Technology and transformation in the American electric utility industry

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Introduction

In 1965, electric utility managers celebrated the eighty-third year of their industry's existence. No one held any "jubilee" festivities for this uneven anniversary, but signs of pride, confidence, and vitality could be seen everywhere: managers justifiably rejoiced as their power-generating technology recorded new heights in technical performance, contributing to the industry's unequalled productivity growth rate since the beginning of the century. They also congratulated themselves for managing a technology that supplied increasing amounts of electricity at declining unit prices, providing for higher standards of living during a period of general price inflation. Meanwhile, utility executives watched happily as investors bid up the share prices of their companies to new post-Depression highs, reflecting the view that previous trends in technology and business management would continue unabated.

By 1975, however, many of the same utility managers lamented their industry's condition. Instead of continued improvement, electric power technology appeared to have reached barriers that could not be breached. As a result, productivity gains disappeared, and the industry became susceptible to the same economic forces that disabled the overall economy. As the industry turned away from a pattern of declining unit costs, regulators abandoned their permissive role and became more activist, trying to represent cost-conscious consumers who ceased to view power technology as safe and benign. At the same time, utility managers encountered culture shock as they discovered that trends in electricity consumption had reversed themselves, and that "growth" no longer meant improved economic well-being for their companies or customers. Finally, investors forsook the electric utility industry as some firms approached uncomfortably close to bankruptcy. In short, the electric utility industry had been radically transformed in just ten years.

This book details the transformation of the electric utility industry. It focuses on the importance of technological progress in the industry's history and the business management principles that evolved to take advantage of improved hardware. But this book does not tell a success story. While providing a background glimpse of early accomplishments, it argues that the electric *utility* industry (which must be distinguished from the electrical equipment *manufacturing* industry) underwent a fundamental reorientation when the basic generating technology reached a pair of performance plateaus. Crippling the industry's productivity growth pattern, these consisted of barriers to thermal-efficiency improvements and to increases in scale economies. Experienced chiefly *before* the 1973 oil embargo, these limits contributed to the end of electricity's traditional features of cheapness and consistent availability. By concentrating on fundamental technological problems, this book therefore challenges the commonly held assertion that the industry's predicament stemmed *exclusively* from disruptions in energy supplies, financial market difficulties, environmentalism, inflation, and overzealous regulation.[1] Though not discounting these serious problems, this book simply argues that "traditional" studies do not paint a complete portrait. Inflation, for example, dogged the utility industry for decades, but it only became a heightened concern when manufacturers could no longer deliver new productivity-enhancing technology to mitigate it. In short, improving technology had always been a primary contributor to the industry's success and high productivity growth rate. When the technology reached apparent limits to improvement, it exacerbated an already decaying financial, economic, and regulatory situation.

To explain the causes of technological stagnation and decline in the electric utility industry, this book introduces the concept of "technological stasis." Stasis is the cessation of technical advances in an industrial process technology. Incremental improvements no longer are made, and the technology appears to have reached its limits. Stasis is not the same as what some people call technological "maturity," though it is related. A mature technology, according to some definitions, is one in which the basic design components of a process technology (or the products it creates) are well-defined. In the utility industry, for example, the design and successful use of steam turbines in the early 1900s set the agenda for further innovations.

Though "mature" as early as the 1920s or 1930s, power technology advanced in small, incremental steps for the next several decades. But during the 1960s and 1970s, barriers to improvement emerged in thermal efficiency and economies of scale. Now even the slow but steady progress ended, leading to industrial deterioration. Stasis therefore describes a condition that occurs in a technology that has already matured.

Stasis comprehends more than a hardware problem, however. It constitutes a technical condition that occurs within a social *system* of engineers, business managers, regulators, financiers, and the general public. Each set of participants (or "stakeholders" – people who have a direct interest in the operations of utilities) has different goals and agendas, and when they conflict, they can make a technology appear moribund. For the first half of the twentieth century, the engineer-managers of the equipment manufacturing firms and utilities developed technology that served all participants well. During the 1960s and 1970s, however, some players (utilities and manufacturers) tried unsuccessfully to speed up development of large-scale technology while others (consumers and regulators) began to distrust the actions of elitist technical managers. The resulting conflict exacerbated technical decay and seriously affected the industry's more obvious financial and regulatory woes. In short, this book uses the concept of technological stasis as a way to emphasize the social dimension of technical development. As such, the book offers a "sociotechnical" explanation for the recent decline of the electric utility industry. (See Appendix A for a more detailed discussion of stasis within the context of technology life-cycle models.)

