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Challenges for fuel cells as stationary power resource in the evolving energy enterprise

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Abstract

The primary market challenges for fuel cells as stationary power resources in evolving energy markets are reviewed. Fuel cell power systems have significant barriers to overcome in their anticipated role as decentralized energy power systems. Market segments for fuel cells include combined heat and power; low-cost energy, premium power; peak shaving; and load management and grid support. Understanding the role and fit of fuel cell systems in evolving energy markets and the highest value applications are a major challenge for developers and government funding organizations. The most likely adopters of fuel cell systems and the challenges facing each adopter in the target market segment are reviewed. Adopters include generation companies, utility distribution companies, retail energy service providers and end-users. Key challenges include: overcoming technology risk; achieving retail competitiveness; understanding high value markets and end-user needs; distribution and service channels; regulatory policy issues; and the integration of these decentralized resources within the electrical distribution system.

Keywords: Competition; Markets; Applications; Barriers

1. Background

Fuel cell systems for stationary electric utility applications have been under intense development for the past 20 years. Building on an initial technology push required for the US manned space program, fuel cell power system are now receiving a new push from large R&D investments for transportation markets. In the early 1980s, EPRI and the US Department of Energy (DOE) focused fuel cell R&D toward high efficiency central station systems involving the gasification of coal. Mean while, the Gas Research Institute and gas companies focused their fuel cell R&D towards smaller, on-site energy power systems in the 40 to 200 kW size range. In the late 1980s and early 1990', it became apparent, through a combination of hardware development, and field trials, that fuel cell stationary power systems would most likely have the best fit as small, high efficient, natural gas, decentralized energy power systems. Today, we refer to these systems as ‘‘Distributed Resources or Distributed Generation’’. The transformation and redirection of fuel cell R&D from a central power system orientation toward a more decentralized power direction was recognized early by EPRI in the mid-1980s.

As the twentieth century comes to a close, there have been very significant efforts to push fuel cell technology into the stationary and vehicular market applications. Phosphoric acid fuel cell systems have been demonstrated in systems ranging from 12 kW to as high as 11,000 kW. Currently there are over 100 200-kW size systems in operation throughout the world. Carbonate systems have been demonstrated in scales of 250 kW up to 2000 kW. Solid oxide systems are currently being demonstrated in sizes ranging from a few kW up to 250 kW. In the past 5 years, accelerated R&D in polymer electrolyte membrane fuel cells have resulted in demonstrations of systems in the 3 to 250 kW scale on natural gas.

R&D fuel cell programs in the 20th century can be characterized as a ‘‘technology push’’ effort rather than a market driven development effort. With electric and energy markets becoming fully competitive in the 21st century, and with limited R&D resources, the understanding

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of the market-driven opportunities and challenges for fuel cell cells will be essential to developing successful commercialization programs.

2. Where fuel cells fit in the evolving energy enterprise

The competitiveness of bulk power produced from central station advanced gas turbines, and the restructured electric utility industry has led to the natural positioning of fuel cells as decentralized energy service options (Fig. 1). In the US, the majority of the 60 to 120 GW of new capacity for bulk power will be generated over the next decade by advanced gas turbine combined cycle power systems. These systems have fuel to electricity conversion efficiencies approaching 60%, modest emissions and a installed capital costs under US$600 per kW. Cost of electricity produced at the bus bar from these systems will be near 3¢/kWh. These central station bulk power facilities with their coupled transmission and distribution delivery systems offer ''grid power'' energy and reliability benchmark services upon which decentralized systems must be compared.

The most challenging aspects for commercialization of fuel cells is the recognition of where the true market applications and opportunities exist. With US electric industry restructuring and privatization of electric markets in Europe and Asia, the role and fit of fuel cell based energy systems need to be carefully re-evaluated. While markets will vary based on regional needs, it is now widely believed that fuel cells will fit better as decentralized energy power systems customized to meet the specific needs of end-users. EPRI's research in distributed generation has identified four plausible long-term markets and the type of energy solutions fuel cell power systems may offer. These include: (1) providing lowest cost energy to end-users; (2) providing solutions for combined heat and power (CHP); providing high power quality premium power; (3) providing peak-shaving solutions; and (4) providing load management and grid power to support electric distribution companies in the management of their assets. As distributed resources, however, fuel cells will also find competition with other distributed technology options: IC engines; micro-turbines; and small gas turbines.

