# Managing Change: Regional Power Systems, 1910-30

*Thomas Parke Hughes*
University of Pennsylvania

In the era of regional electrification during the early decades of this century, two consulting engineers played roles as entrepreneurs. Entrepreneurs of technology differ from business entrepreneurs in several particulars. The dissimilarity arises in part from the technological entrepreneurs' focus upon technology, a subject about which they are unusually well informed. They see finance, institution formation, and political power as means to the end of bringing into use the technology about which they know so much and care so deeply. Business entrepreneurs usually see technology -- about which they know relatively little -- as means to other ends.

Coincidence may have brought consulting engineers to play the entrepreneurial role in large and complex technological affairs between 1920 and 1940, but I am of the opinion -- and it must be an opinion because the subject is virtually unexplored -- that consulting engineers became involved because their profession was generally able to cope with complicated, multifaceted problems. Consulting engineers, in contradistinction to other engineers, especially academic ones, often establish firms or bureaus to institutionalize various engineering functions, thereby further enhancing their ability to deal with large affairs. These functions included, by 1920, engineering design, construction, financing, and management.[1] Such services involved the head and the firm in intimate relationship with technological, scientific, financial, and political centers of expertise and power. Between the wars, as this essay will show, consulting engineers, because of their multifaceted competence and experience, were sought for large-scale and regional planning.

From a number of consulting engineers here and abroad who were involved in regional electrification, I have chosen to write about Charles Merz of England and Oskar von Miller of Bavaria. The history of their involvement is particularly appropriate because the regional schemes with which they were concerned emerged as plans rather than evolving incrementally or because they were men of strong and definable characteristics. Plans are more readily analyzed than incremental growth, and forceful influential individuals are more often written about by their contemporaries and more readily studied by historians.

In writing about the efforts of Merz and von Miller to manage the activities and events culminating in the introduction of the Grid in England and the Bayernwerk in Bavaria, I use the word "manage" in accord with the first of the dictionary variations -- "to bring about." This usage varies from "to take care of," a way in which "manage" is often used by students of administration. The essay following is, then, about the problems Merz and von Miller had to define and confront, the alternative solutions from which they had to choose, and the decisions they made as they brought about the Grid and the Bayernwerk. These were regional transmission systems that integrated and coordinated public electricity supply. During the first third of this century, the creation of regional systems of electrification was considered the most exciting challenge in the energy field by engineers, utility managers, financiers, and even a segment of the informed public. The projects were comparable in magnitude during planning and the early decades of construction with that of the major railway systems in the United States during their early period. In 1854, for instance, the Western Railway of Massachusetts involved a total investment of $10 million; in 1860 the New York Central had invested at least $30 million in physical assets and by 1883 it had a total investment of about $150 million; and by 1873 the system of the Pennsylvania represented an investment of $400 million. These investments and the technology greatly impressed contemporaries and historians studying the managers and financiers responsible, but it should be noted that during planning the Bayernwerk was estimated to cost 32 million marks and the Grid £250 million.[2] In this essay, therefore, I seek to define and analyze managerial problems and solutions of the scale and complexity delineated by, for example, Alfred D. Chandler, Jr. and Stephen Salsbury in their studies of railway management. My emphasis, however, is upon "bringing about" rather than "taking care of."

## CONSULTING ENGINEERS AND ENTREPRENEURS

Oskar von Miller (1855-1934) studied engineering at Munich's Polytechnikum and joined Emil Rathenau in 1884 to establish a firm that evolved into Allgemeine Elektricitäts-Gesellschaft (now one of the world's leading electrical manufacturers) and into the Berliner Elektrizitätswerke (now one of Germany's major utilities). In 1890 he returned to his native Munich to found the consulting engineering firm, Technisches Bureau, O.v.M. By then he had acquired a grounding in electrical technology and science; he also developed a particular expertise -- long-distance power transmission. His enthusiasm for transmission materialized in his organization of dramatic and innovative demonstrations of high voltage transmission at the International Electrical Expositions in Munich in 1882 and Frankfurt am Main nine years later. In those times, international expositions effectively stimulated technological innovation and transfer.[3]

Charles Merz, like von Miller, stemmed from an influential and affluent family. Von Miller's father was the titled sculptor and founder to the royal dynasty of Bavaria. Merz's mother was a sister of the Newcastle shipbuilder, Wigham Richardson, and his father was a man of remarkable culture. John Theodore Merz is known to scholars as the author of *A History of European Thought in the Nineteenth Century* (4 vols., 1896-1914). He also had a reputation as a chemical manufacturer on Tyneside whose enterprise was eventually absorbed by I.C.I., and he was a founder and director of the Newcastle Electric Supply Company, whose vision of large area systems of electrical supply may have influenced his son. Both Merz and von Miller, therefore, had access to persons of wealth and political influence. It is said that

> Charles was brought up in a household where leading engineers, businessmen and financiers were common visitors, including directors of local firms such as the North Eastern Railway, Swan Hunter and Armstrong Whitworth, and of banks and financial houses such as the Lasard Brothers and the Barings....[4]

As consulting engineers presiding over projects like the Grid and the Bayernwerk, an ease and familiarity of this kind was, as will be demonstrated, of professional importance.