As upsetting as it was, stasis did not occur throughout the world's electric utility systems. Rather, it remained an American phenomenon. Several factors account for this localization. For one, the United States constituted the world's largest market for power equipment – in 1969, it contained 43% of the noncommunist world's installed capacity – and it traditionally produced the greatest demand for new technology.[2] And because of an unusual form of competition between utilities (described in Chapter 5), American companies sought technology that continuously offered greater fuel efficiency and larger scale. If practical limits in technological advance were to be encountered, then they would show up first in the United States, where technically aggressive utility managers ordered large quantities of state-of-the-art equipment earlier than their counterparts in other countries.[3] In addition, the United States sported a decentralized and pluralistic utility industry consisting of hundreds of independent power companies, largely financed through free-market mechanisms and governed loosely by state and federal regulatory bodies. As a result, the American system could be affected by a variety of participants that contributed to the onset of stasis in a way that could not be easily duplicated in many other countries. For these reasons, the account that follows describes events occurring in the United States.

A few simple graphs will clarify the problem addressed in this book.

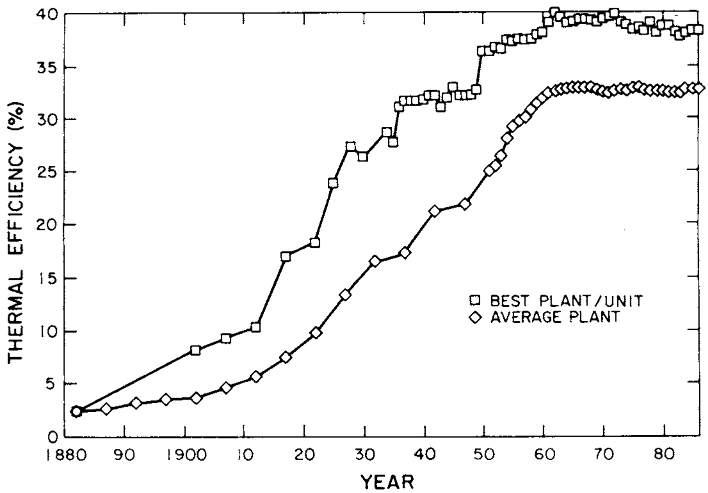

Figure 1. Thermal efficiency of generating units, 1880–1986. Thermal efficiency of power units increased gradually throughout the industry's history, plateauing in the 1960s. For the years after 1965, the data on the top curve relate to the most efficient *unit*. Before 1965, the data relate to the best plant – a combination of units. Data are from Federal Power Commission publications and annual reports of best thermal efficiency in *Power Engineering* magazine.

They also outline its basic themes about technological stasis. Consider, for instance, a graph of thermal efficiencies of power plants (Figure 1). Rising steadily throughout the first eighty years of the electric utility industry's history, the curve flattens out in the early 1960s and remains unimproved into the 1970s, showing that utilities could no longer economically coax more electricity out of a pound of coal or a barrel of oil.[4] Meanwhile, other graphs demonstrate that the capacity of new power units had also leveled off, this time in the 1970s (Figures 2, 3, and 4). Since the increasing output of units generally provided economies of scale that helped reduce unit costs, the flat curve in the 1970s meant bad news. Together, the end of thermal efficiency and scale improvements contributed to the reversal of a trend toward productivity improvements – improvements that previously made electric utilities the marvel of American industry.

These graphs do not necessarily prove a correlation between technological stagnation and industrial decay. But because they demonstrate that significant trends in the industry had begun to change well before 1973, they prompted an examination beyond the common interpretation of the electric utility industry's decline. That is, they encouraged a look beyond energy-supply distortions and economic, financial, and regulatory problems. This book is a result of that examination. Its first part, "Progress and Culture," provides the technical and social background for the utility indus-

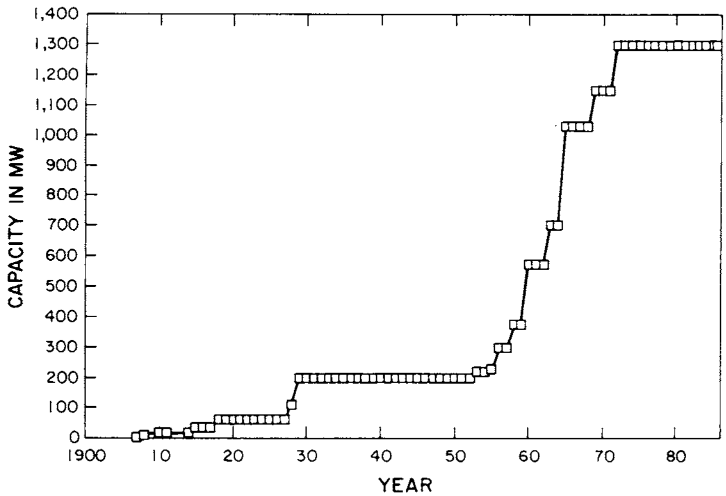

Figure 2. Maximum capacity of extant power units, 1900–86. The output of the largest steam-turbine generator grew dramatically in the period before the Great Depression and after World War II. A "unit" is defined as a "tandem-compound" or "cross-compound" turbine generator. Data are from U.S. Department of Energy, Generating Unit Reference File.