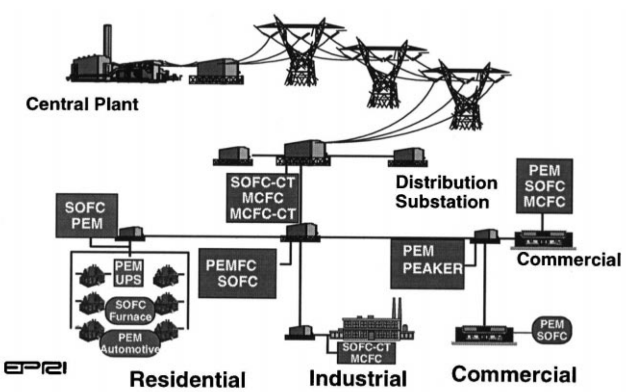

Fig. 1. Fuel cells will be deployed as distributed resources to provide energy solutions for retail energy providers, end-users and to enhance grid operations.

Plausible markets for stationary fuel cell power systems include:

- Combined heat and power
- Peak-shaving
- Premium power
- Low cost energy
- Grid support and load management

A review of the opportunities and challenges for fuel cell power systems in each of these plausible markets will illustrate research priorities to achieve market destinations. Prospective adopters of fuel cell systems and their inherent challenges will also be examined. First let us examine the possible adopters in competitive energy market structures.

3. Adopters of fuel cell power systems

Adopters of stationary distributed power systems will include: Generation Companies (GENCO), Retail Energy Service Providers (RESP), Utility Distribution Companies (UDCs), and end-users like industrial, commercial and residential customers.

Table 1 illustrates how these adopters map into the plausible market segments.

3.1. Generation companies (GENCOs)

The competitiveness of large gas turbines and business strategies of GENCOs will limit the near term early adoption of fuel cell distributed power systems to the larger SOFC-CT and MCFC-CT systems in the multi megawatt scale. Specialty GENCOs will seek power options that can provide the lowest possible electricity as well as peaking power services. These hybrid systems offer the potential for both high efficiency and peaking capability.

3.1.1. Challenges for GENCOs

Technical and operational risks of fuel cell systems must be well understood and manageable, especially accurate knowledge of system heat rate and operating and maintenance costs. Demonstrated performance, price and durability are key issues for this adopter. Fuel cell products in the multi megawatt scale will be of most interest; systems that can provide extra peaking capabilities will offer the highest value in restructured markets in the US. The biggest challenge is price competitiveness with other grid supply options.

Table 1

Adopter of fuel cell power systems	Primary drivers
Generating Companies (GENCO)	Bulk power, low-cost energy
Utility Distribution Company (UDC)	Reliability, grid support, asset management
Retail Energy Service Providers	Peak shaving, reliability, risk management, CHP, environmental management
End-Users	Price, reliability, and improved service, independence Low-cost energy

3.2. Retail energy service providers (RESP)

These companies will most likely be involved in offering industrial, commercial and residential customers bundled energy services which may include forms of onsite-power systems to meet customer needs. RESP's will most likely develop energy solutions involving combined heat and power, uninterruptable power and premium power, and energy bill management and risk management options through onsite power systems.

3.2.1. The challenges for the RESP

They will take fewer technology risks than other adopters — so fuel cell products have to be very reliable and proven. RESPs will also require a good understanding of end-users needs, applications and the solutions fuel cells can provide based on their characteristics. RESPs will most likely not own and operate fuel cell power systems but rather they will enter into contractual agreements with providers of fuel cell power systems. Market and contractual risk management mechanisms between fuel cell vendors, owner/operators and RESPs will need to be developed.

3.3. Utility distribution companies (UDCs)

UDCs manage the grid interconnections and distribution and will be responsible for the reliable delivery of power to end-users and under contract terms with power marketers, RESPs or other third party providers. The value UDCs see from distributed resources include: capacity for meeting distribution needs, management of distribution investment options, reliability and improving grid congestion. In de-regulated power markets, fuel cell power systems that can provide quick peaking capacity will be valued the most by UDCs.

