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Utilities and their investments in fuel cells

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Abstract

Fuel cells are tested on a large scale by utilities around the world. Most of the interest is shown, for obvious reasons, in Europe, the USA and Japan. However, there are still very few fuel cells purchased under normal commercial conditions by the utilities, even though there is a considerable interest from different utilities to introduce fuel cell technology. There are a number of reasons for this, one of the most obvious being the qualified benefits for fuel cells enabling production of electricity with a minimum of emissions along with a reasonably high electricity efficiency. In competition with fuel cells, there are a number of existing technologies under development. One must have in mind that all technologies develop when in competition. The utilities, whoever they may be in the future, look for devices with high electric efficiency and low emissions. Thus, their interest in fuel cells may extend towards a combination of fuel cells and advanced gas turbines, giving a high electrical efficiency, far higher than could be expected from competing technologies today. In the long term there may also be opportunities to consider alternative fuels such as gasified biomass and/or coal to be used in fuel cells. In the further long term, hydrogen may be a fuel to be introduced on a large scale, perhaps becoming the real breakthrough for fuel cell technology. The market for different technologies, including fuel cell technology, will continue to change, as do the actors in the market. As a number of new actors may show up in the market, it is difficult to predict who the purchasers will be in the future. All actors, however, will have the same view on the technologies to be used; technical, economical and environmental benefits must be shown. The above-mentioned factors and parameters will be addressed in the paper, viewing also the fact that new technologies, when introduced, almost always have to show more benefits than existing technologies. © 1997 Elsevier Science S.A.

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1. Introduction

Interest for using fuel cells in the energy system has grown substantially over recent years. The demonstration of fuel cells in many countries has so far shown a reasonable success, where both users and manufacturers have gained benefits. However, problems have also occurred and have shown that the introduction of new technologies, like fuel cells, may take a longer time than could be expected.

The actors in the market, i.e. different users and manufacturers, have, however, not yet fully demonstrated what the requirements of fuel cell technology are, and what can be achieved with the technology when it is close to being established on the market.

2. Fuel cells — why do we pay an interest?

The principle of the fuel cell is very easy. Simply combine hydrogen and oxygen and get energy out of it. The waste product is water. Even if it seems easy, all of us that have been involved in the technology know how difficult it is to go from theory to a practical use of the technology.

What we have learnt is that fuel cells have

- high efficiency;
- low environmental impact;
- low costs also in small units; and should be
- easy to site

These factors, together with the interest for distribution generation, are the main reasons why the utilities show an interest in fuel cell technology and are operating demonstration projects, even though we do not have full knowledge of how fuel cell technology performs in the longer term. This is what we have to find out. In this respect our main concerns are:

- how good is the technology;

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- where can it be used;
- is it competitive; and
- what if it fails?

3. Who are the actors?

Of high importance for the introduction of fuel cells is who will purchase them. Up till now, most of the fuel cells have been purchased by R&D departments in companies. The next step – the commercialisation – will be tougher as commercial departments may become involved and stress the economic factors further. They will most likely not have any special fuel cell technology in mind, but will compare what this technology may give in comparison with other technologies. At the end of the day economics will be paramount.

4. Fuel cell technologies

A number of different fuel cell technologies have been developed over the years. Of the four main different fuel cell technologies, the utilities do have an interest in all of them, albeit for different reasons and with different applications and configurations in mind.

To date, only the PAFC technology has been demonstrated on a scale interesting for the electric and gas utilities. PAFC technology may have a good chance to compete with other technologies in various applications, even if fuel cell technologies with higher efficiencies, like the MCFC and SOFC technologies, most likely will be more economical. But, as said, we are not yet at that point.

In order to find ways and means about the experiences gained by the utilities, a special users group has been established. The European Fuel Cell Users Group (EFCUG) was established in 1992 when the first demo-units on a somewhat larger scale started operation in Europe. The group has now roughly 15 member companies and meets on a regular basis to exchange hands-on operating experience. Still, the discussions concentrate on individual technologies, which is obvious when a technology develops. In the longer term it may be more appropriate just to refer to ‘fuel cells’. This technology then can vary a lot depending on the requirements from the users, and also on what applications we consider.

