scm	16,668.89	8,306.30
Electrical consumption, in MWh	0.00	3.1
Cost of operation of the pre-heating system, considering €/Scm 0,6	€ 10,001.33	4,983.78
Cost for electricity consumption, considering €/kwh 0,12	--	€ 372.00
Total cost of operation, €	**€ 10,001.33**	**€ 5,355.78**
Total saving, annual projection, €	**--**	**€ 8,651.15**
Daily saving, €		**€ 23,70**
Saving of CO2 emission, annual projection, in ton		**29,59**

Total saving, as annual projection, is calculated as follows: saving in 196 days is € 10,001 – 5,355.78 = 4644.22 divided by 196 equals to 23.695 (daily saving), multiplied by 365 = 8,651.15 (annual total saving).

Saving of emission of CO_2 is calculated with a factor 1.9 kg of CO_2 generated by combustion of 1 Scm of natural gas.

Conclusion

Regas EMMA control unit and Robur GAHP state of the art technology have successfully shown that it is possible to manage pre-heating system in natural gas distribution process with major increase in efficiency.

Of course, other on-field tests are underway to confirm and validate the results obtained so far.
In fact, we have noticed how differential pressure inlet / outlet and flow fluctuation (the “load”) have an impact on the resulting economic efficiency; but even in worst cases, total economic savings have never been lower than 20%.
We believe important to emphasize that the appropriate solution needs to be defined for the specific decompression system that need to be upgraded. If “load” is low (low differential pressure and low average flow), then the most cost effective solution might be the Regas control unit, on its own (the lower total investment keeps a very attractive payback period of around 2 to 4 years). When the “load” is high, then the complete system as tested and measured in “Oppeano” will become the most cost effective solution.

Therefore, even considering a total estimated gas use for pre-heating process nationwide of approx. 140 Mln Scm and in turn emission of CO_2 of 266,000 ton, we could calculate that with just a 20% efficiency on 80% of gas stations could bring to total CO_2 saving of 42,560 ton. The use of the combined system EMMA+GAHP will obviously deliver even higher savings in all those frequent situations where load is high.

Finally, we want to thank the gas distributors that have helped us in testing, believing in the project and supporting us in the process, namely 2i Rete Gas, Ascopiave and Gritti Gas Rete (managing the Oppeano station).