3.3.1. Challenges for UDCs

UDCs have the least incentives to adopt fuel cells in the near term. Incentives for adopting distributed resources, in general, are currently non-existent in the US with the exception of state specific performance-based rate-making. Poorly planned or sited fuel cell applications by third parties could cause problems for the utility system and other utility customers. Problems may range from minor voltage flicker disturbances to major equipment failures and islanding conditions that may jeopardize human safety and cause damage to customer appliances. Since fuel cells employ dc to ac inverters, this should be less problematic than with other technologies such as engines and other challenges from the UDC perspective are outlined below.

3.3.1.1. Limited competitiveness. Generally, today's most viable distributed resource options such as combustion turbines and internal combustion engines are competitive as a primary source of electricity only in specific applications: in regions where gas prices are low and electric rates are high; where there are opportunities to utilize waste heat from generation in CHP applications; and in end-use segments where a specific value to the end-use customer can be realized, such as enhanced reliability of service. As primary power sources, fuel cell power will have to be either competitive with delivered grid power or offer other benefits to the UDC.

3.3.1.2. Limited system savings. Fuel cells do not presently provide substantial T&D infrastructure benefits on a general basis. EPRI studies indicate that the ability of distributed power to provide T&D investment savings is technically limited to electric distribution infrastructure costs like distribution transformers, distribution substations, and new distribution feeders-all of which are less expensive than transmission equivalents; savings for transmission infrastructure are generally limited to niche applications.. The ability of fuel cells to support and/or defer T&D infrastructure investments is difficult to establish in a generalized way because applications are very site specific. Because distribution infrastructure is unique to each locality, the possibility for savings varies significantly from site to site.

3.3.1.3. Lack of market rules. The rules of the game are still evolving in the US. Quantification of market values for capacity, congestion, reliability and voltage regulation will aid in the recognition of the value of decentralized fuel cell power systems by UDCs. Quantification and a pricing framework for stranded assets, exit fees, and the cost of providing stand by power are challenges facing early deployment of all distributed resources including fuel cells.

3.3.1.4. Stranded distribution costs. Stranded distribution costs may result from fuel cell deployment because distribution facilities that were required to be constructed to meet a utility's obligation to serve may become no longer competitive or needed if fuel cell power systems become competitive. In the US, these costs are to be appropriately recovered by the utility distribution company, in some cases they may exceed DR-related savings. The policies for recovery of these costs are presently not available.

3.3.1.5. Interconnection and control. UDCs may be the last to own and operate fuel cell distributed power systems in the near term given trends in regulation in the US. The biggest near-term challenge is resolving interconnection and control standards and lowering the cost of interconnection hardware. Extensive work is under way in the US for a national interconnection standard. UDCs will also require application guidelines and software tools to assess the potential impacts of distributed fuel cell systems on the electrical distribution systems. To adopt and recognize the value of decentralized assets, UDCs will require contractual control and dispatchability of fuel cell power systems. Plug and Play interconnection, communication and control systems are needed. The seamless control and interconnection of fuel cell distributed power systems with the power grid will enable the value of decentralized systems to be realized. In deregulated power markets, fuel cell power systems that can provide quick peaking capacity will be the most valued by UDCs.

3.4. End-users as adopters

Certain end-users such as industrial, commercial and residential customers may be early adopters for fuel cell power systems, but in the long term it will be retail energy-service providers (RESPs) who bundle distributed fuel cell power solutions with other services to meet the unfulfilled needs of end-users. A key challenge is understanding the unmet needs of end-users. End-users seek solutions in the following areas: lower cost energy; meeting thermal and cooling needs; reliability; and premium power in terms of service and power quality.

3.4.1. Challenges in the end-user segment

End-users will generally constitute the most reluctant segment to adopt emerging fuel cell power systems unless there are specific and compelling reasons and tangible values. For mass-market applications, fuel cell systems will have to approach appliance like features. This is a difficult market to sell fuel cell products into; end-users prefer service solutions rather than to buy and operate hardware. Early examples with PAFC systems illustrate end-user needs. PAFCs are being installed at data processing centers; banks and post offices and in high T&D constrained areas where there are high demands for reliability and service. Key challenges in the end-user segment include establishing marketing, sales and distribution channels, and providing informed product information and educational material on the cost and benefits of fuel cell power systems.

