ELSEVIER

Journal of Power Sources 61 (1996) 1–6

JOURNAL OF POWER SOURCES

The changing nature of the power generation market — does it create opportunities for fuel cells?

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Abstract

This paper surveys the global power industry seeking trends that might encourage greater use of full cells. The subject is broken into four basic themes: (i) an increasing demand for electricity, and this may not be solved by the traditional form of the integrated state-owned, centralised power utility, with a large infrastructure grid attached, the load curves of these integrated grids becoming unmanageable; (ii) a general trend towards privatisation and deregulation in the power sector, that is shifting its control from an engineering to a commercial paradigm, with unforeseen consequences; (iii) contrary to (ii), the need for supplying security in its most basic sense is increasing rather than declining as power-dependent technology becomes progressively more important in the modern economy, and (iv) the trend in technology, particularly environmental-friendly technology, is towards smaller size of production centres. Within these inter-related themes these are encouraging prospects for the fuel cell community.

Keywords: Fuel cells; Power generation markets

1. Demand for electric power

Between 1970 and 1990, the demand for electricity, world-wide, has grown by 4% per year. In terms of demand of thermal energy, the power sector grew far more rapidly than any other, including transport. Electricity is linked to modern standards of living, including factors such as food and sanitation, education/schools and hospitals. Electricity is not like other commodities. It has an astonishingly rapid and valuable effect on human life. Taken at the lowest level, there seems to be a correlation between electricity provision and life expectancy, see Fig. 1. Nonetheless, a similar correlation can be found between electricity and adult literacy. Consequently, electricity provision is probably one of the most important parameters of modern life, leading to political issues reflected in (i) the migration of the population from a rural to an urban environment in Latin America and in South Africa or (ii) the power supply to agricultural communities in India. This does produce a number of paradoxical challenges to the global electricity supply industry (ESI). Running an effective power supply, the system in a country such as Venezuela with a high expansion rate cannot rely on governmental subsidy. There are no funds suppling new capacity to meet the ever-increasing demand for electricity. This is probably the reason that many South American and Far Eastern countries are pushed towards privatisation of the power sector. This is also the force behind the development of 'independent power producers'.

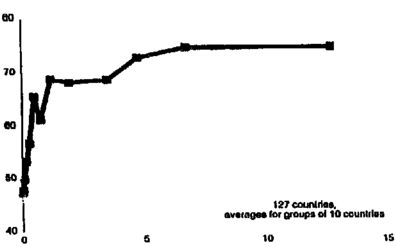

Fig. 1. Life-time expectancy vs. electricity use. Source: World Energy Council.

Yet if rural electricity helps people avoiding migration, the bright lights still attract to the big city. Although difficult to grasp, if current population growth projections are correct, in 2010, Sao Paulo in Brazil, Bombay in India, Shanghai in China and Lagos in Nigeria will be almost as large as Tokyo. Jakarta in Indonesia will be bigger than New York. With this urbanisation comes an intensification of demand for electricity.

Throughout the developing world, electricity is a necessity for economic growth. Its correlation with GNP growth is

PII S0378-7753(96)02331-2

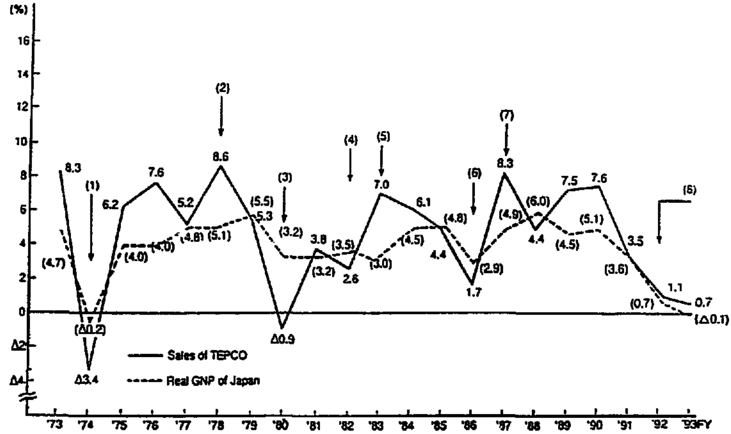

Fig. 2. GNP growth and sales growth (% change from the previous year). Significant changes affected by: (1) first oil crisis, cold summer and legislative restriction of electricity usage; (2) extraordinarily hot summer; (3) second oil crisis, cold summer and energy conservation; (4) cold summer and mild winter; (5) hot summer and extraordinarily cold winter; (6) recession due to yen's appreciation; (7) extraordinarily hot summer, and rapid recovery of industrial activities; (8) recession and cold summer. Source: Tokyo Electric.

shown in this relationship between the sales of the Tokyo Electric Power Corporation (TEPCO) and the overall rate of growth in the Japanese economy, see Fig. 2. Demand follows the growth in the economy and map it; a modern economy cannot grow without adequate power supplies.

