2nd Oxyfuel Combustion Conference

Air separation Unit: Flexibility & Energy Storage

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1. Introduction

The core concept of oxy-combustion is the use of a high purity oxidant stream for the combustion process so that the combustion products are highly concentrated in CO_2, thus simplifying the CO_2 capture process

In some cases ("Semi base load"), the power plant using this technology will also need to be very flexible to follow electricity market demand, and cope with intermittent production from wind mills (Fossil fuel power plant must maximize production when no wind, and minimize when wind is abundantly blowing).

It is thus a major issue to adapt Air Separation Unit to address the requirements in flexibility of power plants.

2. Technologies available for Oxygen production

A commercial-scale coal-fired oxy-combustion power plant would require thousands of tons of oxygen each day. Cryogenic distillation is the only commercially available technology today to produce such large quantities of O_2 economically and at high purity. Other air separation technologies like pressure swing adsorption (PSA), vacuum swing adsorption (VSA) or polymeric membranes cannot compete economically for such quantities, especially to produce >95% purity oxygen. Ceramic membranes (oxygen ion transport membranes) are not yet commercially available for large-scale oxygen production and so it is hard to compare them to cryogenic distillation both in terms of investment and performance.

Cryogenic ASU is considered to be a mature technology. However, the industry has been able to achieve great improvements over the last 3 decades in improving this technology. Figure 1 shows the magnitude of these improvements both in terms of productivity of the distillation columns and in their energy efficiency. This trend is expected to continue in the future, since the overall energy of separation is still significantly greater than the theoretically required separation energy.

Thus the reference technology for oxygen based processes will remain cryogenic separation at least for the period 2010-2020.

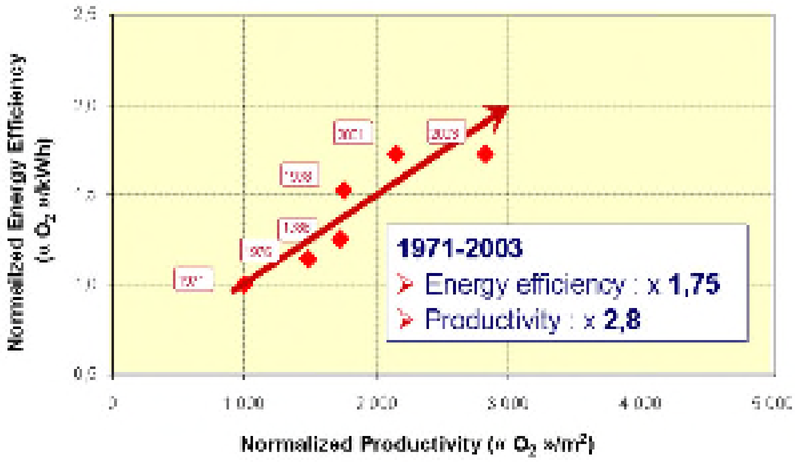


Figure 1: Improvements in productivity and energy efficiency of cryogenic ASU.

3. Flexibility of cryogenic Air Separation Units

An ASU consists of the following equipment:

- Main air compressor
- Precooling system
- Purification unit to remove water and CO_2 prior to enter the cryogenic section
- Heat exchangers
- Distillation columns
- Vaporizers/condensers

For ASU's up to 5,000 tons/day, Air Liquide proposes a process with a double column scheme with no duplication of equipment: one purification unit for water and CO_2 removal with its proprietary radial bed design, one high pressure column and one low pressure column.

The first flexibility issue is the minimum **turn down** that can be achieved by the plant. If we consider a one train configuration, typically

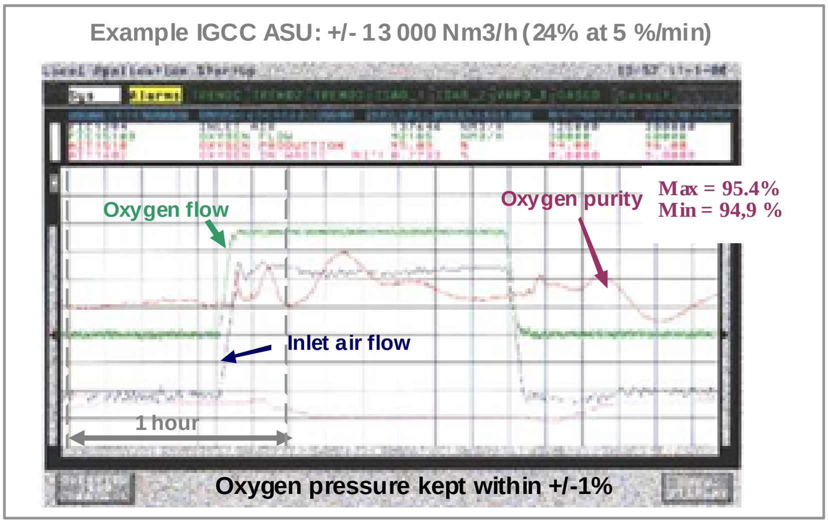
- ✓ Compressors are able to achieve a turn-down of 75% of their nominal capacity without recycling or venting
- ✓ Cold box is able to achieve a turn down of 50% of its nominal capacity.

