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The first demonstration of the 250-kW polymer electrolyte fuel cell for stationary application (Berlin)

Martin Pokojski *

BEWAG, Puschkinallee 52, 12435 Berlin, Germany

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1. Introduction

For many years, fuel cells have been widely regarded as being an option for the power supply of the future. Despite their large energetic and ecological–technical prospects, they have been applied in only a few cases for power supply, particularly in pilot and demonstration projects. The reason for this is attributable to the technical difficulties involved with the use of fuel cells.

In recent times, there have been very promising indications that fuel cells manufactured serially could be used commercially on a medium-term basis. With the phosphoric acid system produced by ONSI, a commercially marketed system is already available. However, the price of over 5000 DM/kW_{el} does not represent an incentive for power companies to apply this system economically.

The Polymer Electrolyte Membrane (PEM) technology is considered to have future prospects of success from an economic viewpoint. Small plants are already being used as pilot systems. They serve the purpose of supporting the power supply or for extending cogeneration in conjunction with heat utilization.

In Europe, the first 250-kW PEM plant will be started up in Berlin at the end of this year. The success of this project is decisive for the commencement of series production by the manufacturer Ballard/ALSTOM in a few years time.

The purpose of the following explanatory information is to show why this project is being carried out in Berlin and where its main line of research is centred. The information closes with a view towards future perspectives and a vision of a power supply organised with PEM fuel cells.

2. Fuel cells' potential in the power market

2.1. The power market

Fuel cells are to be regarded as universally applicable systems. With their wide-range and flexible technical options as well as different applications modes, they provide the pre-conditions for use not only in the mobile sector but also in all areas of power supply requirements.

For high-temperature cells, application in the power plant sector and in the industrial supply is marked out. In the power plant sector, it is the obvious choice to apply fuel cells as single systems, and also in conjunction with gas turbines. The latter option, in particular, offers the perspective of very efficient generating systems in conjunction with inexpensive gas turbines. Efficiencies of over 60% are attainable in this way.

In the industrial sector, process temperatures of up to 1000°C offer the option of supplying process heat requirements in conjunction with electrical power generation. In addition to the classic generating systems such as steam and gas turbines, the industry has a further element which, while maintaining the economic competitive ability, should have chances in this market segment due to its ecological advantages.

A particularly interesting factor is the application of fuel cells in the retail market. The low temperature requirement existing here offers the chance for using low temperature systems such as PEM technologies. It is expected of these that they can be made at a particularly inexpensive price both in mobile as well as in stationary operation due to their many fold application options. Such applications include administration buildings, public buildings, hotels but also the entire sector of private households which, up to the present, have been practically closed to an indepen-

* Tel.: +49-30-267-10403; fax: +49-30-267-14106; e-mail: pokojski.martin@bewag.com

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dent supply of their own. Especially where the household sector is concerned, conditions could be created with cost-optimised systems that would allow an almost extensively independent power supply. In the decentralised system and in conjunction with a heat credit volume, production costs could be realised, which would facilitate a competitive operation under additional consideration of power price reductions related to the competition.

2.2. The retail market as a stimulus for decentralisation

About 50% of the overall electric power consumption is allocated to the sector of households, small-scale trade units and the public sector, meaning, the retail consumption sector. At the same time, this market segment is characterised by the highest prices for electric power. For power companies, this sector has a correspondingly high strategic value.

This market segment indicates a high requirement of heat for heating and for the treatment of service water. In addition, the requirement for refrigeration and climate control increases accordingly. In many cases, this requirement for heat and refrigeration occurs in parallel with a corresponding electric power requirement. Subsequently, there exists a prerequisite for cogeneration. For fuel cells with their manifold application options, this signifies an enormous application prospect. This can be used economically by bundling the demand. This strategy, which is adopted by brokers for the development of profitable power businesses is the basis for an economic application of fuel cells.

A major advantage of fuel cells compared with conventional systems is the feature superior non-polluting feature, making them ideal for the environment. Conventional pollutants such as dust, carbon monoxide and nitrogen oxides are practically negligible. In contrast, attention needs to be paid to fuel cells concerning their carbon dioxide emissions. For electric power production only, this must be given consideration in the form of a high net-efficiency. For cogeneration, this is achieved by means of a high system efficiency which is attainable by the utilisation of heat released for heating purposes, service water and climatisation. Therefore, cogeneration operation contributes to the reduction of CO_2 emissions in the decentralised sector.

Another advantageous factor for the use of fuel cells is their excellent supply compatibility with natural gas, as exists in Germany and other European countries in the retail sector. Natural gas is available over large areas. As the present fuel cell systems primarily operate with natural gas, the application options for these systems are, relative to fuel, only subjected to minor limitations.

