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Powering light boats

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Introduction

The important demand at the European level for electrical boats shows the great interest for such a technology. We can expect an important growth of electric boats production. Thermal navigation is prohibited on a number of European lakes. Thus, two means could be used to provide a maximum of comfort, reliability, silence, absence of pollution and respect of the environment : photo-voltaic and fuel cells. The purpose of the present project is to explore the second solution. A small boat «Hydroxy100 » has been designed as first prototype in the field of a diploma work [1]. A larger boat is on test. This project is sponsored by OFEN [i)].

Hydroxy300

After the « Hydroxy100 » success, the next goal has been to design an electric boat for a 300W portable fuel cell. It is intended to answer questions such as :

- **Technical feasibility**
- How is the PEFC 300W fuel cell behaving ?
- Security problems with Hydrogen on board ?
- Kind of motorization and power electronics (efficiency) ?
- Maintenance problems to be expected…
- Is a hybrid powered boat (wind + PEFC + photo-voltaic) an interesting solution ?
- **Economical feasibility**
- What should be the price of that technology in order to be competitive with existent solutions ?

Boat design

As in the first project, the PEFC fuel cell has been designed by PSI [ii)] and realised by IGS [iii)]. The available power of 300W remains rather small to propel a boat.

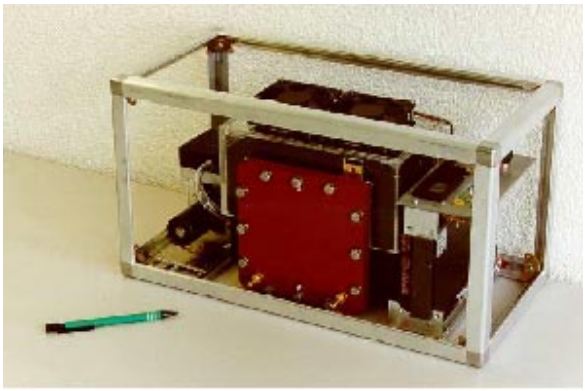

Fig 1 PEFC 300W fuel cell from PSI + IGS.

Energetic of boats is rather complicated. The shape of the hull, it's width but mainly it's length are of prime importance. Power versus speed varies as a cubic function. Thus, a low speed requires only a low power but above the inflexion point, increasing the speed requires

an unreasonable amount of power. This critical point is mainly function of the boat length. In accordance with the boat designer MW-Line, the following shape has been decided to reach a maximum speed.

Fig 2 PEFC propelled boat « Hydroxy300 » 300W – 12 km/h.

Then, the choice for the propeller is also critical. The diameter is related to the torque and the screw to the speed (turns ratio). Both characteristics are also directly related to the electric drive. We shall also mention that any turns ratio adjustment will lower the global efficiency. On those points, our conclusions are obvious :

- The boat has to be very carefully designed.
- The small electric motors still have a low efficiency.
- The propellers efficiency is quite low.

We would like, as far as possible, to use products available on the market, but the use of turbines or paddle propellers will be studied and is expected to improve efficiency of the propulsion. Further interest is to develop the best way to control the fuel cell production. There are basically two ways; control the gas flow with adequate valves or control the load with power electronics.

Valve control of the load
This part of the work is actually under study in collaboration with SILSE* and is the object of another contribution [2].

Electronic control of the load
Power electronics allows an energy conversion supplying electrical energy of the best quality to the motor. It avoids utilisation of the fuel cell in a low efficiency zone and does not need expensive regulating valves. However, this conversion also introduces a lowering of efficiency due to additional losses and entails some cost for the electronic elements and their regulation.

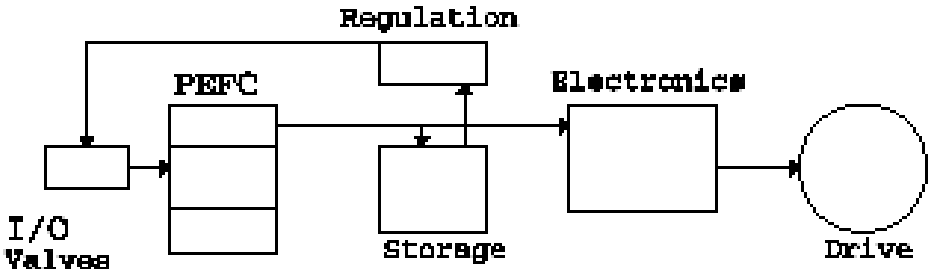

Fig. 3 Principles of an electronic regulation

The choice of solutions are multiple; A storage seems necessary. The simplest way is to use a battery but we are actually studying a storage using super-capacitors, those could be integrated in the power electronics. The choice of the motor is also wide; DC or AC ? If the first solution seems obvious, the second could be interesting for maintenance, efficiency and price purposes. The choice of the voltage for DC drives is made simpler with power electronics. As a preliminary conclusion, we see that there are a lot of solutions; each of them has to be carefully examined, particularly on the following points: efficiency, maintenance facility and cost. In view of industrial solutions, the second and third points come first. But different solutions could be more appropriate according to different power consumption profiles.

Conclusion on application of portable fuel cells for boats

Energetics of boats are all but evident ! The study has just started and so far the results rise more questions than we intended to solve ! For small boats (2-4 people), a power of 100-300W allows a speed of 5-10 km/h, depending on the design of the boat. This last point is the an essential factor for speed. A portable fuel cells of that power is 10-20 kg heavy, which is not a problem for a boat. Autonomy is more critical; now about 6-9 hours with 10L hydrogen cylinders. Also, the boat design allows to use larger or several bottles, but with the drawback of increasing the overall weight. A electrolysis system complementary to solar cells is of great interest, practical/technical solutions remain to be explored. Power controlling is open with quite a lot of solutions; further parts of the study will bring appropriate answers as the problem is relatively well known, easy to simulate and elements are available on the market. Security for users, ageing of cells, price of the cells and of the fuel are also critical points to be solved. However, this study shows a real interest for that application. It provides silence, absence of pollution and respect of the environment. If this solution is convenient for small boats (fishermen, boat for protected lakes, forest guards, following boats for swimming or rowing competitions...), we are convinced that applications would be even more interesting for large passenger boats. The size of the boat, thus the height of the critical speed, the use of the heat, the potential role for more classical fuels (with a reformer) are promising topics for the future on that application.

i) OFEN : Office fédéral de l'énergie).
ii) PSI : Paul Scherer Institute
iii) IGS : Ingenieurschule Soleure
iv) SILSE : Service de l'énergie des SI Lausanne

[1] D Cicio, « Conception d'un bateau à pile à combustible », diplôme *eivd*, 1998
[2] P Favre, D Cicio, JF Affolter, « Fun boat powered by a fully automatic fuel cell », EuropeanFuel Cells Forum, Lucerne, 1999.