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THE EFFECTS OF REGULATORY CHANGES ON THE DYNAMIC OF POWER TECHNOLOGIES : THE CASE OF GAS MICROTURBINES.

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ABSTRACT

Worldwide, for the last two decades, energy network industries have undergone major changes in terms of industrial organization and competitiveness. Led by a combination of economic, technological, political and ideological forces, these industries are now less and less controlled by governments. In the electric power industry, a new era has emerged : several networks activities are now opened to competition. The changes are designed to foster competition in the generating segment of the industry and to reform regulation of the transmission and distribution functions, which continue to be viewed as natural monopolies.

In some industries, monopoly situations are regarded as either directing or delaying innovations. There is an obvious link between the form of industrial organization and the dynamic of technological progress. Thus, one concern is raised : the role of technology in the new organization of electric industries and its contribution to change monopolistic situations in various activities.

Microturbines manufacturers are promoting technologies as low-cost and low polluting solution to generate electricity on site. With the beginning of the electric deregulation, the power industry has virtually abandoned the idea of continuing to build expensive central power plants that take years to be built, require miles of distribution wires and take decade to pay off. Many analysts say that future demand will be met by smaller generators that are closer to end-users.

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1. INTRODUCTION.

Worldwide, for the last two decades, energy network industries have undergone major **changes in terms of industrial organization and competitiveness**. Led by a combination of economic, technological, political and ideological forces, these industries have become less and less controlled by governments. After restructuring reforms in the transportation, telecommunications and natural gas sectors, deregulatory initiatives have been taken in the electric power industry to eliminate traditional constraints and protectionism. A new era has emerged : electric monopoly activities are now open to competition. The changes are designed to foster competition in the power generating segment and to reform regulation of the transmission and distribution functions, which continue to be viewed as natural monopolies. There is lively debate about whether these experiments will succeed and how they should be conducted.

In several industrial sectors, especially in networks industries, monopolies are regarded as either directing or delaying innovations. There is an obvious **link between the form of industrial organization and the dynamic of technological progress**. Thus, one concern is raised : the role of technology in the new structure of electric industries and more precisely, its contribution to change monopolistic situations in various activities. With the evolution of the power industry, the impact of new technologies on deregulation seems to be highly relevant.

In the following, we will focus on the relationship between innovation and electric power industry restructuring. **In the first part**, we will briefly discuss the impact of new technologies on industrial organization and vice-versa, keeping in mind that technological progress' dynamic is different in a regulated market than in a competitive one. Then, **in the second part**, we will study the deregulation of the electric power sector with, more precisely, the evolution of generating units. **Finally**, we will present the case of gas microturbines which might transform electric utilities generation activity.

2. INNOVATION AND REGULATED MONOPOLY.

Network industries such as natural gas, electricity and telecommunications are defined by the need to dispatch goods or services over a *network* that constitutes a **natural monopoly**. They have long been structured in accordance with the belief that a single company can provide service more efficiently. An industry is a natural monopoly « *if total costs of production are lower when a single firm produces the entire industry output than when any collection of two or more firms divide the total among themselves* ».[1] This single firm is characterized by[2] **economies of scale** existing when the average costs of production decrease as output expands. In Economics, the old concept of « natural monopoly »[3] refers to an industry where the technological advantages of large scale production preclude efficient competition among smaller companies.

By the beginning of the twentieth century, it was recognized that railroads, telecommunication and local public utilities possessed to certain extend **some degree the characteristics of a natural monopoly**. For nearly a century, worldwide these sectors has been thought of as a natural monopoly industries where efficient production required reliance on monopoly suppliers subject to government control of prices, entry, investment, service quality and other aspects of firm behavior. Concerned for the **public interest**,[4] these industries were regulated in the United States and publicly owned elsewhere.[5] « *The essence of regulation is the explicit replacement of competition with governmental orders as the principal institutional device for assuring good performance* » (A. Kahn 1970, p.3). Regulation initially required detailed authority over the levels and type of services, revenue amounts, minimum and maximum rates in order to prevent sector concentration, hinder destructive competition, develop the infrastructure and protect consumers.

Despite these goals, the reality of regulation became different. The lack of competition caused by the regulatory regime left firms and entire industry structures frozen over the decades. They were inadequately prepared for competition and had no incentive for innovation. Although regulated companies operated under the regulatory constraints, their financial health was guaranteed. Authorities were careful to ensure financial viability of these firms by shielding them from competitive forces and other risks.