Another advantageous factor for the new systems in the decentralised sector are the presently existing high prices for electrical power. As seen from the viewpoint of consumers, this is a precondition for economic operation. Even if fuel cells produce power at higher costs compared with centralised systems, only the price at the location is decisive for the consumer. For decentralised systems, it offers an interesting economic incentive; at least, the operation of decentralised systems in cooperation with the consumer leads to a new customer relationship. The operation of these plants in the vicinity of the customer corresponds to a power provider service. This results in a new field of activity for the power companies. Fuel cells provide the opportunity for the development of power services.

Despite the declining prices for electrical power, the rising competition for decentralised systems offers economic advantages. Electric power, not required by the operator himself, can be transmitted through the network and sold to other consumers. The basis for economic operation is substantially improved as a result. And, moreover, decentralised systems can be operated as an interconnected system. A mutual reserve is made possible as a result. In addition to and beyond this, electric power and reserve power can be drawn from the public grid under more favourable conditions. The economic preconditions for decentralised systems should improve accordingly as a result.

In summary, it can be stated that the retail market offers favourable preconditions for the economic operation of fuel cells. Cost-optimised systems should have a good chance of gaining a foothold from an economic aspect. The retail market could, therefore, become the key sector for the economic success of fuel cells.

2.3. Cogeneration in Germany

Fig. 1 illustrates the primary consumption in Germany for the year 1996. According to this, about 40% of the total volume of power consumed is used for heat supply and service water treatment. The portion for natural gas is in the region of 42% and that of oil at about 30%. Electric power and coal have 10% each, while the quota for district heating is approx. 6%. About 2% is allocated to other energy sources.

Where power companies are concerned, the question arises as to what consequences a different market penetra-

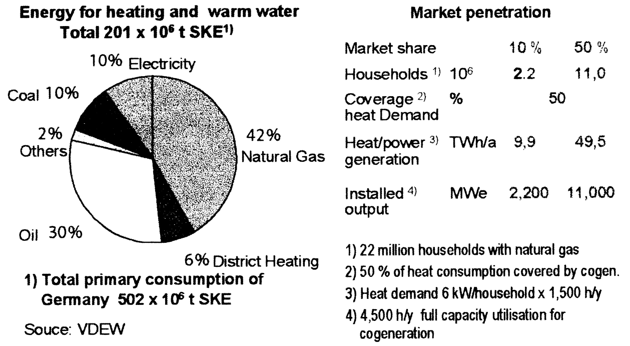

Fig. 1.

tion would have for fuel cells. The basis for this observation here is the assumption that only natural gas supplied systems for the cogeneration of power and heat are implemented.

About 22 million households in Germany are presently supplied with natural gas. Assuming a supply of 10% of these households with fuel cells, this would correspond to a quota of 2.2 million households. Based on a conservative approach, which assumes that only 50% of the heat consumption is covered by supply from a cogenerating system — standard systems proceed on the basis of a coverage rate of over 80%, an electric power production of 9.9 TWh results annually for a power factor (electric output/thermal output) of 1. With reference to a full capacity utilisation of 4500 h annually, this results in an installed electrical capacity of about 2200 MW. If the quota of households which are equipped with fuel cells is 50%, an annual power production of about 49.5 TWh results. This corresponds to an electric capacity of approx. 11,000 MW, which is about 12% of the entire capacity of the public supply installed in Germany. Therefore, fuel cells could make substantial contributions towards a change in the supply structures. This means that power companies, in their own interests, will need to come to terms with this technology. The Berlin demonstration project presently in the planning stage takes this approach fully into account.

3. Berlin fuel cell project

3.1. Project team and financing

Bewag and its partners EDF-Paris, HEW-Hamburg, PreussenElektra-Hannover and VEAG-Berlin are presently installing a fuel cell project in Berlin. For the first time in Europe, PEM technology in the 250-kW performance class is being applied.

The fuel cell to be tested here, based on PEM technology, is applied in a modified form in the mobile sector. This implies (), hence synergy effects should be derived from it. Very inexpensive generation systems could be made available as a result.

The system to be applied in Berlin is derived originally from the Canadian company Ballard who will be producing this system in serially in the future, together with its partner ALSTOM, within the framework of a new company in Europe. A prerequisite is the successful performance of the demonstration project planned with Bewag.

The highly innovative character of this project and its possible positive effects for the European economy has induced the European Commission to financially support the undertaking. The Commission is participating in the overall costs of the project amounting to 7.5 million DM with a contribution of about 40%. The remaining costs are shared by ALSTOM with about 10% and about 50% by the operating power companies.

3.2. Why PEM?

The question is repeatedly asked why Bewag and its partners have decided in favour of PEM technology. From the viewpoint of the power companies, a number of advantages associated with this technology speak for this decision.

