ITALIAN COMPRESSOR STATIONS FOR GAS STORAGE

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1. ABSTRACT
In Italy the gas transmission network, more than 23,000 km long, has 21 compressor stations with a total power of 500 MW. Some of the stations are used only for transmission purposes while others can also be used alternately or at the same time to compress gas into storage fields (Fig.1).

Italy has one of Western Europe's biggest gas reserves in storage fields: in fact the working gas used at the moment is about 12 Gm3 and the gas in place is about 24 Gm3. The total compression capacity is about 90 Mm3/d with discharge pressures of up to 150 bar.

All the stations are remote controlled with no personnel on site. For this, very reliable station control systems are used to control plant, engines and all the station's auxiliary equipment.

A compressor unit consists of a centrifugal compressor driven by a gas turbine. The heavy duty gas turbines have an output of between 3.7 and 10.4 MW, while the jet derivative turbines have an output of 20.5 MW. The gas compressors have two separate stages (sections) that can be put in series or in parallel according to the required compression ratio and flow.

The special configuration of the stations gas piping is designed to match operating requirements.

Examples of series/parallel configurations of the compressors and of the gas piping are given with an explanation of the pros and cons.

2. INTRODUCTION
SNAM is responsible for the supply, transportation and sale of natural gas in Italy, the transportation of oil and oil products, and for the provision of some general services for the whole ENI Group, of which SNAM is one of the main companies; natural gas is SNAM's core activity.

Natural gas, after extraction from the field, filtration and dehydration, must be transported to the consumption areas, which may be thousands of kilometres away.

In Italy gas is transported at a maximum pipeline pressure of 75 bar.

The gas pressure at the beginning of the pipeline is in general the gas field pressure suitably reduced. The gas pressure, which drops along the pipeline, is kept at optimal transmission level by compressor stations, located every 100–250 km.

In Italy the maximum power installed in a transmission station is about 65 MW, while the maximum power of a single compressor unit is 22 MW.

The main parts of a compressor station are naturally the compressors, driven by its motor and generally housed in its own casing for protecting and soundproofing.

There are also station automation systems, aimed at enabling the stations to be run unattended by remote control.

For example in the SNAM case the San Donato Milanese Dispatching Center coordinates operations and optimizes gas flow and pressures; it can, according to the operating needs of the station, start, stop and control the compressor units and the auxiliary equipment, safely and in accordance with pre-established criteria.

The gas piping constitutes all the pipes, valves and other similar equipment of the station necessary for the correct gas processing.

The piping is of high quality steel, (for storage service generally API 5L-X60 and API 5L-X52 are used for rating up to 150 bar) and it is generally laid underground.

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The configuration and/or arrangement of the piping must be designed to match the different services and/or various operating conditions required.

Since the efficiency and economics of a compressor station solution will be a compromise between dimensional aspects and performance, more consideration should be made in order to realize the optimal solution.

To complete the plant, the station includes auxiliary equipment such as gas filters and gas coolers in order to provide the correct values of filtration and temperature, fuel and starting gas supply systems and other minor equipment.

3. EVOLUTION OF THE COMPRESSOR UNITS IN SNAM'S EXPERIENCE.

By the end of 1992, 22 gas compression plants were in operation, 14 of which were transmission stations, 2 storage stations and 6 which could cover either services at the same time or alternatively. Installed power is approximately 500 MW, including about 3 MW for units with reciprocating compressors, while the balance refers to units equipped with gas turbines and centrifugal compressors.

The course of installed power during the last 30 years is shown in diagram A. The evolution of gas compression stations in Italy can be divided into four chronological and distinct stages.

During the first phase which goes to the beginning of the sixties, available machines on the market were mostly reciprocating engines coupled to reciprocating compressors.

Operations required the constant presence of personnel for the necessary controls as the few automatic systems in use at time were very basic.
Centrifugal compressor driven by electric motors appeared during the second stage, spanning the sixties. Although this simpler and less expensive system had to depend on external power supplies, it was nevertheless supported by the availability of great quantities of low cost electric power.

In that period, simple control sequences of the machines and pneumatic-type adjustments of equipment were introduced. Operations still required the constant presence of personnel working in shifts.

During the third stage, at the beginning of the seventies, units featuring gas turbines driving a centrifugal compressor came into use. This was due to the necessity of reaching autonomy from external power sources and having remote-controlled systems automatically respond to changing service conditions.