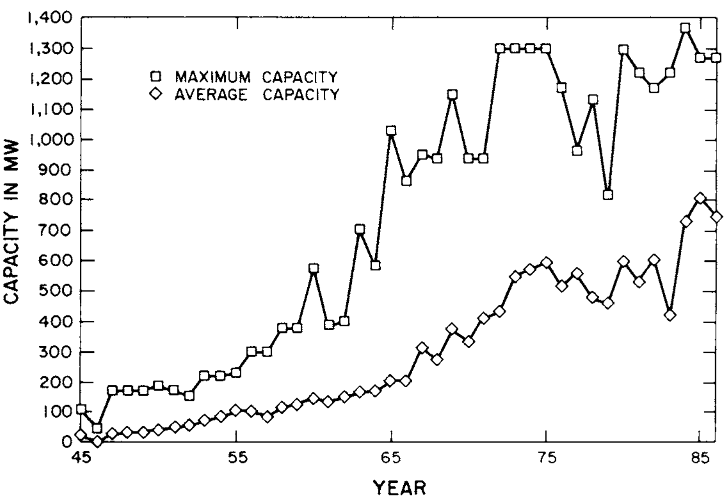

Figure 3. Maximum and average capacity of new units, 1945–86. The output of newly installed fossil-fueled and nuclear units increased until the early 1970s. Data are from U.S. Department of Energy, Generating Unit Reference File.

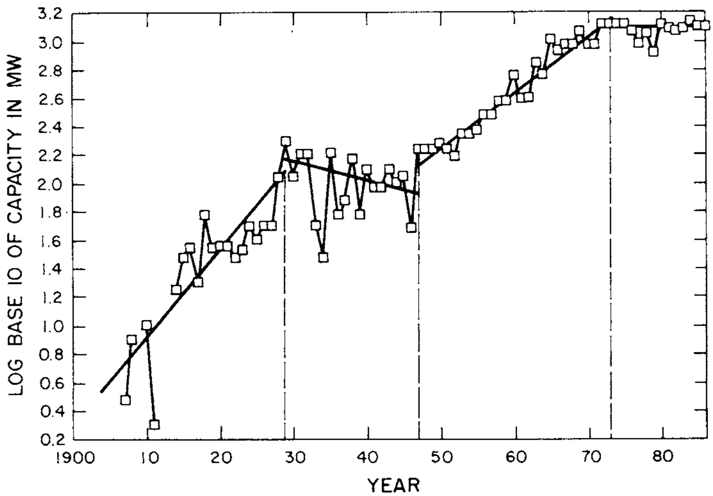

Figure 4. Largest unit installed by year. This logarithmic graph emphasizes how unit size increased exponentially before the Great Depression and after World War II. Two periods of stability existed from 1929 through the end of World War II and after 1973. Data are from U.S. Department of Energy, Generating Unit Reference File.

try in the post-World War II period. It focuses on the community of engineers and managers who made electricity an abundant and reliably produced commodity and who felt strongly that greater electricity usage meant increased living standards and economic welfare. Considering themselves important members of their communities, managers rightly cherished a graph recording exponentially increasing sales until the 1970s (Figure 5). The graph's message was symbolically reinforced by one utility company's annual report cover carrying the single word "GROWTH," with all its attendant positive connotations for the company and its customers (Figure 6). Perhaps more important in representing this "good" feeling is the graph that illustrated the declining cost of electricity (Figure 7). Not only did managers make a useful commodity abundantly available to their customers, they also did it in such a way that unit costs spiraled downward. These graphs and image alone would be enough to explain the satisfaction enjoyed by utility managers. They viewed themselves as true public servants.