PEM fuel cells can be applied both in the mobile and in the stationary sector. The manifold application options offer synergy effects can result in advantages for stationary applications. Subsequently, there is the expectation that the possible cost-saving effect of mass production in the mobile sector may also be utilised for stationary applications.

Compared with all other technologies, PEM has the highest power density. A continually existing development prospect indicates that a further increase of power density should be possible. Both are prerequisites for () smaller and space-saving systems as required in decentralised applications.

The stack temperature level of PEM fuel cells, in the region of 90°C, is very attractive. In this way, water can be heated to about 75°C. This temperature level is more than adequate for future heating systems with the inclusion of regenerative cycles.

The manifold applications in the stationary sector speak in favour of PEM. They range from small-scale applications in the watt range, over decentralised applications in power-heat cogeneration, and up to applications in emergency power supply. PEM meets expectations here in all cases. Accordingly, this technology is to being evaluated as universally applicable. Higher production figures should result here again, which is advantageous to this technology from the aspect of costs.

3.3. The fuel cell process

The fuel cell system to be used in Berlin (Fig. 2) works, including reformation, under pressure. The operating pressure is about 4 bar.

The arrangement of the system corresponds to the design concept used in ONSI-plants: natural gas is cleaned, reformed and then supplied as an H_2/CO_2–gas mixture to the fuel cell. In the fuel cell, unused H_2 serves reformer

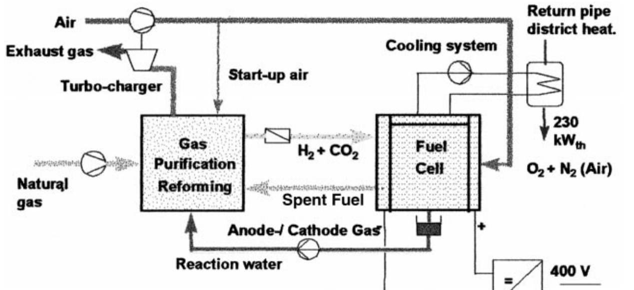

Fig. 2.

energy requirements. The steam requirement of the reformer is adequately provided by the condensate recovered in the fuel cell. For part load operation, deionised water is supplemented and made available from the heating plant.

Pressure operation is a special factor. It facilitates the construction of a relatively small and compact design with relatively low weight. For the stack, this results in a higher performance and higher efficiency compared with atmospheric operation.

Pressure operation requires the compression of natural gas and process air required in the fuel cell. In particular, the power requirement resulting from air compression normally entails a significant increase of the operator's own requirement. By utilising the energy contained in the exhaust gases by way of a turbo-charger, this requirement can be reduced substantially. When the gases are expanded to ambient, the power requirement of the air compressor is completely accounted for.

The process envisages cogeneration of heat for heating purposes from the fuel cell. The cell has a cooling water flow in the primary circuit, and this cooling water transfers its energy to the district heating system by way of a heat exchanger. If there is no heat requirement, an emergency cooler provides for adequate by-pass cooling of the primary circuit.

3.4. Integration of the fuel cell into the Treptow heating station

The fuel cell plant is integrated into the existing heating plant at Treptow. This heating plant with its two steam generators, each with an output of 12.7 MW, and the hot water boiler with an output of 18.7 MW serves to supply a direct heating network with a present maximum requirement of about 25 MW. The minimum requirement in the summer is 500 kW.

It is planned to integrate the fuel cell into the existing system by way of a by-pass. The hook-up is in the return line by way of a heat exchanger which heats up the return water of the direct heating network by about 10°K, normally from 65°C to 75°C. The low temperature level of the return over the full year makes it possible to completely use the exhaust heat of the fuel cell at all times.

The electric output of the fuel cell plant is up to 250 kW. This power is sufficient for the entire requirement of the heating station. It provides the pump power requirement for circulating the heating water, the drive of the burner fans and a low level miscellaneous requirement for the upkeep of the heating plant.

3.5. Approval procedures

The plant will be examined and tested within the framework of the German Federal Commission Protection Law. The main aspect of examination here is the technical testing by TÜV Rheinland Berlin/Brandenburg. Work already commenced on this in January of this year. The SC tests cover the individual testing of components, safety and functional testing. All work related to the manufacture and preliminary testing will be performed in Canada. These tests are carried out in accordance with the latest European Directives for pressurised equipment as well as the Canadian Standard CSA. The objective is, within the framework of the testing procedure, to carry out all tests possible, which will be required later for the serial production.

Functioning and safety testing will be performed in Berlin. If required, further individual testing will be performed in accordance with the specified requirements of the TÜV and the approval authority. The entire approval procedure is expected to be completed on the beginning of 2000. Independent of this, a startup of the plant is planned for December of this year (1999).