Charles Merz attended Armstrong College in Newcastle but left without taking a degree to pursue more worldly matters as an apprentice at the power station of his father's Newcastle upon Tyne Electric Supply Company (NESCo) and later at the electrical manufacturer, British Thomson-Houston. These early experiences help explain Merz's subsequent invention of improvements in power plant equipment. In 1899, eight years after von Miller, Merz set up a consulting engineering firm, which took the name of Messrs. Merz and McLellan after William McLellan joined him in 1902, having worked earlier with Merz on an electrical engineering project. Merz and the firm in subsequent years manifested less interest in long-distance power transmission than did von Miller, but from the beginning the Englishmen showed a bias toward -- and aptitude for -- the creation of coordinated systems. In 1905, for instance, Charles Merz was the leading advocate and witness of a parliamentary bill that, if it had passed, would have brought systematic order out of the chaos of systems, frequencies, and voltages in London where medieval political boundaries confined the geographical expansion of the numerous utilities.[5] As a consulting engineer, he also took part in the formation and operation of the first large-area power utility in England. By the time World War I began, Charles Merz had also taken a leading role in making the Newcastle Northeast Coast industrial region one of the most rationally and economically supplied in all of the western world.[6]

## ANTECEDENTS AND INCLINATIONS

Von Miller's involvement with the Bayernwerk had antecedents in his interest in harnessing the water power of the Bavarian Alps. He was one of a number of engineers who proposed in the first decade of this century, once long-distance power transmission was possible, that electricity should be generated at water power sites in the Alps and used at load centers in Bavaria. For centuries, Alpine streams had turned water wheels but, before the era of electrical transmission, the energy had to be consumed in the immediate vicinity. Until the advent of power transmission at high voltages, use of water power was sharply constrained by natural factors, for instance, by the geography of stream flow. Von Miller's vision, however, extended beyond the exploitation of hydroelectric plants by a few load centers located on point-to-point transmission lines. He saw regional systems supplied by large plants providing power for urban centers, industrial sites, and agricultural communities spread over thousands of square miles.

Circumstances thrust him into an advantageous position from which to pursue his vision of a regional system when the King in 1919 named him to the Upper House of the Bavarian Parliament. There he took advantage of substantial interest among the members in exploiting Alpine hydroelectricity. He set about organizing inchoate and often contradictory actions and objectives into coherent plans. Using the varied competences of his consulting engineering bureau, he prepared plans for parliamentary consideration. The first, ready in 1915, emphasized the design of a very large hydroelectric plant at the Walchensee, an Alpine lake about 50 kilometers south of Munich;[7] the second plan, ready in 1918, dealt with the regional power transmission system designed, in part, to use the energy stored in the Walchensee [26 and 30].

In 1919 the new republican government of Bavaria gave von Miller, who had never lost sight of his goals during the war, the opportunity to fulfill them in the chaotic postwar conditions. As commissioner and manager of construction for the Walchenseewerk (Walchensee installation) and for the power transmission system called the Bayernwerk, von Miller had the satisfaction of presiding over the first phases of organization and construction. He also saw in 1924 power begin to flow from the Walchenseewerk into the transmission lines of the Bayernwerk, but by then he had resigned his authority because of disagreements and dissatisfaction over organizational policies [15].

Charles Merz, like von Miller, became involved in the planning of a regional transmission system during World War I. This simultaneity of concern and action demands explanation, but must be explored elsewhere. Merz, as observed, had furthered the development of a regional system of supply in the Northeast of England and had tried to systematize London's supply. For these and other reasons Charles Merz was named head of a subcommittee on the future of electricity supply in Great Britain formed by the Ministry of Reconstruction. In its report, largely written by him, are found Merz's views on the organization of a national system of electrical supply [23]. Essentials in this report were then incorporated in a 1918 report of a Board of Trade Committee headed by Sir Archibald Williamson and including Merz among its members [22]. The so-called Williamson report resulted in the Electricity Supply Bill of 1919, establishing a framework for regional cooperation in electrical supply without providing the authority needed to bring about an integrated centrally controlled system.