In a regulated market, **companies are not incited to invest in technology** to improve operational efficiencies. One specific source of inefficiency is rate-of-return regulation which

results in excess of total costs. Averch H. & Johnson L.[6] (1962) argued the rate-of-return regulation leads to an inefficient use of capital. When regulators set the allowed rate-of-return above the cost of capital, the firm uses more capital than if it were unregulated. This constraint creates an incentive for the utility to accumulate an excessive amount of capital relative to the cost-minimizing level. Excess capitalization (the so-called « *Averch -Johnson effect* ») arises from the absence of competitive pressures on producers.

Conversely, **technological performances can be stimulated by regulation**. In some situations, protection and constraints imposed by regulators favor development of new technologies. Competitive firms could not afford to invest in some new technology. A regulated firm can be more able to support such costs. For instance, in France, during the mid-80s, EDF innovated in building large efficient power plants (≈1400 MW).[7] But, regulation can also lead to technological excessive considerations : the French electric monopoly is sometimes perceived as « *over-engineered* ».

The majority of **academic literature** has not focused on the regulated firm's incentive to adopt new technologies. The effects of regulation on technology are not so clear.[8] One intuitive reaction is that monopolies stifle innovation and are technologically obsolete. The general perception is that regulation discourages innovation. According to A. Kahn *« it seems a fair generalization that regulation has on balance been obstructive both of competition and the innovation that it helps stimulate and justify* » (1988, p.247). In one of the few theoretical analyses of the issue, G. Swenney argues that « *in many circumstances a regulated monopolist can maximize the present value of profits only by delaying adoption of an innovation* » (1981, p.437). In the specialized press on energy, interviews with top executives indicate that they also believe regulated firms are slow to adopt new technology.

Different technologies would have been developed in the absence of regulation. As economists have recognized for many decades,[9] monopolies tend to retard technological progress in a variety of industries. For example, AT&T would have digitized its network much earlier in a competitive environment. Similarly, prior to deregulation, airlines favorized large aircraft for trunk line operations which were dominant before 1978. Regulation did not require maximum of utilization of airplanes for continued service. However, after deregulation, profitable hub-and-spoke operations called for smaller planes. Parallel behavior occurred in the US railroad transport industry. From 1900 to 1980, the railroads were slow to innovate, partly because of their monopoly positions as well as the indirect effect of regulation. But, after the deregulation in 1980,

where competition became strongest innovation increased, especially in the East of the United States.

However , the state of technology in the past must be considered as well : innovations can often **erode or eliminate monopoly** as has also occurred in many sectors. For instance, in the related services of microwave transmission, AT&T policies were deeply monopolistic and technologically slow. AT&T's failures in innovation strengthen the resolve of political agencies and the Courts to dissolve the monopolistic Bell System in order to increase innovation efficiency. The divestiture in 1984 was highly successful in all dimensions and was particularly effective in unleashing product and process innovations in the entire telecommunications sector.

Industrial organization and new technologies are clearly linked but **the nature of the double relationship is not so obvious.** The outcome of monopolization in parallel sectors was a tendency toward suppressing competition and retarding innovation. It can also lead to excessive considerations of innovations. Monopolistic situation can have a positive and a negative impact on new technologies. Moreover, new technology can be the key to eliminate monopolies by giving new comers special advantages. The dynamic of technological progress is complex and depends on the degree of competitive pressures. An important argument to defect regulated monopoly is its failure to recognize that new technologies evolve over time that they are efficient at much lower level of output than old methods of production.

3. DEREGULATION OF THE ELECTRIC POWER INDUSTRY : THE GENERATION ACTIVITY.

The electric power industry can learn from the experiences of previous regulated industries to provide useful information for the ongoing debate over the restructuring electric power system. The electric utility industry is undergoing a transformation from a regulated market place to one exposed to the influence of market forces.[10] It is still unclear what kind of organization will emerge from these changes. The electric industry, likely the most stable structure in the United States in terms of growth forecasts, rates stability, earnings and methods of operation is about to experience a major upheaval. A « **new age of competition** » begun at all three levels of operation. This new area also means opening of all significant markets to vigorous competition.

In North America, many states through their regulators are considering various initiatives of increased wholesale competition for electric generation and even direct access for retail customers. The power generation function will be driven primarily by cost minimization considerations. Transmission is likely to assume regulated common carrier status. And local distribution companies will emerge as full services suppliers of the energy need, both natural gas and electricity, to their customers.

Although claims about « natural monopoly » continue to influence public policies and academic discussions, this concept has become less relevant to some activity of modern power industries.[11] It is sometimes argued that creating a separate generation sector now makes sense is that the generation of electricity is no longer a natural monopoly due to technological change. An alleged reduction of the economies of scale that once made this activity a natural monopoly. Recent improvements in technologies are transforming generation units and therefore electric power industry organization.