3.6. Measuring program

The objective of this project is to test all the characteristics and features of the system within the scope of a comprehensive measuring programme. All parameters for the systems will be recorded and evaluated. The main aspects of the measuring program are as follows:

Demonstrating that the plant operates satisfactorily on natural gas and that the reforming process functions as it should;

Range under which the efficiency remains constant;

Plant ageing and rate of voltage decrease;

Demonstrating that the stack and the entire plant have an adequate working life;

Examining the way in which the plant fits into the power and heat supply systems.

It is planned to start up the plant at the end of 1999. The intensive monitoring phase will take about 12 months.

It is planned to operate the plant for a period of approx. 5 years. During this time, statements on working life, maintenance expenditure and other significant operational characteristics will be issued.

4. Developments–expectations

4.1. Product development

The demonstration plant to be started in Berlin is the first European plant of its kind. The objective of the project is to apply a product which covers the requirements of the European market to the greatest possible extent. This includes the application of the system as well as the approval procedure which presently makes reference to the European directives otherwise applicable in future.

Independent of this, the objective of the development work is to make the product even more compatible for the market. The following projections by ALSTOM BALLARD reflect the efforts being made in this respect:

	Today	Goal
Price	MDM 6.25	MDM < 0.75
Efficiency	35%	40%
Weight	20.4000 kg	12.500 kg
Size	2.4 × 2.3 × 7.3 m	2.4 × 2.3 × 6.5 m

4.2. Applications of fuel cells in the decentralised sector

Development is aimed at using consumer-focused fuel cells for direct power and heat supply. This requires systems which can be conveniently integrated into existing supply systems. In addition, the plants must be conceptually designed in such a way that noise disturbance for the consumer is avoided when the plant is installed outdoors. For the demonstration plant in Berlin, this means that a noise emission level of max. 45 dBA is ensured.

For economic operation, it is necessary that the plants allow extensive substitution of the electrical power as supplied by the power companies. The economical feasibility of the systems ultimately depends on the electric power credit. The heat credit also contributes to the economical aspects as well as to all savings such as energy, performance and maintenance costs.

Experience shows that a supply to individual consumers does not necessarily lead to the desired economic success. Prerequisite for an efficient operating mode is the bundling of demand. The provision of the requirements of many consumers makes possible a significant reduction of the mean consumption of the individual customer, such as households or industrial users. As a consequence, the power requirement needed for the supply can be substantially reduced. On the same scale, an increase of the full capacity utilisation can be assumed and this is decisive for the overall economical feasibility, in particular power-heat cogeneration systems. This can be achieved by way of larger fuel cell units — for example, the module planned for use in Berlin — where the management operation is secured by one single user. Contractual partners are industrial units, housing companies or, in the extreme case, a large group of individual customers who are supplied in a network system (Fig. 3).

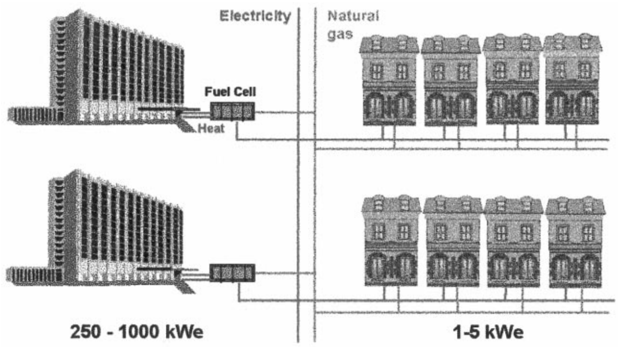

Fig. 3.

With a supply to consumers by way of numerous small units with unit capacities in the magnitude of up to 5 kW_{el}, this suggests that facilities () in a network system. They provide each other with a mutual reserve, and provide, in the network system, the requirements of the consumers supplied; () exchange electricity generation by way of the house-internal network or the public grid. As a consequence of this, a decentralised network system would develop, counterpart to the () high voltage network system.

5. Conclusions

In summarising, it can be stated that fuel cells may represent an interesting solution for the purpose of providing the heat and power requirements of the retail market in power and heat cogeneration. This applies in particular for the PEM technology.

The Berlin fuel cell project, with its comprehensive test programme, is a substantial and meaningful contribution towards the introduction of the fuel cell in the power economy. The project can be regarded as a very significant step on the route for commercialisation PEM technology. However, it is too early to predict detailed performance expectation, which must await this demonstration coming on stream.

The economic application of fuel cells depends decisively on the bundling of demand, meaning, the supply of a large number of consumers with a system and a system network. In this way, and with corresponding economic success as a supplement to the existing central network, the fuel cell could lead to the development of a decentralised network system.