Technical and lay opinion continued to press for a national system of supply and, when the government of Stanley Baldwin took power in November 1924, a newly formed committee under the chairmanship of Lord Weir began review of the problem [24]. The committee was assisted by a technical subcommittee including Charles Merz.[8] Williamson, who had chaired the wartime committee, served as one of the three members of the principal committee, so Merz's ideas and recommendations were well heard and greatly influenced the committee report. The report of the Weir Committee, published in 1926, brought the Electricity (Supply) Act of that year and the decision to construct and operate a national system of supply -- the Grid.[9] Merz, incidentally, seeing a resemblance between its layout and a gridiron, bestowed the name upon the system. The Grid, the world's first national system of supply, can be characterized as an invention and a development by committees. So far as one mind can be seen in the sustained collective effort, it is Merz's. As in the case of Oskar von Miller, however, the contribution of the consulting engineer depended upon the support of his consulting firm.

## NATURE OF REGIONAL SYSTEMS

In essence what were the Bayernwerk and the Grid? They differed in detail, as will be explained, but the fundamental concept common to both -- and to other planned and realized regional systems -- was a ring, or network, of transmission lines supplying energy by generating plants through transformers raising the voltage of transmission very high in relation to the current, and supplying energy to consumers through transformers lowering the voltage for safe distribution to consumers. An underlying principle was the knowledge that transmission losses would be less at higher voltages than at lower ones. Low losses made it economically feasible to substitute transmission for new generating plants of small size and low efficiencies.

Many analogies can be used to explain transmission systems. Perhaps the most helpful is that of a high-pressure gas transmission line. If high pressures are used (read voltages) then smaller-diameter pipe lines (read transmission lines) can be employed to carry the same energy. The pressure is maintained by pumping stations (read generating plants). As in the case of electricity, the pressure is reduced for distribution to consumers. The analogy breaks down in one essential category of comparison: electricity, unlike gas, cannot be stored. Water and coal used in generating electricity can be, however.

Numerous economies by 1910 recommended transmission systems. These can only be touched upon here. The network made possible interconnection of power plants of varied characteristics and the exploitation of these variations to compensate for weaknesses and to take advantage of strengths. For instance, coal-fired plants in the system could be fully utilized when coal was abundant and water relatively scarce, and hydroelectric plants fully utilized under reverse conditions. Also, efficient plants could carry the unvarying base load and less efficient ones the sporadic peaks. In addition, the network, or grid, made possible the exploitation of diverse loads present in a large area. The peaking of demand varied according to the nature of the load and its location, if the region served was quite large. For instance, electrochemical plants usually gave a steady 24-hour load, lighting peaked in the evening, and industry and transportation at different times during the day. Load centers, therefore, had different load curves according to the mix of consumers in the region. In the Northern Hemisphere a more southerly area within a region might also have a different load because of warmer climate; a more westerly area peaks later than easterly ones because of real sun time. The management of load was called exploitation of the diversity factor; the economies and social advantages achieved were said to be analogous to life or property insurance.[10]

The economies and social benefits made a cult of regional electrification. Men like von Miller and Merz were looked upon as the great engineers of a new and heroic age of technological revolution. They took themselves far less pretentiously. The numerous issues to be confronted, problems to be solved, and decisions to be made prevented their dwelling upon the boldness of -- and likely transformations attendant upon -- their concepts.

## ISSUES AND PROBLEMS

A major issue both engineers had to confront was political parochialism, or the prerogatives of local authority. In Merz's

England the phenomenon was most easily observed. Since public supply electricity had first been introduced around 1880, the vestries, parishes, counties, and other political authorities of medieval origin saw the threat of large electrical supply systems to local authority. Large systems spread over political boundaries and were difficult, if not impossible, to regulate by local government. Furthermore, large systems could not be socialized easily by individual local authorities unless the authority would be satisfied to have a power plant without distribution lines or the lines without the plant, according to how the system was dispersed. If a local authority had invested in a gas lighting plant or in a small electric supply system, the problem of introducing an area or regional system including the local authority's district was further complicated.[11] The local vestries and parishes frustrated Merz when in 1904 he tried to introduce a coherent system of supply for London. Contrary interests in London were too strongly represented in Parliament for it to grant the necessary powers for the laying of cable and the situating of other facilities in public places and along public ways.

In 1917 Merz's subcommittee on "Electric Power Supply in Britain" took the offensive against parochial interests. Its report [23, p. 15] sharply defined the issue:

> Parliament was apparently convinced [in the past] that the generation and supply of electricity must be dealt with in a big way, though how important this would become they perhaps hardly foresaw. They were, however, apparently afraid [*sic*] to insist on the amalgamation of the existing lighting enterprises which, as has been shown, were and are still each limited to a few miles of area instead of covering, as they should, a few counties.

Merz and others battling for regional supply had to find means of overcoming Parliament's fear.

