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Integration of Fuel Cells Systems into Chlor Alkali Plants: The Chlorine Industry Perspective

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1 Introduction

The chlor alkali industry has always been considered an important target for the fuel cells industry, mainly because it is an energy intensive process that produces big amount of high purity hydrogen as a side product. While fuel cells manufacturer have provided over the time their strategies on how to approach the chlorine market, few information are available from the chlorine industry perspective on the specific conditions that will facilitate the application of fuel cell systems in such specific industry. In this article, the specific characteristics of the chlor alkali industry will be discussed, highlighting the potential for fuel cells applications from the perspective of one of the most important engineering companies active in the field.

2 The Chlor Alkali Industry

The chlorine – caustic soda industry in one of the corner stone of the world chemistry, being those chemicals, directly or as intermediates, involved in more than 50% of the chemical industry. Chlorine, caustic soda and hydrogen are produced simultaneously throughout the electrolysis of a concentrated solution of sodium chloride, using three different technologies that have evolved with time: mercury cells, diaphragm cells and ion exchange membrane cells, being the latter the only technology commercialized today (Figure 1). The chlorine industry is a highly specialized industry, with very few technology licensors: UHDENORA of Milan, a joint venture between Uhde GmbH of Dortmund, Germany, and Industrie De Nora, Milan, Italy is one of the relevant players in this market.

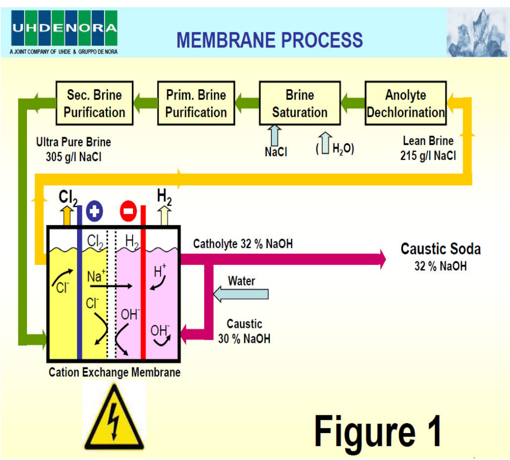

Figure 1

2.1 The numbers of the chlor alkali industry

On a world basis, a capacity of approximately 68 million ton per year of chlorine production is today installed, achieved by a total of about 550 chlorine plants. Main chlorine producers are China (24 MTPY), Asia (11 MPTY), North and South America (13 MTPY) and Europe (10 MTPY).

Considering a 90% plant utilization factor, the associated hydrogen production is equal to approx 216 ton/h, for a total theoretical potential of approx. 3.2 GW electricity production. The total accessible market, however, is to be considered much smaller, since only the hydrogen that is vented to the atmosphere, thus at zero value, will be of interest during the initial phase of fuel cells applications; this market can be estimated at 400 MW – 600 MW, depending from the characteristics of the fuel cells considered. The hydrogen used as a chemical will never be accessible for other uses, while the hydrogen that today is burnt to produce steam may became available to fuel cells if the overall system price will allow interesting paybacks (1,2).

2.2 The importance of fuel cells for the chlorine industry

Electricity consumption is the key parameter to measure the competiveness of a chlorine plant, being electricity up to 60% of the variable production costs. With the most up to date electrolysis technologies, the electricity consumption can be considered close to the thermodynamic limit, leaving only a small space for further power savings. The two possible breakthrough toward the reduction of power consumption for the electrolysis are both related to the use of the hydrogen available in the plant: the first is through the so called Oxygen Depolarized Cathode technology, where additional oxygen is fed to the cathode and H_2 is reduced to water inside the membrane electrolysers, with 30% of potential energy reduction, the second through the conversion of the hydrogen into electricity using fuel cells, with a 20% of potential electricity reduction(3). To be underlined that the recovery of hydrogen through ODC technology is already used by UHDENORA and Uhde for the electrolysis of aqueous solution of hydrochloric acid to chlorine, with a demonstrated energy saving of approx 30% with respect to the standard diaphragm electrolysis and a licensed capacity of more than 330.000 ton of chlorine per year.