Regulation is often thought to discourage innovation. Capital cost disallowance based on avoided costs, by penalizing high costs or low performances outcomers, discouraged the adoption of new technologies whose performance is uncertain. This issue is not obvious in electric utility behavior until the mid-70's, during which time utilities adopted various new generating technologies. Since, many arguments have evolved to explain the decline in innovations by electric companies :

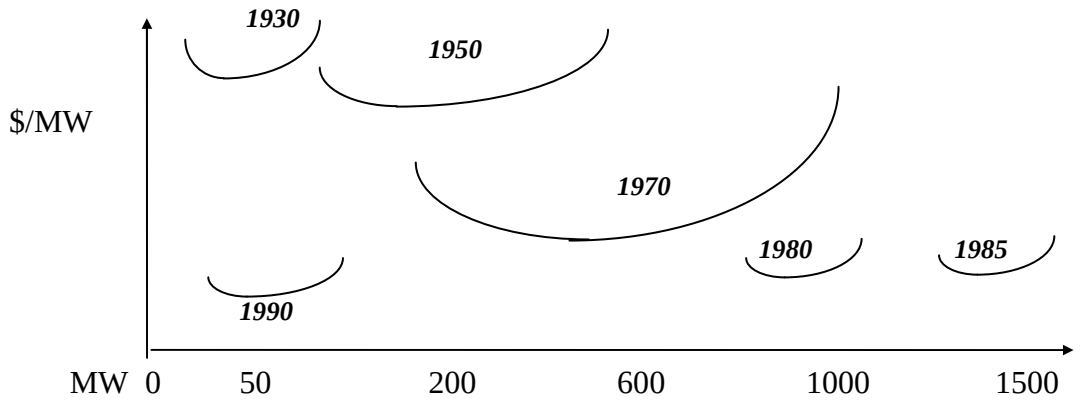
- Underlying steam turbine technology has exhausted improvements in scale economies and thermal efficiency[12] (this argument does not explain the reluctance of utilities to adopt new small scale technologies).
- Regulatory incentives for conservation and load management have displaced new construction (this does not explain the small role of new technology in the construction plans of utilities).
- Managerial culture within companies, which traditionally emphasized large-scale technologies, has been slow to accept of smaller scale alternatives.[13]
- Changes in regulatory practice have undermined incentives for innovation.

In the past, significant variations in the **speed** with which utilities have adopted new generating technologies have been demonstrated.[14] In United States, two important laws have been necessary to promote innovation : the 1978 the Public Utility Regulatory Policies Act

(PURPA) and the 1992 Energy Policy Act (EPAct), both of which specifically promote coordination and competition. Indeed, PURPA helped to stimulate the technologic innovation in combined cycle generating technologies using natural gas as fuel. Competition and innovation increased gradually, although the process has just begun and strong monopoly positions and attitudes remain.

The most important assumption underlying the proposal to deregulate electricity generation is that once deregulated, the electric generation market is expected to perform much more like a competitive market than one that has been historically plagued by natural monopoly. In the deregulation of the electric power beginning for instance in California, the power industry has virtually **abandoned the idea of continuing to build large expensive central power plants** which take years to build, require miles of distribution wires and take decades to pay off (see the discussions on stranded costs). A significant impetus for change in power generation processes is the loss of economies of scale. This has reversed the long trend towards ever larger central plants, back to smaller and modular capacity (Fig. 1).

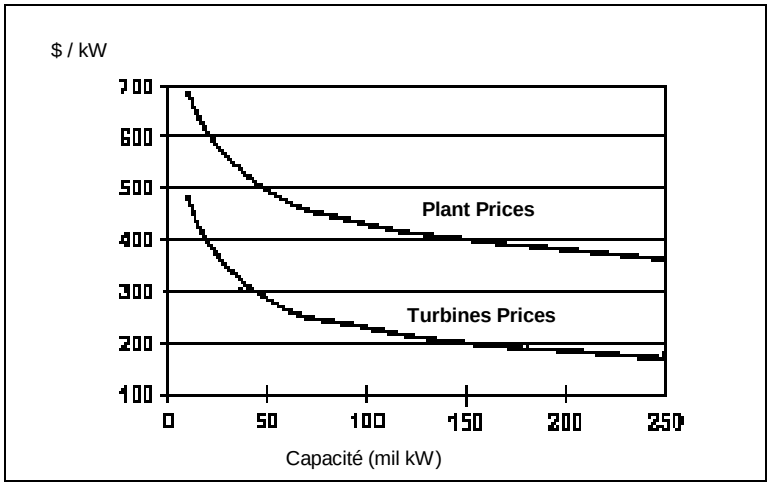
Figure 1 : Optimal plant size (per MW costs curves 1930-1990).