The ways tried were undoubtedly resourceful and numerous. The technical and economic arguments were obvious; the political ones were less so, but probably more persuasive in Parliament where the issue would be resolved. Prime Minister Lloyd George had so instructed Merz years earlier by pointing out that matters of electricity supply were politics, not engineering [19].

Merz's argument was cast on the highest level of national policy. In 1917 he appealed to the mood of a people concerned about national survival. He translated the wartime struggle into the terms of the peacetime one inevitably to follow -- the ceaseless struggle for industrial supremacy. The essence of his logic was syllogistic: the leading industrial powers exploit the most advanced energy technology; the most advanced energy technology is regional electricity supply; and, therefore, England to lead must adopt regional supply. His report of 1917 illustrated and provided evidence for the argument by reference to higher use of electrical power per worker in the United States, to vital new industrial processes using electricity in Norway, Sweden, and Germany, and to the larger supplies of hydroelectricity available to other industrial nations. The conclusion to be drawn was manifest: parochial must give way to national interest, and a national system of supply was in the national interest.

Despite the wartime commitment to national interest, Merz's and other reports and the ensuing legislation of 1919 did not achieve the goal. The legislation of 1919 (as noted) did not provide the powers needed to bring about the area systems defined as desirable [9]. A committee of electricity commissioners established by the legislation tried suasion to achieve the goal, but with limited success. Unemployment, the call for socialization by some Labour Party members, the continued pressure of international economic and industrial competition, and the conviction that the age was one of electric power resulted, however, in the establishment in 1924 of a committee under Lord Weir of Eastwood to "review the National Problem of the Supply of Electrical Energy" (see Note 9). The influence of Merz on this committee stemmed from his role in the deliberations of the wartime committees and from his being named by Weir to a technical subcommittee.

The reasoning used to advocate a national system of supply in the Weir report is similar to that Merz and others used elsewhere. "It is a commonplace," the report insisted, "that the coming age will be one of electricity" [24, p. 5]. Featured boldly in the report was the information in tabular form showing that, on the eve of the age of electricity, per capita consumption of electricity in Great Britain fell behind consumption in California, Chicago, Canada, the northeast states of the US, Switzerland, Tasmania, the US as a whole, Norway, Sweden, Sydney, and Shanghai. (Obviously, former colonies and small countries were far better prepared than a nation which was once the undisputed industrial power.)

Stressing the obvious, the report observed that the information was "very disquieting." But, as expected, there was a remedy -- interconnection not only within large areas identified by the legislation of 1919, but between them so as to achieve a national system. The Weir committee discounted the country's lack of hydroelectricity sites even at a time when water power was being rapidly exploited and widely celebrated throughout much of the world, because, it was ventured, Britain could exploit coal, had the advantages of a high level of urbanization, and had the close proximity of industrial load centers. Great Britain, Weir's committee reasoned, "is in many respects an ideal electrical area, and is far more compact than other countries" [24, p. 8]. Elsewhere, in commenting upon the report, Charles Merz wrote that Britain's grid would be more like a high-voltage distribution system than a high-voltage transmission system. He was using the common distinction, between transmission as long distance and distribution as short.

In 1916 Merz [17] had said,

> Proceeding on these lines [high voltage distribution for the compact industrial districts of England] we shall not be merely copying America or Germany -- we shall be doing something that is right for England because it is England, because England is radically different from other countries as regards the technical development and layout necessary to secure cheap power.

In suggesting that a proud nation could move from a backward to an advanced status without simply following the leaders, Merz's psychological acuteness is obvious.

The technical report done by Merz and McLellan for the Weir Committee emphasized the economic argument. Local authority and other vested interests should give way -- the implication is clear -- not only to considerations of national power and prestige, but to economies resulting from systematization of supply. According to the technical report, the cost of generating electricity under the grid scheme would be reduced by 1932, when the first construction phase was complete, by 42 percent, as compared with the cost of generation in 1925. Moreover, Merz and McLellan concluded that the total annual expenditure upon the scheme in 1932, including all charges, would be approximately £17 million and a surplus of some £150,000. After 1932 the surplus would "steadily increase" [24, p. ix]. Such figures, the Weir Committee concluded, indicated the reduced electricity bill of the country and suggested that "the magnitude and importance of the saving demanded immediate and decisive action" [24, p. 9].

