The History and Evolvement of Electrical Peak Load Control Systems in Europe and the U.S.

By Dr. Brett D. Steele, Ph.D. and Theo Breitenstein

Using electronic control systems to curtail electricity consumption reflects deep shifts in the mindset of the utilities industry, as far as load management is concerned. Samuel Insull and the Commonwealth Edison Company of Chicago pioneered the strategy of "flattening out" the inefficient peaks and valleys of their load curves during the late 19th and early 20th Centuries. To execute this strategy, Insull acquired a diversified range of customers whose energy consumption peaked at different times of the day. These included street car operators, brickyards, offices, commercial stores, and private residences that possessed both electric lighting and new electric appliances.[i] Thanks in part to Insull's political prowess, the early public utility regulators tolerated the utility company's demand charges for businesses. This involved charging for the maximum level of power used, in addition to the total energy level consumed. Such a pricing policy, however, had little to do with load management or the higher marginal costs associated with peak loads. Instead, it reflected the utilities' revenue maximization strategy that exploited the value for manufacturers of in-house power generation. [ii] The capital cost for such production was directly dependent on the maximum level of power required. Many manufacturers found it profitable to generate electricity in-house during the early 20th century, due to the useful heat that was generated and the absence of transmission costs. By the 1920s, the electric utility monopolies largely eliminated such independent competition, while retaining the profitable demand charges. Samuel Insull thus engaged in a pioneering "demand-side" management campaign to stimulate the highly profitable consumption of electricity throughout the day, not to mention a political campaign to eliminate competition. Coupled with GE's and Westinghouse's engineering ability to supply larger and more efficient generating plants, Insull's Commonwealth Edison set in motion the growth and centralization of electricity generation, based on a strategy of maximizing power consumption. It would dominate the strategic mindset of the American electric power industry through the mid-1970s.

The early German and Swiss electric utilities initially followed the American strategy of maximizing energy consumption across a diversified array of customers, as demonstrated in such cities as Berlin and Zurich at the turn of the 20th century.[iii] The higher price of fuel and greater dependence on hydropower gradually induced more conservation-minded thinking in Europe, however, especially in Switzerland. That Alpine nation completely lacked coal or petroleum deposits, while its abundant hydropower was heavily dependent on the weather. Likewise, the physical devastation of World War II restricted Switzerland's ability to trade energy with the French and Germans during the winter months when hydropower was in short supply. As a result, the publically-owned Swiss electrical utility industry was struggling by the late 1940s to achieve a more balanced or flattened load profiles. They faced a particular challenge in meeting the growing demand peaks that occurred within a relatively short time window, given the strong post-War economic recovery that was commencing. Swiss population typically returned home for their main meal during the middle of the day. Since they cooked almost entirely on electrical stoves during the 1940s—a legacy of the Swiss enthusiasm for electric technology in the early 20th century—the highest peak demand time occurred around noon. The Swiss state-owned electric utility therefore responded with the radical solution of imposing restrictions on domestic households during this critical peak-demand phase. This included the outright blocking of power to residential washing machines and HVAC boilers. As shown below, the load profiles of a hydroelectric power plant in the Swiss Alps and a utility company during that era reveals a stark peak demand at mid-day.

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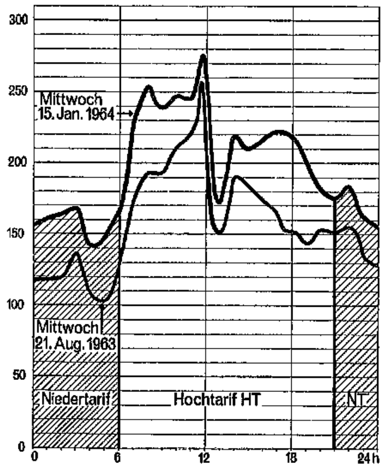
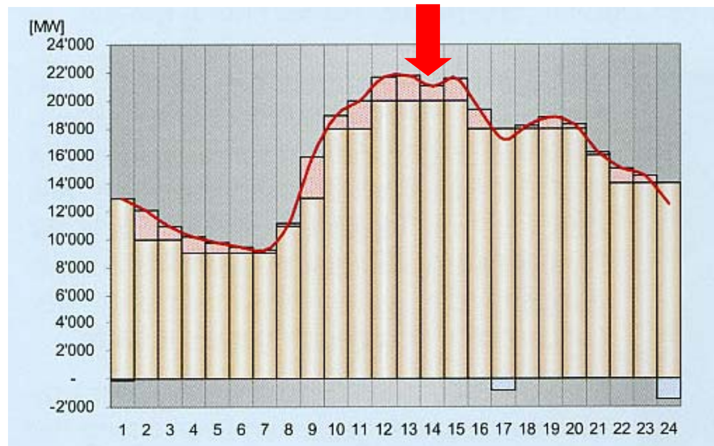