The fuel cell as a technology must be seen as a component in a system. It is by no means an isolated technology operating by itself. In most cases the fuel cell is an integrated part of a total system and, thus, we have to consider all aspects with regard to this system when looking at the fuel cell itself.

As we know, there is a kind of competition between the different fuel cell technologies. We may dream that fuel cells might be the key technology and final solution for the future. To be frank, however, how much attention do we pay in this respect to the development of competing technologies? In most cases the real competition will come from there.

5. Fuel cells on the market

The market for fuel cells is mainly directed by the demands for technologies that are low-priced, with high efficiency and low emissions. Fuel cells, however, have to face severe competition from still developing technologies, like highly efficient gas turbines in combined cycles. Apart from improvements in conventional techniques, fuel cells will also have to compete with new energy generation techniques such as solar and wind energy.

Therefore, the role fuel cells will play in the future will be determined by the prevailing economic conditions and environmental regulations. The most important applications will be found where avoiding pollution is a crucial supplementary condition. As in densely populated areas, market penetration will also depend on the price for the total system offered, compared with prices form competing technologies equipped with emission control equipment.

The fuel cell may be installed in a number of applications such as on-site, combined heat and power systems as well as in large centralised systems. Only the market forces will show and tell us where fuel cells will be most applicable and where they will find their market. At present we see one market in the small-scale applications, e.g. on-site, and one other market in the small district heating area or industrial area.

The user of the technology is of course interested in using fuels that are normally used in the energy system. In the short term and for a number of applications, natural gas is to be used. An interesting development in the longer term is the possibility also to utilise gas from coal or biomass gasification, and the direct use of hydrogen in fuel cells — in which case the reformer is excluded. The latter technology makes the fuel cell, as such, easier to operate and will also give a higher efficiency to the plant. As always, the problem is that hydrogen does not exist free.

In various branches of industry large amounts of hydrogen are available, which makes the application of fuel cell systems an attractive option from both an efficiency and a cost perspective. In addition, industry seems a very appropriate sector to start the introduction of fuel cell systems, having in mind the experience in this sector with process units similar to fuel cell systems.

Fuel cell systems for co-generation in urban areas, for use in offices, restaurants, hotels, hospitals and housing estates, may have a capacity of up to approximately 1000 kWe. Urbanisation is characterised by a high heat/power ratio in energy demand. Given the low heat/power ratio of fuel cell systems with respect to the demand in this market segment, the utility sector will be the obvious partner to realise and operate decentralised fuel cell CHP projects.

For application in the industrial sector, fuel cells in the multi-megawatt range are needed. Possible users are to be found in (petro)chemical, food industry and (heavy) steel industry. For industrial application the temperature level of the produced heat will be a significant parameter for market penetration.

Crucial for the market penetration to fuel cell systems are specific investment costs and operating costs. The specific investment costs will be determined by the potential sales and hence the price restrictions associated with mass production. It is, however, important to realise that the competitive specific investment costs for fuel cell systems are different for each country, as parameters affecting these specific investment costs may differ considerably. Besides this, the competitive specific investment costs will also vary with the type of application.

It is important to know which parameters are affecting the market introduction of fuel cell systems and how important these parameters are. Those parameters are all to be find in any of these groups:

- technical
- environmental
- economic

6. Technical considerations

A number of technical items are still unsolved for the fuel cell technology. Many of these items will be solved when the manufactures develop further the fuel cell stack and systems to a commercial level. When using a fuel cell the user has to look at the costs for installation, operation, maintenance etc. At the end of the day the main interest is the total cost to be spent over a longer period — the life cycle cost.

Some of the conclusions from the operation of fuel cells today are:

- It is very important to have an early indication of the specifications for different applications.
- It is essential not only to have reliable fuel cell stacks but also to have a total system that does not fail, causing problems for the stack.
- The utilisation of heat in a variety of applications has a major influence on the technical requirements for fuel cell systems in different countries.

7. Environmental considerations

Environmental considerations will play an increasingly important role in the installation of technologies for energy systems in any country.