## MINISTERIAL AUTHORITY

In Bavaria, a few years earlier, Oskar von Miller, trying to establish a system of electrical supply in the region, also encountered authorities staunchly guarding local interests. In Bavaria, however, the opposition came most noticeably from government ministries, judging from von Miller's remarks made as a member in the Upper House of the Bavarian Parliament over a number of years. Von Miller lamented, as he strove to develop and win parliamentary support for a single system of high-voltage transmission in Bavaria, that the Transportation Ministry concerned itself primarily with the supply of state-owned, electrified railroads; the Finance Ministry focused upon the stimulation of steam plants, some of which von Miller insisted would be redundant because of the

Walchenseewerk; and the Ministry of Interior encouraged the development of isolated plants by industry, installations that could not be integrated in a regional system when constructed.[12]

Von Miller, like Charles Merz, called upon the spirit of cooperation and rationalization abroad during the war. In the last months of the war, the Parliament, persuaded by von Miller, authorized construction of the hydroelectric plant at Walchensee and of the all-Bavarian transmission system. Von Miller, as the commissioner for the two projects, then managed to begin construction immediately after the war by showing how desperately the returning soldiers needed employment and the people positive goals. His arguments were not unlike ones used by Charles Merz and others to overcome local and private interests in England. Lloyd George's admonition to young Merz that electrical matters were political rather than technical problems applied in von Miller's Bavaria as well.

Having launched the projects, Miller also managed to avoid lodging administration of the Bayernwerk and Walchenseewerk in a single ministry or some combination of them, for he sensed divisiveness would severely handicap, if not fatally flaw, the projects. He established the Bayernwerk as a corporation best characterized as a mixed ownership enterprise with subcontracting powers. The Bayernwerk was intended by him to be 50 percent owned by the state of Bavaria and the remainder by the various existing utilities that would supply power to and take power from the transmission system. He recommended that the Walchenseewerk be an entirely state-owned corporation. These innovative structures would have the advantage, he believed, of businesslike organization and management and of protecting the general interest of the people [26, pp. 17-18]. Interestingly, the Electric Lighting Act of 1926 in Great Britain which established the grid provided a similar organization, outside the existing civil service and ministries, for its administration [10, pp. 1-4]. Not too many years later in the United States, the Tennessee Valley Authority also had a similar charter or commission [21, especially p. 3].

## BURDEN OF HISTORY

Von Miller and Merz had the burden of history thrust upon them. Actively campaigning for a Bavarian system shortly before the war, von Miller warned the members of the Bavarian legislature that trends, a momentum, was generating that could soon eliminate the possibility of establishing regional systems of supply. Since the era of electric light and power stations had begun in the 1880s, utility companies of varying size -- mostly quite small before 1900 -- had sprung up throughout the industrial world. As explained, political boudaries constrained the growth of many of these, but technical limitation had also an effect until alternating, or polyphase, current and high-voltage transmission made feasible large-area supply. Even after larger systems supplying entire cities and, in some cases, surrounding rural areas were established, the utility companies owning them often took technical pride in introducing levels of voltage, frequency of cycles, and phases of current deemed especially appropriate for the local district or area. This meant, of course, that the would-be integrator of utilities faced complex problems of standardization.

London had the unenviable distinction in the eyes of the rationalizers of encompassing 70 local authorities supplying electricity to the public using some 70 generating stations, with 50 different types of current (direct, alternating, and so on), 10 different frequencies, and 24 different voltages [22, p. 6]. Moreover, 7 railway and tramway systems could not exchange electricity because of different technical characteristics. The rest of the country could not deride the irrationality of technology in London, however, because the patchwork system throughout had, in 1916, 230 privately owned companies and 327 local authorities (governments) providing electricity to the public [22 p. 14].

In Bavaria von Miller realized the immediate and far-reaching implications of the growing diversity of supply. During the half decade before the outbreak of the of World War I, he watched as utilities proliferated in Bavaria and -- more ominous from his perspective as a rationalizer -- invested more heavily in the various equipment suited for each utility's kind of supply. Von Miller's sophisticated knowledge of economics and technology quickly alerted him to investments becoming vested interests, in particular in frequencies, voltages, and types of current. Not only was investment of funds in hardware of specific characteristics heavy but personnel, especially operating engineers and technicians, were becoming committed to the kinds of equipment they had come to know well. The remarkable diversity of the utilities was reinforced by the electric manufacturers supplying the utilities with specially designed generators, transformers, and other items. There was, most certainly, a momentum building up that could overwhelm any effort to systematize, coordinate, and standardize. Furthermore, the managers and engineers committed to certain kinds of technology could join forces with local politicians and civil servants who for various reasons believed that small, even in 1914, was beautiful.[13]

One way the Bavarian government countered fragmentation and encouraged amalgamation was to enlarge the scope of regulation. In 1913 the government began granting large area franchises for electrical supply to utilities that accepted regulation of rates and stipulations about the consumer's right to supply. (Utilities avoided supplying isolated rural loads because of the heavy capital charges.) By enlarging the area for regulation, the government expected to stimulate the establishment by combination of utilities able to take advantage of the attractive framework of opportunity provided by the natural monopoly [3, p. 16, and 25, pp. 13-14]. In the United States seven years earlier, the states began to assert regulatory authority with the encouragement of utility magnates such as Samuel Insull who were willing to accept regulation in return for a natural monopoly over a large area of supply. In America large manufacturers, such as General Electric and Westinghouse, inclined toward standardization and mass production of equipment and reinforced the trend.[14]