Load Profile Utility of Zuerich Wednesday, January 15, 1964



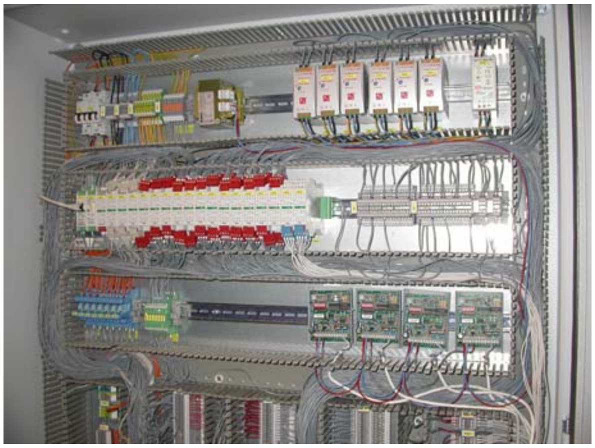
Load Profile Grand Dixence (The Grande Dixence Dam, in Switzerland, is 285 meters (935ft) high one of the world's tallest dams and the highest in Europe)

The Swiss electric power monopoly initially approached the problem by using a simple relay signal that propagated over a power line to typical households, which interrupted washing machines at noontime or shifted the recharge of hot water boilers to off-time hours. That centrally-controlled on-off approach proved to be very effective and is still employed throughout Europe over 50 years later for certain curtailment tasks.

In spite of the new reservoirs being built in Switzerland during the late 1940s, the growing demand for electricity consumption continued to challenge the Swiss's capacity to generate electricity. As a result, new innovations in demand limiting, especially for industrial applications, slowly emerged. Simple demand-drag indicators (*Schleppzeiger*) became commercially available in the 1950s, which measured the maximum power used. By the early 1960s, Landis and Gyr, a pioneering Swiss manufacturer of electrical utility meters, introduced the 'Duomax." It permitted basic demand limiting action by shutting down machines when a specified power level was surpassed. Given the time-of-day pricing policies that electric utilities introduced throughout Europe during the 1950s, the Duomax became a popular device for curtailing electric power use.[iv] From the late sixties to the early eighties, however, the European ability to curtail limit peak-load spikes in commerce and industry was limited to relatively simple technical and managerial approaches, due indirectly to the high expense of computer processing power.[v] These included radio controlled water and space heaters and more simple time clocks that could stagger the use of appliances.[vi] More efficient consumer appliances became popular as well, such as point-of-use heating for showers and washing machines, small refrigerators, clothes lines, and even heavy *Rolladen* shades to minimize heat loss in windows. Such conservation-minded action certainly reflected the relatively high prices of energy, thanks to heavy energy taxes, especially in those countries, like Italy, which had to import virtually all of their energy resources.

The United States had an entirely different attitude towards conservation. Well into the 1970s, the US electric power industry dismissed as absurd, if not threatening, the notion that excessive peak loads should be addressed through "negative" demand-side management solutions, such as load curtailment and peak-load pricing. Given the highly regulated and monopolistic business environment, profits were directly coupled to capital spending on new power-generation plants. And before the regulators would permit their construction, the utilities executives had to offer convincing projections of increased energy consumption—something that conservation would threaten. The Energy Crisis of 1973, however, dramatically boosted the cost of running petroleum-fueled energy plants. Increased safety regulations led to massive cost-overruns in constructing nuclear power plants. As a result, hostile utility industry attitudes towards conservation and load curtailment slowly started to change.[vii] This was reinforced by the passing by Congress of the Public Utilities Regulatory Policies Act of 1978 (PURPA) and the National Energy Conservation Policy Act of 1978 (NECPA), which formally authorized electric power companies to help customers lower their energy consumption. By the late 1970s, electric utilities therefore started managing their loads by offering incentives to customers to curtail their individual peak loads.[viii] Among the measures being explored included basic managerial practices for shifting loads in industry. These included the use of more accurate collection of energy consumption data, time-of-day pricing, simple demand-limiting equipment, more flexible production scheduling, and in-house electricity generation.[ix] The City of Los Angeles, in fact, experimented with peak-load pricing for residential neighborhoods as early as 1976.[x] Building Management Systems (BMS) emerged as another response during the early 1980s, especially with the dramatic rise in the power of microprocessors during the 1970s. They allowed facility operators to curtail their aggregate peak loads by changing temperature or other performance settings, which the BMS would then achieve through simple on-off feedback control processes. The use of active control systems to curtail peak loads back down to a defined limit in a facility, a process that required a BMS to be in place, was also proposed in the US during the early 1980s.[xi] It was in Switzerland and Germany that the translation of such theory into effective practice occurred, however, given the far greater commercial demand for peak-load control that existed in those countries.