2.3 Fuel cells for Integration in C/A plants

UHDENORA, as system integrator, does not develop any proprietary fuels cells technology, rather is selecting from the industry the most promising products for this application. With the term “Integration”, we intend a fuel cell system that is completely embedded into the electrolysis process, installed inside or close to the cell room, built in full compliance with the safety regulations and with customers technical standards, with a balanced tradeoff between the maximum system simplification and its safe performances. Other approaches are possible, such as the installation of fuel cells running on purified hydrogen form the chlorine plant, and feeding the AC power to the grid, that can be considered a valid solution for some applications, but that will not allow the full exploitation of the available market.

For an effective integration, the main characteristics requested to fuel cells are the following:

1. Capability to operate on a 24/7, 320-350 days per year.

2. Base load operation, with slow load following capabilities (30% - 100%)
3. Able to operate with industrial grade hydrogen
4. Good resistance to sudden shut down
5. Easy monitoring of main parameters
6. Minimum balance of plant provided by the fuel cell supplier for the integration into the system
7. High quality heat for possible CHP use (low pressure steam generation the best)

All those characteristics have a direct impact with the overall system design, thus with the fuel cell system cost. As an example, few data are available on long term fuel cells performances in presence of the contaminants typical of the hydrogen from the chlorine plants (i.e. caustic soda or mercury). As a consequence, very high purity hydrogen is sometime requested, increasing the cost for the hydrogen purification section. A second example is the determination of the consequences of the number of shut down on the fuel cells durability: if complex systems are requested to properly manage such critical situations, the system complexity increases, as well as its costs.

3 System Characteristics

In the last four years, UHDENORA had designed and demonstrated a proprietary technology for the integration of fuel cells stacks and minimum balance of plant inside the electrolysis circuit of electrochemical plants, with direct connection to the DC bus bars of the electrolysers [4]. The pilot system has the following main characteristics (Figure 2):

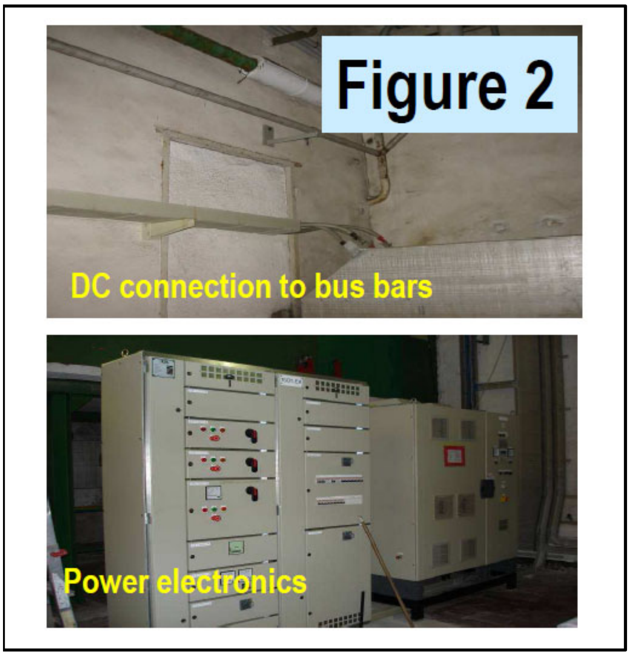

Figure 2

1. Modular configuration to fit different plant sizes, capable to accommodate different fuel cells technologies
2. Usage of DC power from fuel cells to reduce electrolysis power consumption
3. Installation and maintenance without perturbing the chlorine plant production cycle
4. Designed for installation inside electrolysis room
5. Remote control and monitoring capabilities in environments characterized by strong EM noise

It is to be underlined that most of the chemical companies have internal standards for equipment and materials, and all the fuel cell system equipment must be supplied accordingly. While standardization of performances is possible for most of the plants, standardization of equipment is more difficult to be achieved, and specific know how and experience is requested [5].

4 Value Proposition and Cost Targets

The payback time of the fuel cell system depends from the end use of the electricity generated:

- DC power from fuel cells is directly used to reduce the DC power consumption for the electrolysis process. Main variables to be considered for the payback are the hydrogen value and the grid electricity price.
- DC power from fuel cells is used to increase the chlorine plant capacity. This is of particular importance in areas where the grid capacity is already at the upper limit. Payback time depends also from the value of the extra production.
- DC power from fuel cells is converted to AC and sent to the grid. Main variables are the hydrogen value and the grid electricity price.