2. Rapid expansion

According to the latest IEA World Energy Outlook, the world will need to build incremental power generation capacities of 1431 GW, worldwide, between 1991 and 2010, see Fig. 3; this figure does not include all the power capacity one would like to build, merely what can be built with the resources available. One should, therefore, double the global

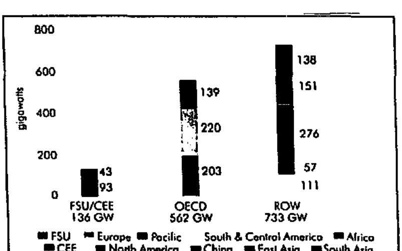

Fig. 3. Incremental power generation capacities, the 1992–2010 'capacity constraints' case. Source: International Energy Agency.

power output: 20 308 TWh in the year 2010. Even in the case of 1431 GW one has to build 79.5 GW of power capacity every year during eighteen years, or a 1528 MW plant every week.

Bearing in mind the projects in India (Dhabol) and in Pakistan (Hab River), examples of conventional power plants, often entail high financial risks; it is, therefore, merely impossible to attain a power suply of about 1500 MW/week. Electricity is extremely political. It should be built in small unities. To be part of the world of computer technology, developing countries need power supplying systems.

3. Load curves

Fig. 4 shows a daily load curve of the Tokyo Electric Power plant. It shows a sequence from the early 1960s when the centralised power utility was, rightly, judged as the solution to all our problems. The difference between the top of the graph and its lowest point could be encompassed by a shift of 3000 MW of capacity. In the 1970s, we were looking at roughly 6 GW of wheeling plant on line between 7.00 a.m. in the morning and midnight. In 1993, one may see a difference of 30 GW of capacity between the top and bottom shifting between 5.00 a.m. and 4.00 p.m. in the afternoon. The reason is a simple one. If the world's most electrically intensive economy — computers, videos, TVs, rice cookers and neon lights — have a load curve that shifts by 30 GW in eight hours, what happens in another two decades?

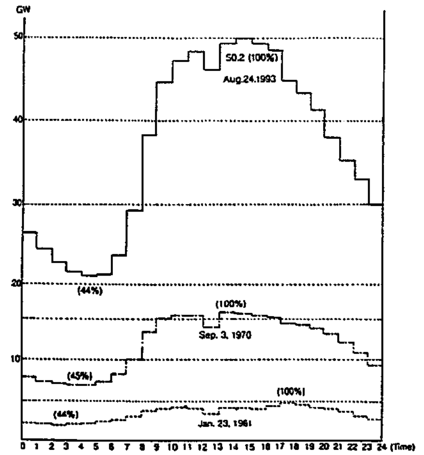

Fig. 4. Daily loadcurve (at the day when annual peak load was recorded). Source: Tokyo Electric.

MITI has plans for a further 40 000 MW of nuclear capacity. Nuclear power is base load, if it is to achieve any economic viability, since it is capital intensive with low fuel costs. But a public reluctance to accept large-scale power is undoubtedly growing, regardless of the fuel. Both in the USA and Europe, the difficulty of building 1000 MW stations is growing. If it is not the station itself, due to the difficulty of road transport for coal, or the dangers of gas storage, it is the widely held belief that 400 kV lines cause cancer. The grid itself is under pressure.

4. Commercialisation

In the UK and USA, where the notions of privatisation and electricity have so strongly taken hold, the notion of electricity as a tradeable commodity has become paramount. In both countries, there was previously a belief that 'security of supply' was more important than the marginal price of that supply. The commercial and financial paradigm has taken over from the engineering one. This process has liberated the industry, and auto-generation and co-generation power supplying systems at a local level have become much more available in a liberalised market place, where the state utility no longer polices the supply of power through monopoly power.

In the new liberalised system, there is no obligation of any of the new entrants to the market to prepare for a catastrophic event, or even a highly unusual burst in demand. One of the draw backs of the new system may well be an increase in outages and power surges at a local level as companies abandon the old engineering principles of investing for reliability.