Challenges in the end-user market include:

- Understanding customer needs; drivers and price points
- Knowledge and education about fuel cell systems
- Specifications of systems that meet the highest value end user needs
- Building designers have limited knowledge of fuel cell systems
- Belief that energy costs are fixed
- Belief that de-regulation will provide lower cost of service
- Buy or lease decisions

Fuel cell systems that offer the highest value to end-users include:

Combined heat and power systems	MCFC and SOFC
On-site premium power	PAFC, MCFC, SOFC, PEMFC
Peak shaving	PEMFC
Energy Storage and UPS	PEMFC

3.5. Regulatory policy will play a key role in fuel cell deployment

The rules of the game in the US for treatment of fuel cell systems are presently being debated by policymakers as the electric industry restructures to a competitive and non-regulated market. As part of this debate, EPRI supports the development of an unbiased level playing field for distributed resources and conventional electricity service. This level playing field reflects the concept that market forces should allow fuel cells and other distributed power systems to develop where it is the most cost-effective electricity. solution. Several of the challenges in the policy area are briefly outlined below.

3.5.1. Economic principles

In a deregulated, competitive environment, the selection of fuel cells as an energy option should not be hindered by uneconomic costs or barriers nor be enabled with subsidies.

3.5.2. Ownership and operation

Limitations on who owns or controls the fuel cells should not be used so long as ownership and control do not result in violations of regulations or antitrust principles.

3.5.3. Transition and exit charges

Fuel cell system implementation must be accomplished in a manner that allows electric utilities to recover an appropriate share of any costs incurred due to stranded investment or for upgrades necessary to support fuel cell system implementation, but does not shift costs — either stranded or implementation — to others.

3.5.4. Back-up charges

Because today's charges for back-up service are not based on widespread use of fuel cells, provision should be made for new back-up tariffs that reflect the real cost/price of providing back-up service for all distributed resources of the future.

3.5.5. Power system benefits

Because in a deregulated industry it will be markets that determine the mix of resources, appropriate provisions should exist for rewarding fuel cell system owners for providing system benefits and for penalizing them for non-performance.

3.5.6. Power purchase provisions

Net (two-way) metering, with properly designed provisions agreed to by the fuel cell owner and the entity effectively purchasing the energy, may provide an easy, low-cost means of integrating fuel cell power systems into the distribution network.

3.5.7. Interconnection standards

To ensure security and non-discriminatory treatment for each electricity supplier as required by FERC, interconnection standards should be developed and adopted by all stakeholders that reflect present safety and reliability standards.

3.5.8. Tax treatment

Because present utility depreciation schedules of 15-20 years are not appropriate for fuel cell equipment, which has a much shorter economic life, tax depreciation schedules for all distributed power owners such as utilities and others, should be developed that are consistent with the actual economic and operating life.

3.5.9. Emissions requirements

Because fuel cell systems have both local and net system-wide reduced environmental impacts, a higher degree of regulatory flexibility may be required to achieve the appropriate level of equity and environmental control.

3.5.10. The revolutionary prospect of fuel cells lies in the long term.

The convergence of distributed power systems and information technologies in the long-term will offer the very real possibility for substantial re-engineering of the power delivery and distribution system of the future to provide an electricity analogue of the Internet, a concept introduced in the EPRI Electricity Technology Roadmap. Technological convergence of distributed power systems and information technology will change electricity networks from one-way delivery routes into networks where two-way flows carry both energy and information between decentralized resources, end-users, utility distribution companies, and energy service providers. However, before any such electricity Internet is realized, the technology gaps discussed earlier, as well as capacity, control and protection issues associated with the two-way flow of power need to be closed and policy issues addressed.