In England, Charles Merz and the advocates of size and system impatiently pointed to the momentum of the diverse national aggregate, as had von Miller in Bavaria. The longer the history of small area supply, the greater the burden of diversity. Finally, when the Electric Supply Act of 1926 became law, the opportunity presented itself to reverse the trend. The question was, then, how to bring about technical integration and standardization after the political obstacles had been cleared away. The technical problem is analogous to the standardization of the gauge of railroads necessary before national systems of rail transport could be created late in the 19th century.

Standardization of electricity supply was a Chinese box -- problems within problems. On the level of high-voltage transmission the question of voltage and phase was not complicated, in much of the country, by existing commitments and extant equipment. Most high-voltage transmission was new construction. Moreover, the transformation of voltages from the generating plants and to the low voltage distribution systems was a well-established practice. Transformers could be wired on one side for local conditions and on the other for the standard 132,000 volts decided upon for the main transmission lines. The transformer was, in one sense, a coupling device or an adapter that permitted the integration of subsystems with different voltage characteristics.

In 1926, the question of choosing a standard type of current offered little problem for technical advisers such as Merz, because polyphase, or three-phase, alternating current had become a world standard for general lighting and power. Pockets of direct current survived in large cities where highly efficient direct-current Edison stations had prevailed until about the turn of the century. It was, however, understood that the transition would be made and in the meantime another coupling device, the AC-DC converter, allowed the direct current areas to be fed by polyphase currents and encompassed in systems primarily polyphase.

The most troublesome question was standardization of frequency. It was especially vexing for Charles Merz and his associates at Merz and McLellan for they had played an instrumental role in designing, supervising the construction and coordination of an integrated regional supply system in the northeast of England, and, ironically, its frequency would now be defined as nonstandard. The Newcastle upon Tyne Electric Supply Company, mentioned earlier in connection with Merz and his father, had provided the framework upon which an extended system involving other power companies was constructed. The process of integration, by means of high-voltage transmission, centralization of control, and standardization took more than a decade, but by 1916 the system of the northeast coast could, with justification, be characterized as one of the most economically and rationally supplied industrial regions in the world [4, p. 26]. The system supplied electricity to industry producing approximately one-fifth of the coal, one-third of the iron, and one-half of the shipbuilding of the nation. Transportation and households were economically supplied as well. With the exception of only a few pockets, the transmission voltage in the 1,400-square-mile region was 20,000 volts, the current was three-phase, and the frequency was 40 cycles per second (cps) [23].

From the 40 cps arose a dilemma for Merz and those associated with him. Because 50 cps was the European standard, excepting Italy, because most of the existing British plant was 50 cps, and because British manufacturers wanted a market outside of England for the equipment they would design and supply in quantity for the grid, the managers of the grid, the Central Electricity Generating Board, decided upon the uniform 3-phase 50-cps grid for the entire country [17]. The decision was of serious consequence, for it entailed conversion of hundreds of turbogenerators, hundreds of thousands of motors, and almost half a million consumers from other frequencies. Ironically a large share of the nonstandard equipment was located in the well-functioning, highly efficient, impressively economic region that Merz and his associates had been instrumental in creating.[15]

The blow was softened, it seemed, when the Act of 1926 provided for a government loan for the conversion. The entire electric supply industry had to share the repayment cost; each utility, or authorized undertaking, had to make an annual payment over 40 years on the basis of revenues. Projections and analysis estimated the total cost of frequency conversion at £10.5 million. Detailed studies, however, revealed a far greater problem than the one for which Parliament provided. By 1930 the estimate for the conversion in northeast England alone amounted to a gross of £9 million. Because of the escalation, action was delayed and alternatives explored to integrating the already well-integrated Northeast into the large national system.[16]

Electrical suppliers and the large industrial consumers in Merz's Northeast rose up against the changeover. There were a number of good reasons. The government had arranged funding for the conversion, but not for the disruption of equipment and facilities while the work was under way. The Northeast system, moreover, had a very high load factor, and the argument could be made that increased economies, if any, resulting from incorporation in a larger system would be small. In a report on standardization of frequency on the Newcastle upon Tyne Electric Supply Company, and associated companies, a member of the Merz and MeLellan firm advised the Central Electricity Generating Board not to go ahead with conversion [24, 7, and 8]. As yet I have not established Charles Merz's position in the situation, surely difficult for a man who had long advocated a national system of supply. It may be indicated by his saying that many of his friends in the private enterprise side of the electrical industry were critical of his role in bringing the Grid [19].