But there was more. Utility managers also savored the feeling of being responsible stewards of technological progress. From the start of the industry, managers – who overwhelmingly had engineering backgrounds – used improving technology to raise thermal efficiency and to increase the scale of operations. To them, lower "heat rates" (a measure of greater efficiency) and the ever-increasing scale of turbine generators symbolized the techno-

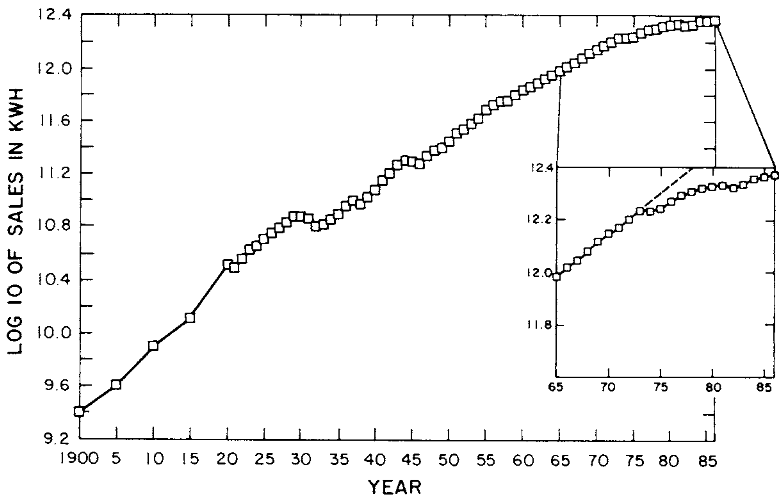

Figure 5. Sales of electricity, 1900–86. This logarithmic graph shows steady growth of electricity sales until 1973, when the Arab oil embargo and much higher energy costs spurred conservation efforts by users. Data are from Edison Electric Institute, *Edison Electric Institute Pocketbook of Electric Utility Industry Statistics*, 34th Ed. (New York: Edison Electric Institute, 1988.)

logical achievements that meant benefits to everyone (Figure 8). In short, these illustrations connote the exuberance of utility people who, for almost a century, understood and managed a complex technological system with little interference from "outsiders." They derived pleasure in knowing that their work contributed to the public good, and they developed a culture – a set of values, assumptions, and historical lessons – that became entrenched as they pursued further progress into the 1960s and beyond.

This book might be interesting in itself if it simply explained the development of a managerial culture that grew out of a specific set of historical experiences with technological systems. But such an exposition is merely prologue to a discussion about how this history affected management decisions concerning a stagnating technology. In the second part, "Stasis," the book argues that electric generating technology, which traditionally improved through small steps, no longer achieved many gains in the 1960s and 1970s. The text first explores the technical reasons for limits to progress in the industry. It continues with an explanation of how management practices in the utility and power-equipment *manufacturing* businesses contributed to the creation of barriers and how responses to stasis by *utility* managers did not help the situation. For example, the book argues that utility executives ignored some signals emerging from the graphs displaying stagnation because they continued to rely on successful, but

Figure 6. Cover of the 1968 *Annual Report* of the Virginia Electric and Power Company. The single word "Growth" implied good things to utility managers, stockholders, and customers in 1968. Reprinted with permission from Virginia Power Company.

now invalid, business assumptions and practices that no longer had sound bases in experience.

Exacerbating technical problems, the industry suffered after World War II from its inability to lure the most innovative engineering and manage-

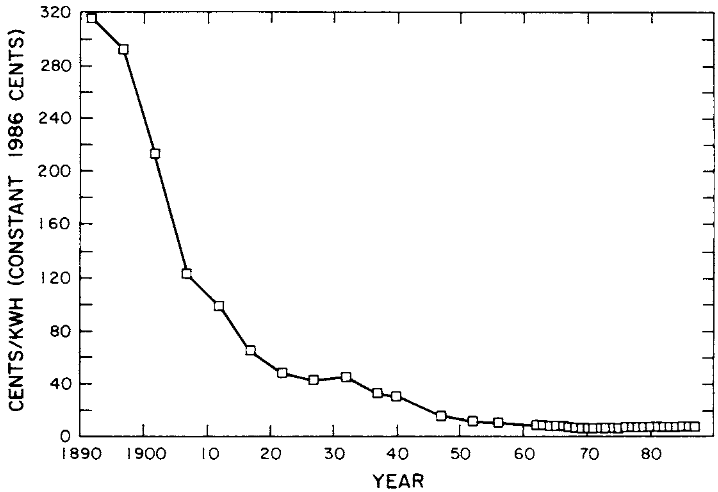

Figure 7. Average adjusted price of electricity. For residential service, the real (inflation-adjusted) price of electricity fell (in terms of 1986 cents) from over 300 cents per kilowatt-hour to about 7 cents per kilowatt-hour. Beginning in the late 1960s, the real cost of electricity ceased declining, so that the price in 1986 was about the same as it was in 1970. Data are from Edison Electric Institute, *Edison Electric Institute Pocketbook of Electric Utility Industry Statistics*, 30th Ed. (New York: Edison Electric Institute, 1984) and "1988 Statistical Report," *Electrical World* 202 (April 1988): 61.