In the same period use of wired control devices and of electronic equipment introduced the first remote controlled compression station. Since that time, all SNAM stations in Italy are automatically run from the San Donato Dispatching Centre, and do not require any attendance to run smoothly and safely.

The introduction of microprocessors has made control and adjustment systems more and more complex, and has allowed the optimization of operations.

The last important change took place at the beginning of the eighties when energy saving became a sensitive issue.

This fourth stage saw therefore the installation of jet derivative-type gas turbines, or heat-recycling systems on the exhaust of industrial type turbines.

4. GENERAL ASPECTS OF GAS STORAGE

A gas pipeline, especially if of large diameter and with continuous flow at normal operating pressure, can have a sufficient storage volume to meet daily variations in gas consumption.

When the variations become greater or consumption rises for long periods (for instance increased gas consumption in winter due to domestic heating) storage as near as possible to the consumption area is required.

In Italy, these reserves (storage) are obtained today by injecting gas into semi-depleted or depleted underground gas reservoirs. During those periods in which there is more gas available because consumption is lower (generally during the hotter months) the gas is injected into the reservoirs; in the times of higher demand (in the colder months) it is returned to the pipeline system.

Diagram B shows the typical annual figures for production, importation, consumption, and the transfer of gas to and from storage.

The storage reservoirs therefore make it possible:
- to deal with the variations of gas demand more regularly and economically
- to optimize the quantity and the flow of imported gas from both a technical and contractual points of view
- to handle temporary supply interruptions in an emergency.
The importance of having a storage strategy increases when the demand is mostly based on importation from foreign countries or if the network is not a grid-type but consists of a main pipeline from which various distribution systems derive. The underground storage, if located in the vicinity of a large area of consumption, can also have a daily peak supply function.

There are eight underground storage facilities in Italy operated by AGIP (another of the ENI group's main companies). All are in porous rock formations. The ultimate capacity of these facilities is, at present, approximately 12 Gm3 and approximately 7 Gm3 of working gas are normally withdrawn.

The peak production rate, at full reservoir capacity, is currently 200 Mm3/day.

The actual trend is to increase the quantity of the storage; this is being achieved by increasing both the number of fields and the pressure.

5. TECHNICAL ASPECTS

The re-stocking of this kind of reservoir is carried out by compressor stations, usually equipped with centrifugal compressors driven by gas turbines to handle high values of flow and pressure, if the flow is lower a reciprocating compressor is suitable.

Depending on the particular configuration of the storage fields and the operation of the pipeline, the same stations can provide two additional services:
- to compress gas from the reservoirs into the transport pipeline when the pressure and/or the flow from the field decrease too much (compression for production).
- to compress gas for transmission if the station is also connected directly with the network.

SNAM is now developing a new type of compressor station to use for very big underground storage. Analysis and design are just starting, but the most suitable criteria seems to be a plant organization as described in point 5.2.b. The project will probably have two steps: the first with two stage centrifugal compressor driven by a 40 MW gas turbine for operating up to 200 bar.

In a second step, if and when the Italian gas system will require supplementary gas storage, single staged units will be installed to refill the gas field, to reach a final pressure of about 300 bar.

5.1 Possibilities of base configurations

The most interesting aspects, according to SNAM's experience and the general trend in increasing the volume of storage, are related to compressor units consisting of centrifugal compressors driven by gas turbines.

Depending on the normal final pressure values of the storage, which is normally about 150 bar, the base type of centrifugal compressor is the two stage-intercooled type. It consists of two separate stages, each one with its own suction and discharge, on the same shaft and contained in one casing (fig. 2).

Figure 3 shows the basic module of a typical compressor unit and a simplified scheme of the piping arrangements. Generally the module has its own gas filter and flow meter system on the suction pipe and two separate gas coolers, just after the discharge of each stage.

There are also two types of valves, the typical "unit valves" to separate the unit module from the rest of the station piping and others units, and the "operating mode valves" that are used to select the mode for running the compressor stage: series or parallel.

This is an interesting and easy way to increase the flexibility of operations, simply configuring the piping of the unit to obtain two different services to better cope with operating needs.