Events on a larger scale, however, relieved the tension. After the Central Electricity Generating Board found that the choice was between conversion or isolation of the Northeast coast (frequency converters were found impractical as couplers), an approach was made to the government to allocate several million pounds in unemployment grants to the project. This would mean, at least, that the country's suppliers would not be burdened by an intolerable debt. The industrial Northeast was feeling the depression, and the changeover was seen as a palliative, a highly rational and, in the long run, an economically desirable project; so funds were appropriated.

## OTHER CONSIDERATIONS

I have only begun here to explore the complex problems that had to be solved by presiders over the introduction of regional systems of electrical supply. The foregoing, however, should indicate the complex responses, especially political ones, demanded of consulting engineers, such as Oskar von Miller and Charles Merz. Other problems such as the selection of stations to be linked to the grid and of the load centers to be supplied and stimulated economically by it, required highly sophisticated cost and distribution analyses. Needless to say, there were interesting technical problems, such as telemetering and automatic control, to be solved. Despite its limitations, however, I believe that this essay is evidence that the problems of bringing electrical systems into being presented entrepreneurial problems and stimulated tactics and strategies in response that, when more fully described and analyzed, will constitute a major chapter, comparable in significance to the history of railway management. Those who write, and a few do, that the history of electricity supply offers little that is new and complex are not, I believe, sufficiently well informed. Furthermore, I am of the opinion that many of the strategies and tactics developed to solve the problems of electrical system building have become generalized now as entrepreneurial and managerial practices in other complex technological fields.

## NOTES

1. Generally in the United States a holding company in the electrical supply field was closely associated with one consulting

engineering firm.

2. Cost of Bayernwerk was estimated in [26, p. 4]. The cost ("new money") of the Grid over a 15-year period was estimated in [24, p. 18]. Information on the railways is from [6, p.129].

3. Oskar von Miller was -- and remains -- well known in Bavaria. His bearded, forceful countenance; his family ties and roots in Munich; his love of the Bavarian countryside; his numerous achievements as an electrical engineer and entrepreneur; and his founding of the world-famous Deutsches Museum for the history of technology and science, an act accompanied by prodigious feats of money raising, have all left strong impressions -- and street and place names. Among the biographies are an informative one written by his son, Walther von Miller [23], and a more recent popular study [15].

4. [4, p. 24]. On John Theodore Merz's vision of large area supply, see [18]. I am grateful to Eleanor Symons, archivist at the Institution of Electrical Engineers, London, for bringing this booklet to my attention. Also on Charles Merz, see [19], a history of the consulting engineering firm privately published by it.

5. A "Select Committee of the House of Lords to consider the Administrative County of London and District Electric Power Company Bill" met in 1905.

6. Messrs. Merz and McLellan were consulting engineers for the Newcastle upon Tyne Electric Supply Company, later, the North-Eastern Electric Supply Company, Ltd. On the growth of the company (NESCo) into a regional system see [19, 1, 2, 4, and 23].

7. [29], copy in library of Deutsches Museum, Munich. The 15-page report is, among other things, a treatise on the economics of power systems. See also [27].

8. Merz and McLellan prepared a technical report for the Ministry of Transport (Weir Committee), "National Electricity Supply: Technical Scheme," May 1926.

9. For an exhaustive and authoritative account and analyses of the history of the grid see the forthcoming study by Dr. Leslie Hannah (Cambridge University) of the history of electricity supply in Great Britain. Dr. Hannah heads the History Project, the Electricity Council, London. I am indebted to Dr. Hannah for many suggestions and comments upon my own work in the international history of electricity supply.

10. On the economics of large area or regional systems see [14, 20, and 11].

11. The early history of electricity supply and of the electrical manufacturers in Great Britain is analyzed by an economic historian in [5].

12. Von Miller's presiding over the planning and organization of the Bayernwerk and the Walchenseewerk will be found in more detail in my essay, "Oskar von Miller and the Electrification of Bavaria," [13].

13. The general problem of momentum and particularism is

discussed in [14].

14. On the origins of state regulatory authority, especially in Wisconsin, see [16].

15. This information on problem of conversion was supplied by Dr. Leslie Hannah.

16. Cost of frequency standardization was estimated in [24, 7, and 8].

REFERENCES


1. James R. Beard, "NESCo in the Very Early Days," *Nesco Magazine* (reprint (no date) in Merz and McLellan document files).

2. ________, "Their Achievement -- Our Heritage" (Institution of Electrical Engineers, 1959), in Merz and MeLellan files.

3. George Boll, *Entstehung und Entwicklung des Verbundbetriebs in der Deütschen Electrizitätswirtschaft bis zum Europäischen Verbund* (Frankfurt on Main: VWEW, 1969).