Source : Bayless C. (1994).

Figure 1 shows the change of the short run average cost and size installed capacity over time. Optimum size has shifted from 1400 MW to smaller units over sixty years. In 1930, a 50 MW unit was cheapest to build. Thanks to technological progress, the cheapest unit produced 200 MW by the 50's, more than 1000 MW (French nuclear units) in the 85's. The size of the cheapest plant dropped dramatically. Today, the cheapest unit produces 100 MW. However, Figure 2 shows that there are still some economies of scale for turbines up to about 250 MW.

Figure 2 : Simply cycle turbines and plant prices.



Source : Linden H. (1997)

As soon as the total cost of new power plants became smaller than the operating cost of traditional plant, new units have been developed. Obsolete facilities have lost a lot if not all of their financial value. Thus, such facilities provide the bases for **claims of stranded costs**. For Schumpeter J.A.[15], obsolete investment (stranded costs) is the price that incumbent firms pay for technological progress. He deplored policies that slowed innovation or compensated those that it harmed. But in the absence of stranded cost recovery, some utilities might have to divest some assets in order to remain financially viable. Probably the most critical issue associated with new power technologies is : how to address stranded generation costs.

These changes in generation technology, coupled with economic theory, suggest a move away from large companies to small units built by a host of new companies. In the United States, ten years from now, the list of generating companies will hold names which have not yet been seen to date. Recent technological advances have resulted in the **emergence of highly efficient new small generating units** which are about to revolutionize the electric power industry.

4. CASE OF NATURAL GAS MICROTURBINES.

As W. Shepherd[16] notes « *US electricity is now often a laboratory to test the role of new technology in promoting or blocking new competition* ». Small natural gas turbine plants can generate electricity at a lower cost and therefore more efficiently, than more traditional and considerably larger coal plants. At currently low natural gas prices, these smaller units compete favorably with traditional coal units.

Makers of microturbines are promoting them **as a low-cost, low pollution method of generating electricity on site.** While the generator may be a perfect fit in remote areas like oil rig sites and gas fields, where it can produce electricity from natural gas which is often simply burned up, makers have come up with 300 other applications, from powering supermarkets to making pizza, to helping power companies meet peak demand. Figure 3 indicates how they stock up against other energy sources currently available or under development.

Figure 3 : Comparison with gas microturbines.

	Microturbine	Gas turbine	Fuel cells	Solar cells	Wind power	Gas turbine combined cycle power plant	Existing coal power plant
Capacity	30-200 kW	1-50 MW	3 kW - 2 MW	1 kW-100 kW	700 kW - 5 MW	400 MW	30 MW-40 MW
Efficiency (% converted to electricity)	22%-30%	21%-42%	40%-65%	n.a.	n.a.	60%	32%-35%
Cost (installation per kilowatt)	$450-$700	$650-$900	$900-$3000	$1000-$6000	$1200-$1500	$350-$400	$900-$1300
Maintenance (per kilowatt hour) *	0.3¢ -1.0¢	0.3¢ -0.8¢	0.5¢ - 1.0¢	$8-$12 a year	$20-$30 a year	0.2¢- 0.4¢	0.5¢ - 1.0¢
Emissions (nitrogen oxide, pounds /MW)	0.1-0.5	0.1-2.0	0.1-0.2	n.a.	n.a.	0.2	4.0-10.0

* Costs do not include price of fuel, which varies depending on source. ¢ = US$ cents

Source : Electric Power Research Institute (1997).

Rapid advances in microturbine technology with low gas prices have made it difficult for fuel cells and high-tech renewable sources, to find substantial market niches due to relatively high operating and fixed costs. The advantage of gas microturbines is that it has only one moving part. Air heated by fuel drives a turbine, a generator and a compressor that spin on a single shaft. They can burn a variety of fuels including natural gas, diesel, gasoline and methane.[17] Most turbines use oil as lubrication. However gas microturbines use a cushion of air, making the machine virtually maintenance free. A shorter construction cycle that minimizes risk gives gas turbines another advantage. While turbine generators have been in use for years, the microturbine is quieter, cleaner, relatively maintenance free and does not require long power lines. Without or with less wires, maintenance costs of the grid diminish. The functions of power transmission and distribution should be transformed.