The ever growing hunger for electrical power in Europe was hardly stifled by the use of time-of-day pricing, the limited capacity of power plants, and the powerful anti-nuclear power movement that the Green Party promoted. As a result, companies such as RSW, Mensch & Technik, Borer, and Janitza began to develop computer-controlled demand-limiting systems by the mid 1980s. These firms continued to leverage the rapid development of software and PCs during the 1990s, and delivered commercially viable products of growing capability as a consequence. By utilizing sophisticated control algorithms, as well as connecting to accurate variable frequency drives, these intelligent demand-control systems achieved noteworthy success in both conserving energy, as well as reducing the demand costs from lighting, manufacturing processes, and HVAC systems. Since they only marginally reduced the performance of any particular machine, rather than shutting down entire systems, end-users were often scarcely aware when a curtailment event occurred.



iPLC (intelligent demand control system from Emacx Systems, Inc.)

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Today, over 50 European manufacturers have offered some form of intelligent demand control system during the past 25 years, and have installed over 60,000 advanced systems. Today, many European countries have taken Demand Limiting Systems to new heights. Many major industrial, commercial, hospitality and healthcare companies, as well as government agencies employ peak demand limiting systems throughout their facilities with considerable economic success.

Demand control systems in the United States during the 1990s and early 2000s, by contrast, remained downright primitive from a European perspective. At worst, they were simply upgraded versions of Landis and Gyr's Duomax demand limiting device that shut down particular machines when limits were reached. At best, they deployed simple software systems that could shut down prioritized list of machines or lighting systems when requested. The lower energy costs of the 1990s in the U.S. contributed to this neglect, as well as deep-seated misperceptions that load curtailment would impose unnecessary costs and acceptable risks on facility managers.

The American assumption that manual curtailment processes sufficed, and that automatic systems were an unnecessary expense, proved to be fallacious in California during the chaotic energy crisis of the early 2000s. PG&E's demand response program, where businesses were paid to curtail their energy consumption when blackouts threatened, generally failed to work as planned. Too many businesses simply failed to respond to PG&E's requests. Likewise, the growing deregulation of the electric power industry, where utilities started enjoying greater flexibility in offering better incentives for more reliable demand response, prompted more interest in European-style peak-load control systems. As a consequence, Theo Breitenstein, an experienced Swiss electrical engineer and energy manager, established Emacx Systems, Inc. in 2001 to formally such European technology to the United States.

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[i] Thomas P. Hughes, Networks of Power: Electrification in Western Society, 1880-1930 (Baltimore: Johns Hopkins University Press, 1983), pp 217-223.

[ii] John L. Neufeld, "*Price Discrimination and the* Adoption of the Electricity Demand Charge," The Journal of Economic History, Vol. 47, No. 3 (Sep. 1987), pp. 693-709.

[iii] For the early development of the electric utilities industry in Germany, see chapter VII, "Berlin: The Coordination of Technology and Politics," in Hughes, Networks of Power, pp. 175-200. For the early electrification of Switzerland in general and Zurich in particular, see David Gugerli, "Sociocultural Aspects of Technological Change: The Rise of the Swiss Electricity Supply Economy, Science in Context, Vol. 8, No. 3 (1995), pp. 459-486

[iv] C. M. Cannon, "The efficiency and fairness of the terms and conditions under which electricity is sold to British manufacturing establishments," Applied Economics (1977), p. 176. Also see "Electric Load Management in Industry, p. 42, 47, for a description of the use of the Duomax in Italian industry in response to time-of-day pricing, see http://www.leonardo-energy.org/webfm_send/480

[v] J. Acton, E. Gelbard, J. Hosek, D. McKay, "British Industrial Response to the Peak-Load Pricing of Electricity," R-2508-DOE/DWP, (RAND Corporation, 1980).

[vi] Bridger Mitchell, Willard Manning, Jr., Jan Paul Acton, Peak Load Pricing (Cambridge, MA: Ballinger Publishing Company, 1978): 122-123.

[vii] For a detailed account of the Environmental Defense Funds' transformative success in convincing PG&E during the late 1970s that they could actually maximize their profits by promoting energy conservation, see David Roe, Dynamos and Virgins: An advocate's personal account of the struggle to force a new idea, and a new future, on the nation's power companies (New York City: Random House, 1984).

[viii] Joseph Eto, "The Past, Present, and Future of U.S. Utility Demand-Side Management Programs," LBNL-39931 (Dec 1996), p. 6. http://eetd.lbl.gov/ea/EMP/reports/39931.pdf

[ix] Reginald Stuart, "Coping With Power Peaks: Managing of Demand at Peak Hours by Utilities," New York Times (Aug. 10, 1975), p. 115.

[x] Mitchell et. al., Peak Load Pricing, pp. 198-202.

[xi] Donald Eppelheimer, "Electrical Demand Control," Proceeding of the First Symposium on Improving Building Systems in Hot and Humid Climates (August 1984), pp. 47-49. http://repository.tamu.edu/handle/1969.1/6466