Thus, if a power plant equipped with CCS wants to achieve a 50% turn-down (which is the typically flexibility of present air blown boilers), the compressors should be duplicated (2x50%) which also gives some advantages in term of reliability of the Air Separation Unit (the main contributor to ASU un-availability are the compressors)
If a multi-train configuration is considered (due to very large O2 quantities requested), there are more degree of freedom to reach 50% turn down (or even less).

The second flexibility issue is the **load change velocity** usually expressed as %/min. In the case of 'conventional' ASU' producing pure Oxygen (eg for steel industry, ….), the typical load change velocity is ~0.5%/min. In the case of ASU producing impure Oxygen (as requested for Oxy-combustion and IGCC), the typical load change velocity can be increased to 1-2%/min depending on process.

AL has developed some special **'fast load change'** devices to boost this velocity up to 5%/min (or even more), through advanced process control and specific cold box equipment and design.

This technology has been demonstrated for high pressure Oxygen supply, and allowed to keep the purity and pressure of oxygen within a very narrow tolerance range, as illustrated in the graph below:



4. Energy storage opportunity with Oxycombustion

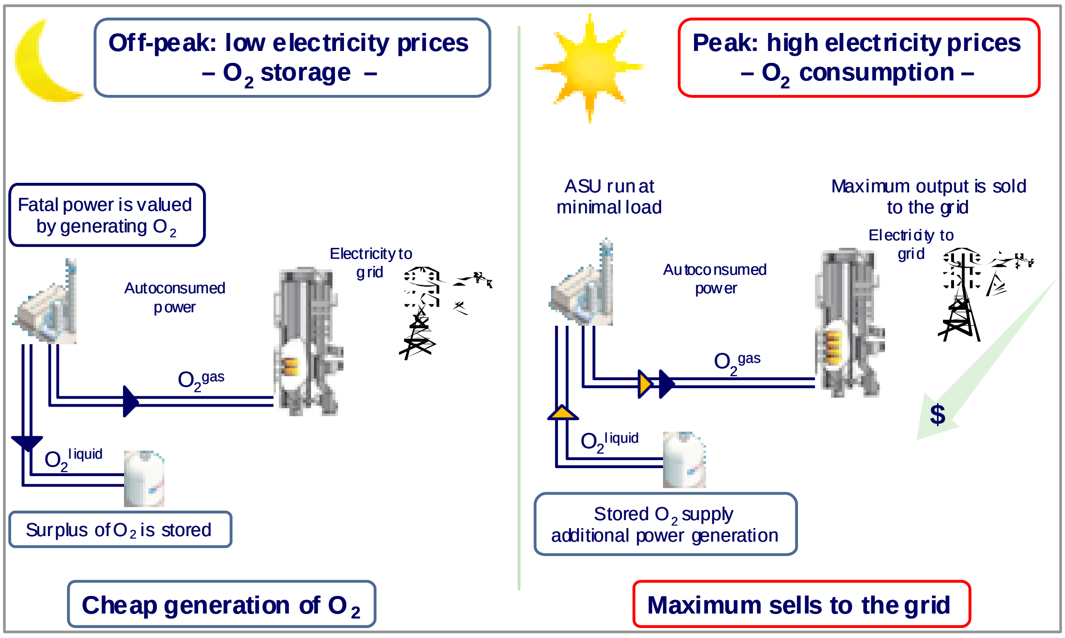
AL has developed a specific concept for semi-based load power plant to leverage electricity price volatility and variations in boiler operation. This concept is called ALIVE™ (AL Innovative Variable Energy)

The main principle is to de-synchronize the operation of the ASU from the operation of the boiler, by using a set of cryogenic liquid storages.

A first application of this principle is energy storage:

- During peak time, ASU is operated at its turn down while power plant is operated at its maximum. During this period, the missing Oxygen needed by the power plant is taken from a liquid oxygen storage (which is filled during off-peak time).
➔ This allows exporting additional power to the grid

- During off- peak time, ASU is operated at its maximum capacity while power plant is operated at its turndown. During this period, part of the oxygen from the ASU is stored as liquid oxygen
➔ This allows consuming fatal power produced during night time



In order to reach a very high storage efficiency (typically > 95%), a smart system is implemented to recover liquefaction energy from LOX.

Others application of the ALIVE™ concept will be further developed during the OCC2 conference such as Partial (or phased) capture with Oxycombustion, etc..

5. Conclusions

Air Liquide has made several technical advances to increase the attractiveness of the CCS Oxygen-based processes for clean electricity production from coal. In the past years work was mainly focused on Oxygen supply to base load power plant and resulted in a 20% reduction in specific energy

A complementary approach called ALIVE™ addressing semi based load power plant has been developed and opens new opportunities for significant improvements both on the **operation and investment point of view**.