Many analysts say future demand will be met by smaller generators which are closer to where the electricity will be used. Small, prepackaged generating units also give customers and competitors the technical ability to run their own power plants. History just might repeat itself with the small generator revolutionizing the power industry just as the microprocessor did the computer industry. The little turbine engine has the same relationship to large power plants that the PC had to the mainframe : it **puts the source of power at the user site.** However, not everyone sees the microturbines as a surefire blockbuster as there are skeptics who say that small-scale generation will never be economically viable.

In the past, it took a great deal of engineering expertise to design, construct and operate a power plant. Today, the order, connect and run cycle is much simpler. Two barriers to entry (high costs and specific technical expertise) have evaporated : however the regulatory barriers still persist. Some regulators and utilities may be able to keep the barriers intact longer than others. Nonetheless, when private and independent producers pressure lawmakers to deregulate, the remaining barriers will fall. The shift in the size curve (Fig. 2) implies a constant influx of new entrants even if traditional utilities become more efficient in power generation. Clearly, the generation activity is undergoing major transformation which will affect the industrial organization of power industry.

5. CONCLUSION

Structural and regulatory reform of the electricity sectors in the United States and other countries is following the basic model previously applied to network industries. Potentially competitive segments (like electric generation) are being separated from the natural monopoly segments (distribution and transmission). New technology will probably be decisive for these experiments. With the loss of significant economies of scale and innovations in microturbines generators, a new generation market is emerging. The long trend of large central plants is replaced by smaller units closer to end-users. The innovations will be indeed capable of reducing much of the monopoly in this sector. Electric utility companies have to show agility and strength in controlling the new technology rather than letting their positions erode. New technologies can be captured by firms, such that their control is extended rather than ended.

Traditional utilities, about to know competition, have to evolve in order to survive. As C. Bayless underlines, « *the winners will embrace competition early and learn to compete. But in the end, the message will be the same for all - change or die* » (1994, p. 25). Power companies have to adapt the newest technology and cut costs. Since 1992, a **wave of large electricity mergers** has arisen, tending to enlarge and strengthen the firm's monopoly position before the competition arrives. With the deregulation of the generation segment, many gas utilities are merging with electric power companies. Aeroderivative turbine technology has had the most visible impact on **convergence of the electric and gas industries**. However, as competition intensifies, vigilant **enforcement of antitrust laws** will be essential for the preservation of an open competitive industry.

FOOT NOTES

[1] Cf. The New Palgrave, a dictionary in Economics ed. Eatwell, Milgate and Newman (reprint 1994), McMillan Press Limited, pp. 603.

[2] Generally a natural monopoly is characterized by subadditivity of a representative firm's cost function. If all prospective firms in the industry have the same cost function, or if one firm has a uniformly better technology, then subadditivity implies that industry costs are minimized if only one firm is active in the market. While subadditivity is a purely technical condition, it is also possible for natural monopoly to arise from purely economic forces if imperfectly competitive outcome is inefficient.

[3] Marshall A. (1890) was one of the first to identify formally the technology in the form of the representative firm's cost function, as the fundamental determinant of industry structure. Industries with increasing average cost of production were generally competitive or monopolistic. Clark J.M. (1923) contributed to the understanding of natural monopoly through his careful analyses of the economics of overhead costs (economies of non convexities). He was also a pioneer in the empirical study of declining average cost industries.
About theory of natural monopoly, see Sharkey W.W. (1982), Baumol W.J., Panzar J.C. & Willig R.D. (1982), Trebing H.M. (1984) and Train K.E. (1992).

[4] For the public interest theory see Feldman P. (1971), Crew M. & Kleindorfer P. (1986) and Khan A (1988).

[5] Concerns over price and cost distortions from monopoly power are addressed by regulations if companies are privately owned, or by outright public ownership.

[6] See Averch H. & Johnson L.L. (1962).

[7] See Bouttes J.P. & Leban R. & Lederer P. (1993).

[8] See Vietor R.H.K. (1994).

[9] For instance see Sherer F.M. & Ross D. (1991) and Shepherd W. (1996, 1997).

[10] See Chevalier JM. (1997).

[11] See Boiteux M. (1996), Mourre B. (1996)...

[12] See Hirsh R. (1989) and Joskow P. (1989).

[13] See Hirsh R. (1989).

[14] See Joskow P.L. & Rose N. (1985).

[15] See Schumpeter J.A. (1934).

[16] Cf. Shepherd W.G. (1997).

[17] See Schuler F. Jr. (1996), Zuckerman L. (1997), and Linden H.R. (1997).