4. J. M. Burnett, "Charles H. Merz 1874-1940," in *Papers Presented at the 4th IEE Meeting on the History of Electrical Engineering*, Durham, 2-4 July 1976 (London: Institution of Electrical Engineers, 1976).

5. I. C. R. Byatt, "The British Electrical Industry," Oxford University diss., in Bodleian Library, Oxford.

6. Alfred D. Chandler, Jr. and Stephen Salsbury, "The Railroads: Innovators in Modern Business Administration," in Bruce Mazlish, ed., *The Railroad and the Space Program* (Cambridge: M.I.T. Press, 1965).

7. Electricity Council Archives, London, Minutes of Central Electricity Board, 10 January 1930, "Standardization [*sic*] of Frequency."

8. ________, "Report on the Standardization of Frequency on the System of Newcastle upon Tyne Electric Supply Company and Associated Companies."

9. *Electricity (Supply) Act, 1919*, 9 and 10 Geo. 5, Ch. 100 (London: His Majesty's Stationery Office, 1919).

10. *Electric (Supply) Act, 1926*, 16 and 17 Geo. 5, Ch. 51 (London: His Majesty's Stationery Office, 1926).

11. "Electrification of America: The Growth of Systems," paper presented at the annual meeting of Society for History of Technology, 18 October 1975, Washington, D.C.

12. T. P. Hughes, "British Electrical Industry Lag," *Technology and Culture*, Vol. 3 (1962), pp. 27-44.

13. ________, "Oskar von Miller and the Electrification of Bavaria," *Proceedings of the ICOHTEC Conference* held in Jablonna, Poland, August 1973.

14. ________, "Technology as a Force for Change in History: The Effort to Form a Unified Electric Power System in Weimar, Germany," in H. Mommsen, Dietmar Petzina, and Bernd Weisdorf, eds.,

*Industrielles System und Politisce Entwicklung in der Weimarer Republic* (Dusseldorf, Germany: Croste, 1974), pp. 153-67.

15. Wilhelm Lukas Kristl, *Der weissblaue Despot* (Munich: R. Pflaum, 1970).

16. Forest McDonald, *Let There Be Light* (Madison: American History Research Center, 1957), pp. 115-22.

17. C. H. Merz, "Electrical Power Distribution," *Engineering*, (15 September 1916), pp. 262-63.

18. Robert Nelson, "Comments," in *Proceedings at the Unveiling of a Memorial Tablet to the Late Charles Hesterman Merz, October 11, 1946* (London, Institution of Electrical Engineers).

19. John Rowland, *Progress in Power* (Merz and McLellan, 1960).

20. "Technology and Public Policy: The Failure of Giant Power," *Institute of Electrical and Electronic Engineers Proceedings*, Vol. 64 (September 1976).

21. Tennessee Valley Authority Archives, Knoxville, *Tennessee Valley Authority Act*, 48 Stat. 58 (18 May 1933).

22. UK, Board of Trade, Electric Power Supply Committee, *Electric Power Supply* (London: His Majesty's Stationery Office, 1918).

23. UK, Ministry of Reconstruction, Reconstruction Committee, Coal Conservation Subcommittee, *Interim Report on Electric Power Supply in Great Britain* (London: His Majesty's Stationery Office, 1918).

24. UK, Ministry of Transport, *Report of the Committee Appointed to Review the National Problem of the Supply of Electrical Energy* (London: His Majesty's Stationery Office, 1926).

25. Verband Bayerischer Elektrizität -- swerke e.V., eds., *Elektrizität in Bayern 1919-1969* (Munich: VBE, 1969).

26. Oskar von Miller, *Bayernwerk zur einheitlichen Versorgung des rechtsrheinischen Bayern mit Elektrizität: Projekt Oskar von Miller, February 1918: Frläuterungs-Bericht* (19 pp.) and Beilagen-Verzeichnis (31 items). Copy in library of Deutsches Museum.

27. ________, "Die Verwertung der Walchensee-Wasserkraft für ein Bayernwerk," *Electrotechnische Zeitschrift*, Vol. 37 (1916), pp. 85-89 and 102-105.

28. Walther von Miller, *Oskar von Miller Nach Eigenen Aufzeichnungen, Reden, und Briefen* (Munich: Bruckman, 1932).

29. *Vorschlage des Herrn Oskar von Miller in München über den Ausbau und die Verwertung der Walchenseekraft an das Hohe Königl. Bayer. Staats ministerium des Innern* (Munich, 9 October 1915) Copy in library of Deutsches Museum, Munich.

30. C. Zell, "Das Bayernwerk," *Elektrotechnische Zeitschrift*, Vol. 39 (1918).