ment talent available. Once viewed as exciting and "high tech," the electric utility industry lost recruiting battles to the electronics and aerospace industries, which carried with them the aura of exciting technological frontiers. By failing to attract the most competent individuals who may have anticipated stasis, the utility industry was left with people who would not challenge long-standing practices and assumptions that had become part of utility culture. They therefore allowed old assumptions to become even more entrenched, and they resisted change when a new business and technological environment emerged in the late 1960s. They also resisted efforts to cooperate in performing research and development on new forms of power technology, relying on their manufacturers to continue doing what appeared to be eminently successful in the past.

The third part, "Accommodating Stasis," describes basic strategies that some managers have inaugurated for dealing with an industry whose technology has reached stasis. As a first step in this direction, managers have been required to understand the values of each of the stakeholders in the power matrix and realize why conflicts arose. In the "good old days" before the 1960s, a consensus had been established among parties, and it accorded great power to utility executives to pursue technological developments as

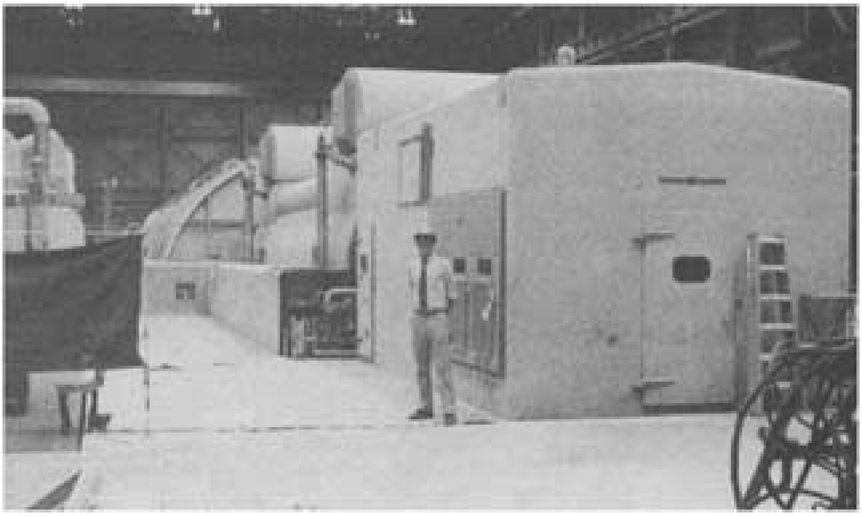

Figure 8. The author standing next to a 1,145-MW-turbine-generator set. Photograph by Frank W. Bliss.

they saw fit. But when consumers, for example, began viewing electric power technology as expensive, polluting, and dangerous, they influenced regulation and hindered managers' efforts to pursue traditional goals. As the consensus unravelled, some managers in the 1980s began to recognize that their values and business strategies must change too. For the short term at least, they realized that a new consensus could be built around managing the existing technological system and discouraging the need to install large amounts of new equipment.

For the longer-term future, however, new technology will be required to meet the demands of a growing country. One approach to develop the equipment has consisted of overcoming stasis and effecting further technical advances in conventional technology. (Indeed, one of the attractive features of the notion of stasis is that it leaves open the possibility of further technical improvements.) The chapter entitled "The Search for New Technology" therefore discusses attempts made to overcome stasis. But the new technology may not resemble what predominated during the first seventy years of this century. Instead, to achieve a new consensus, some players are developing small-scale technology, to be operated by unregulated firms that compete or collaborate with established utility companies. Though highly controversial among utility managers, this new approach may have the effect of rerationalizing the entire industry. It may also be a way for the industry to provide enough electricity at reasonable prices while also balancing the needs and values of various participants.

Finally, the book reiterates the importance of appreciating historical experience as a factor in running a business or industry. The conclusion suggests that in order to manage technological enterprises successfully, individuals should realize that a history of accomplishment can adversely affect management behavior in the future. It therefore cautions against reliance on past practices and advises that awareness of an industry's technical and cultural roots must be cultivated by today's managers. In short, the book argues that studies of the past should play a significant role in managing events in the future. Since views of current technological and business situations are molded by representations of the past, managers must use historical understanding to distinguish between unchallenged assumptions and wise practice. This lesson holds true as much for other businesses as for electric utility companies.