One of the problems in a competitive system is that it is difficult to make up a reward structure for a station that sits as a very marginal plant, just above that peak load demand. If it never supplies anything, arguments rage about how much it is worth.

The problem of pricing incremental marginal plant is a significant one. It combines with the speed of demand growth to question whether large-scale coal and nuclear plant should be built, if their construction time is extended. Large, slow-to-build 1000 MW plus stations were also part of the engineering/centralised monopoly structure which dominated the 1960s and 1970s. Ten years forecasts decided the level of demand and the utility built it ready for the time it was needed. The new competitive structure does not allow for this leisure approach. Not least of the reasons why combined cycle gas turbine (CCGT) technology has triumphed is that it is extremely quick to build, and often has a small unit size. It can start to load following immediately the first gas turbine is in place.

The growing pattern towards retail wheeling in the UK and USA will allow utilities to bury each others' markets by bringing new plants on line at a cheaper cost and on a base and medium load, being a matter of 'just in time' concept of investment. There is no set target as to how much capacity is needed. The key issue is price. Therefore, sustaining the distribution grid only makes sense if this is a profitable activity. Provision of supply to remote places, via the grid, is likely to be reduced. Equally, there is no longer a compulsion to sustain the system by over-investment to meet statuary obligations.

5. Supply security and technological change

The net result of this may well be a significant increase in supply insecurity. At present, in the UK system, the full implications of deregulation are not yet fully understood, at least by the general public. The issue, however, is that in a system dominated by competition on price, rock solid supply security is likely to suffer. The system will no longer be over-engineered.

Yet this is curious because it conflicts with another trend. At no stage in history has a sophisticated society ever been more dependent on secure electricity supply. The fact is that the whole of the information technology business is a secondary technology to electricity supply. Information technology in computers have an increasing role in our Society and the consequences of their failure, through lack of power, is now economically enormous. Consequently, most of those involved are increasingly taking action to provide themselves with back-up power in case of disaster.

Such a scenario is gradually being understood by more and more people. Under most conditions a centralised grid may well be able to undercut the cents per kWh output of a small trip gas-turbine or diesel. If an organisation has to have certainty in its power supplies, it will have to pay the capital cost

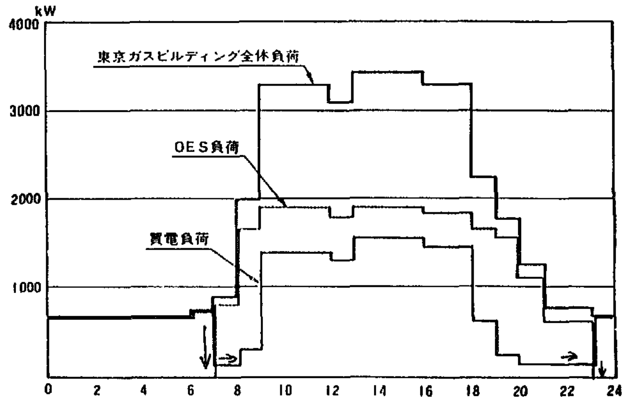

Fig. 5. Daily load curve of Tokyo Gas Building. The top curve is the demand from the grid without turbines. The second is the supply provided by the turbines and the third is the supply from the grid when the turbines are running.

of its own generator anyway. If it uses only grid supply, then this cost is a waste of money.

Such a switch towards small-scale generation from emergency to general use also threatens the economics of the centralised utility and makes it more difficult to reach its overall investment targets. Regular use of such small generators would deprive the big utility of a large part of its base and medium load. The utility and the grid end up picking up only the peak load with more of its plant, there by making more of its generation capacity idle, while the grid and distribution chains get less use too.

This is illustrated by Fig. 5, a rather obscure graph. It is the load curve of Tokyo Gas, whose headquarters contains some small gas turbines as an alternative to the grid. The top curve is the demand from the grid without the turbines. The second is the supply provided by the turbines and the third is the supply from the grid when the turbines are running. This neatly shaves the peak demand required by the grid. Unhappily, if the turbines are run all night, the requirement for grid electricity is reduced to — well — nothing. Tokyo Gas can, if it is allowed to, strip out the grids base load as well as reducing its peak.

This is not such a strange scenario. Competition has introduced a major wave of co-generation power supplying systems in much of industry where there is an adequate steam load. It is growing rapidly in Japan anyway, regardless of competition policy. In our new kind of information technology-dependent society, it will not take much in the way of failure in the peak generation and distribution business of the utilities and the trend towards self-generation could grow rapidly. At minimum, the shift to competition has meant that who supplies a manufacturing plant, or a hotel, or a bank, is no longer assumed to be always the local utility.