Changing the operating mode is done outside the compressor and is very simple: you need only open or close valves:

- SERIES CONFIGURATION
  - A and C valves close
  - B valve open

- PARALLEL CONFIGURATION
  - A and C valves open
  - B valve close

Of course these are draft schemes; their accuracy must be tested when the piping is completed with the antisurge systems for protection of the centrifugal compressor and/or to operate very low flow and high compression ratio condition, pressurizing valves, performance test system etc.

Correct specification and selection of wheel curves and compressor design points is, of course, the most important aspect, but also pipe and valve sizing and lay-out needs careful evaluation and analysis for the various scenarios and all the operating points.

5.1.a Simple series configuration

This is the main configuration, dedicated to the storage service in which high pressures are required (fig. 4).

As shown in the figure, the gas is compressed in the first stage and then cooled by an air cooler. After this the gas is compressed again by the second stage and again cooled to about 50 °C before being injected into the field.

Under these conditions the performance and the efficiency of the machine are optimized.
C.R. compression is optimized for a particular running area and this is important for optimization of the system.

5.2. Complex configurations

The single module of a storage compressor unit can be used to build the particular complex global configuration of the station. Here are some alternative schemes for compressor configurations at storage stations:

5.2.a More compressor units in parallel

This is simply the paralleling of single units; in this case you can also have the stages in series (fig. 7.a) or in parallel (fig. 7.b) depending on the process conditions.

Whatever the compression power required, usually a storage service has to be completed in a few months and the units run generally only during summer. Economics says that, generally, having a stand-by unit is too expensive.
5.3.a More units in parallel with booster

In this case (fig. 8.a) you can have first a transmission type – single stage compressor unit for medium level of pressure and large flow (you can also have more than one unit if you need a stand-by). In series with this you will have a number of normal storage units.

For example this configuration is useful when you have a very large flow and pressure up to about 200 bar.

At the beginning of the storage, only the single stage unit is used because of the low pressure ratio; when the pressure reaches the maximum level for the unit, the storage units will be brought on line to keep up the pressure until the final maximum level of the field is achieved.

Of course, the two stage units could be also run alone, without the booster; figure 8.b shows the performance changing between using and not using the booster unit.

Variation of the injected flow is obtained by the regulation of other units and the number of storage units used.

The single stage unit can also be conveniently used for compression from the field or for normal transmission if necessary.

This choice can be evaluated both from the technical and economic points of view; if you need the two different services you can install less units or less power, saving plant, operation and maintenance costs.

5.3.b More units in parallel with post-booster

This configuration (fig. 9) is the opposite of the previous one: first there are storage units in parallel and then there is a single stage unit with low compression ratio. The convenience of this configuration mainly depends on external situations and it is not directly related with the technical design of the single compressor units.

For example, if there is a variety of fields requiring various levels for injection, you need the compression of the whole flow up to the lower pressure level; part of the compressed gas goes directly into some fields while the remaining flow needs additional compression for the injection in the fields at higher pressure.

In other situation, for example for large and high pressure storage fields, the build-up of the storage capacity, and consequently of the station, can be divided in steps. First you can have operating condition at an intermediate pressure level, so you can first install the minimum number of storage units in parallel (see point 5.2.a). Then, to reach the final operating condition, saving all the existing plants, it will be enough to install additional compressor units.
5.3.3 Other complex configurations

Other situations that require special configuration are the possibility of having different levels of pressure in suction or discharge when the station is multipurpose and different operating criteria have to be satisfied. For example, Fig. 10 shows the scheme of one station that usually operates for storage service but in an emergency can also be used for network transmission services.

Here the units are operating with two suction pressure levels and a single discharge, but by simply selecting valves the plant can be made to operate with two discharge pressures and one or two suction levels.

Other plant arrangements could be made using separate single stage units, configured in parallel for the first step of compression and other units in series for the final step. Usually this means more units need to be installed to have enough reliability for the service and operations, this arrangement may not be flexible enough to satisfy all the variables of standard network operating conditions.

6. CONCLUSIONS

Operating a large complex gas system can mean managing the network at maximum capability, with high reliability, correct optimization and using all the possible opportunities to satisfy the gas demand at all time, while coping with gas availability. This makes the use of the gas storage and consequently storage compressor stations important. Choosing between all the possible solutions, analyzing and evaluating all compressor types and plant arrangements, it is possible to realize the solution for optimal operating conditions.

7. REFERENCES


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