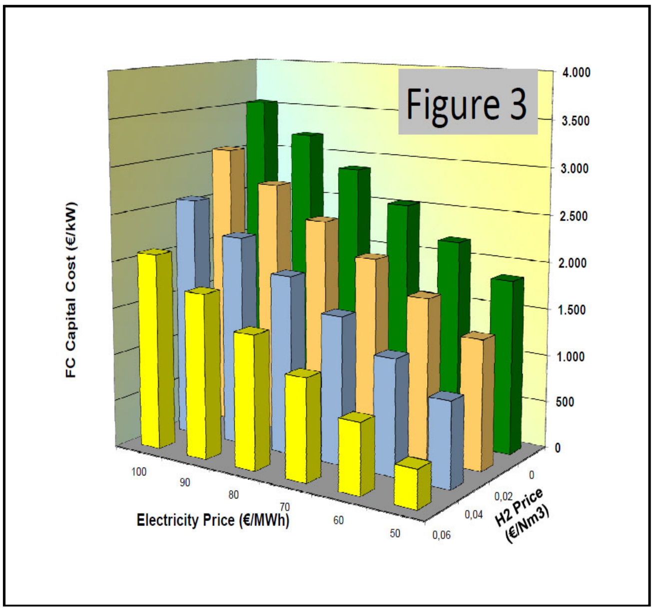

Figure 3

In Figure 3 the sensitivity analysis between fuel cell system capital cost versus price of grid electricity and hydrogen value is reported (Simple payback: 5 years, fuel cells system net efficiency 45%, heat recovery partially considered). It is to be noted that results can be substantially different depending from the technology considered (i.e. low temperature Vs high temperature fuel cells), in particular considering the associated operating costs. No subsidies or feed in tariffs have been considered in the calculations, since there are strongly dependant from the local supporting policies.

As a reference, for investment in energy saving equipments, the average requested payback is approx. 3 years; only for particular projects that may involve additional advantages, such as green image or achievement of CO_2 reduction targets, payback can be extended to over 5 years.

5 Commercialization

As previously anticipated, the integration of fuel cells into chlorine plants presents unique advantages for an early adoption, such as:

- Hydrogen is already available and with high purity
- Fuel cells and chlorine industry speaks the same electrochemical language (low acceptance barriers)
- Energy reduction is paramount to this highly competitive industry and the energy produced with fuel cells is 100% CO_2 free, generating additional advantages for green image and plant eco efficiency.

In spite of a such positive characteristics, only few demonstration projects have been deployed in the field in the last 10 years. This consideration alone should indicate that the market is not as easily accessible as it could be anticipated.

To our knowledge, the majority of the fuel cells applications located into chlorine plants are based on the use of the available hydrogen to produce AC electricity to be fed to the grid. Some of these applications use the hydrogen available to test on a large scale fuel cells technologies for transportation, or to improve fuel cells performances and for cost reduction.

We believe that for a successful fuel cells application, a deep knowledge of the chlorine industry needs and the associated dynamics is necessary: ignoring the rules of this market is very dangerous, and companies who have tried different approaches have already disappeared.

From a system integrator perspective, a number of information are still missing from the fuel cells industry, such as performances in presence of specific contaminants (both at the anode and at the cathode side), and durability data under the typical operating conditions of a chlorine plant. All those issues can be technically resolved at balance of plant level, but the associated increase of complexity will increase the overall costs, further limiting the total accessible market.

A second important step to commercialization will be the availability of commercial guarantees from fuel cell system suppliers. Today, depending from the fuel cells technology, it is still difficult to consider guarantees in line with industrial expectations. As an example, the electrolysers membranes can have a typical guarantee of 4 years, and fuel cell components must have guarantees in line with those values.

6 Conclusions

1. The chlorine industry is a real opportunity for fuel cells, upon satisfaction of the specific industrial requirements for the application.
2. The chlorine industry is not the "Nirvana" for fuel cells applications, but is a tough market that needs specific competence to be approached.
3. In the last years, the fuel cells industry seems to focus mainly on small size systems, far from the megawatt size and ruggedized applications needed for the chlorine industry.
4. The chlorine industry represents an unique application, where the energy savings opportunities are linked to CO_2 emissions reduction, making the application interesting for corporate and policy makers.

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