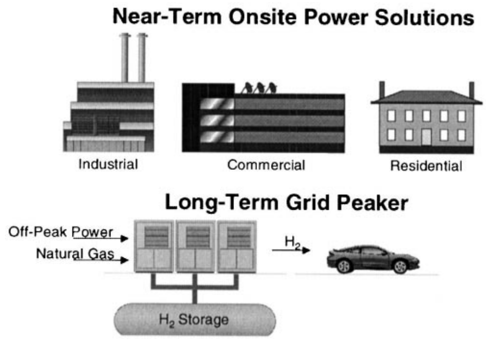

Fig. 2. Near term and long-term high impact markets for fuel cells.

A truly value-enhancing role for fuel cells could be via a convergence of transport and stationary power applications. The concept illustrated in Fig. 2 is being evaluated by EPRI, DOE and a consortia of sponsors. Such a configuration allows for the production of hydrogen from either cheap off-peak power or from natural gas, depending on fuel and energy prices. Electrolysers and compact fuel processors provide for fuel conversion into hydrogen. Hydrogen is stored in an underground vehicular filling station much like gasoline is stored today. Off road vehicles or special service vehicles, e.g., airport moving systems or delivery vehicles, are hydrogen fueled. A PEM fuel cell power block in the 100 to 1000 kW scale provides peaking power and load management support to the local distribution grid. The vehicular filling station/power station provides synergistic values to two markets.

3.6. EPRI's programs

EPRI, founded in 1972, is a nonprofit scientific research consortium that provides energy-related products and services to more than 700 organizations in 40 countries. As a world leader in science and technology, EPRI works through a multi-disciplinary team of scientists and engineers to help solve today's toughest energy and environmental problems for the ultimate benefit of the public. Research, development, and demonstration of fuel cell technology has been an element in EPRI's agenda since its inception. Historical emphasis has been on developing key science and technology associated with a portfolio of high-efficiency fuel cell technologies including PAFC, PEM, MCFC and SOFC.

EPRI's present fuel cell program provides members with a broad portfolio of products and services to

- understand the role and fit of fuel cells in the evolving energy enterprise;
- understand the markets and business cases for fuel cell systems
- understand fuel cell technology characteristics: cost,

- performance, durability, emissions and reliability, and operating and maintenance costs;
- facilitate the migration and application of fuel cell systems in real-world applications including demonstration testing; and field evaluation trials
- identify, develop, and facilitate the commercialization of fuel cell systems through new ‘‘private R&D investment initiatives’’.

The 1999–2000 programs include technology assessment and market analysis for all fuel cell type systems. In addition EPRI is conducting or planning to test, and develop projects in the following areas:

1. Development, test and evaluation of a PEM/UPS system
2. Test and evaluation of 3–7 kW PEM residential power systems
3. Develop and Demonstrate a 50-kW PEM power system derived from transportation programs.
4. Test and evaluation of planar solid-oxide fuel cell systems
5. Test and evaluation of tubular solid-oxide hybrid prototypes
6. Develop high power density, reduced temperature planar solid oxide technology
7. Development and demonstration of fuel cell power/fuel cell vehicle filling station.
8. Application and assessment of PAFC systems in field demonstrations
9. Application and assessment of MCFC in field demonstrations

A key effort in EPRI’s program is to facilitate the deployment and demonstration of emerging fuel cell systems into the marketplace. Technology risk and uncertainty about performance and durability are key challenges facing all fuel cell vendors. EPRI seeks to identify, screen and select new science and technology ideas and concepts, world wide, for incubation, and development in private collaborative programs. As such, EPRI matches technology opportunities with markets needs and shapes the development of new products for energy service providers.

4. Summary

Fuel cells have the greatest market potential as decentralized distributed resources in evolving competitive energy markets. Of all the likely adopters of fuel cell systems, retail energy service providers have the best leverage and profit opportunities to utilize fuel cells in the near term, provided technical and price targets are achieved. In the long term, fuel cell peaking and storage systems may prove to be the most valuable to utility distribution companies as a load management and grid support technology. EPRI’s program is evolving to facilitate the deployment and demonstration of emerging fuel cell power systems. EPRI seeks R&D investment opportunities in emerging fuel cells programs which offer a competitive advantage to early adopters to help manage deployment risk. Several commercialisation and demonstration initiatives will assist fuel cell developers and are planned to help facilitate the early deployment of emerging systems into high value applications and to establish the critical market and distribution channels into the market place.