The fuel cell is normally referred to as an environmentally clean technology; all the experiences gained from the operation of PAFC units show that the environmental impact from fuel cells is very limited. However, it seems clear that, depending on the environmental concerns of interest, it might be useful to study the whole chain of the ‘fuel cell cycle’. The justification is that the consideration of the fuel cell in a system also includes manufacturing constraints and disposal of the waste. Life cycle analysis may play an important role here. However, it is then of course important to understand that the figures obtained can only be used as a reference, and also that other technologies must be analysed in the same way.

8. Economic considerations

It appears difficult to find a general conclusion about the economics of fuel. The economics very much depend on the actual situation where it shall be applied. Even so, some conclusions can be drawn.

- Fuel cells will meet tough competition from reciprocating motors, gas turbines and combined cycles.
- The stack replacement cost must be reduced. This could be done either by extending the lifetime of the stack, or by reducing the reinvestment cost, or preferably by achieving both things at the same time.
- It is important to design the system in such a way that maximum use of the surplus heat from the fuel cell will be acquired. Therefore, in co-generation mode a high total efficiency is of greater importance than a high electric efficiency.

For the user of the technology the investment cost is of high interest. However, of even higher interest is the cost of the generated electricity per kWh. Also, a number of other parameters such as efficiency, environmental aspects and electricity distribution costs are of importance in the calculations.

9. Fuel cells and the utilities in the future

The future market for fuel cells, in all applications, depends mainly on the demand for low-cost production of electricity together with environmental regulations. How fuel cells may compete here is not easy to say, as the technology still is under development, and also that the competing technologies will be further developed in order to meet the demand from the market. For the fuel cell itself, it has been proven that the emissions of NO_x will be substantially low (1–2 ppm). Thus, the positive factors with fuel cells are easy to show. On the other hand, there are also problems, as have been mentioned. The most obvious one is that we still do not know what the long-term operation costs will be and, due to this, we do not know the size of the market that fuel cells will cover.

A number of items related to the long-term costs that will affect the user, both direct and indirect, have to be considered. As fuel cells of all types still do not have many operation hours, it is difficult to identify all the important issues that should be taken care of. Some of the lessons learned from the operation of the demonstration units can be mentioned, such as the lifetime and reliability of different components that are critical and can affect the lifetime of the whole system, and especially the stack. Moreover, efficient and accurate troubleshooting is essential, and a compact design should be applied to a reasonable level regarding the needs for maintenance and repair. The matters that must be essential for the manufactures are therefore to simplify the system and single components that would allow further cost reduction, increasing the lifetime for critical components as well as developing a low-cost stack for easy replacement.

It is understandable that, within the short time fuel cells have been demonstrated, an important issue for fuel cell development is to collect operating hours and gain experience from this. All those now looking for the possibility to demonstrate fuel cell technology and later purchase commercial fuel cells have a keen interest in this. The question we raise is: how good is the technology from a technical and economical point of view, and what will be the cost for the generated electricity? For this reason it is logical that the customers/users co-operate when evaluating the technologies, including the fuel cell technology, they may use in the future.

So, fuel cells seem to have found a role in the energy systems around the world, and especially in co-generation systems. How long it will take before the technology will give a substantial input to the system is impossible to predict, as this depends on so many factors. Of most importance is how fast the competing technologies will develop, and to what extent fuel cells will be helped in its introduction by grants from Governments. Before that, a number of technical issues have to be solved, and the investment and operation costs must be lowered. For this reason, more operation hours have to be demonstrated and the manufacturers have to work hard to introduce effective low-cost systems. However, there is no doubt that fuel cells will play an important role in the energy systems around the world.

The fuel cell as a technology has been known for more than 150 years. Our knowledge in its use and utilising the benefits from it has a much shorter history. When William Grove in 1839 showed the principle of what today is named the fuel cell, nobody could predict the future use of the technology. The same reflection can be applied today; nobody knows the direction fuel cells may take in the future and to what extent new inventions may change history. The future for fuel cells very much depends on both the development of the technology itself and the possibility to utilise the technology in our system for the production and utilisation of electricity and heat. There are many of us that strongly believe that fuel cells will play an important role in future energy systems. There are uncertainties, but one thing is clear: only time will tell us how right or wrong we are in this respect.