6. New technology

Finally, this potential increase in small-scale generation matches the new environmentally aware technology shift. Some of these technological ideas are illustrated in Fig. 6 although it suggests that a demonstration fusion reactor will be available at the same time as solid oxide fuel cells. Very few environmentally acceptable technologies for power generation run to a scale above 40 MW. Given that large-scale hydropower has its own problems, there is no renewable energy form that can take on the burden of thousands of MW at a time. Solar, wind, biomass, run-of-river hydro, etc., are generally localised and of a small scale.

What is true for renewables is also true for the urban environment. The urban distribution grids of many US cities are now running out of boardwalk space for yet more cables in the revolution of information technology. Superconductivity may help reduce this cable requirement by cutting space requirements by a third. Superconductivity can and will reduce the size of virtually any form of electric motor or transformer making localised plant more acceptable in size. It cannot, and will never do, make long-distance overhead cable covering miles of grid. The technology of electricity supply is thus likely to become smaller and more localised.

7. Conclusions

Outside in the developing world there is an inreasing demand for power, suggesting that its incremental demand

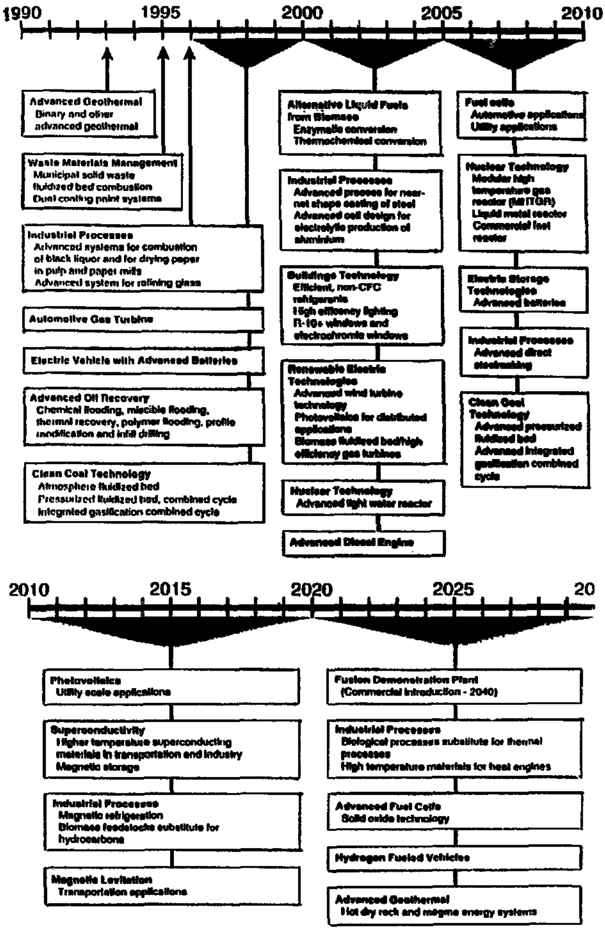

Fig. 6. Time-frame for the development of existing and new energy technologies (Source: US National Energy Strategy, DOE, Washington, 1991, with minor modification).

cannot be met by building huge amounts of large capacity. Governments find it less and less easy to fund the centralised system. Emergency incremental supplies are increasingly provided by small machines and to achieve an acceptable level of supply, many of the most sophisticated modern plant and organisations will need to build their own capacity to avoid failure. The financial difficulties of building 100 MW stations are enormous and a major problem of independent power suppliers.

In more sophisticated countries, an ever-increasing demand creates a problem of meeting peak supplies. A shift from engineering values to commercial ones has also removed the obligation to supply anyone and anytime and anywhere. But this has taken place at a time when the adequate supply of electricity is an ever more important thing to make Society work. Vital institutions, who know this, are now building stand-alone emergency generators. If supply becomes at all unreliable there will be a major shift to auto-generation, which will further undermine the centralised utilities.

Finally, benign generating capacity is largely small scale and likely to remain best suited to small scale applications. The difficulties of building large scale and with large grid systems, due to environmental considerations, are growing.

Fuel cells, once reliably tested, are admirably able to fit into this changing structure. In urban applications, there are obviously better environmentally than trip diesels or turbines. Equally, the increasing difficulty of providing a trouble-free and reliable supply via the grid, is putting an increasing premium on stand-alone small scale supply.