The Bary Curve

500 kilowatts but including a few as low as 100 kilowatts, and averaging around 2,500 kilowatts.

Traction covers the individualized supplies of 60 cycle polyphase and 25 cycle single or polyphase services at high tension voltages to electrified railways and railroad systems.

Street Lighting covers the individualized supply of service for street illumination of a series or multiple type, where the utility either owns or does not own the utilization facilities.

Sales to Other Electric Utilities covers individualized firm service supplies from the bulk transmission system to neighboring utilities for resale.

Interdepartmental Use covers the supply of service to other departments of the utility.

The basic determinants of classification in this model of the load structure are (a) the physical character, that is, voltage level, of service supply and (b) the general nature for which the service is used. Accounting and rate classifications are made to fit the structure of this model, rather than the other way around.

EMPIRICAL RELATIONS

The quest for knowledge and understanding of the behavior of the load structure cannot stop with the class loads. To understand the behavior of the class, it is necessary to understand what goes on within it. To obtain that knowledge, means must be found for establishing for each general class the probable trends that are going on in the load behavior of its individual elements, arranged in groups according to the significant controlling characteristic under which the particular class is administered in the utility's operations.

There are two such controlling characteristics of significance on a modern electric utility system: the individual customers' energy use; and, the individual customers' monthly load factors by billing demand intervals. The former applies in our model primarily to customers of the residential class, the latter, to the manufacturing and nonmanufacturing classes.

Energy versus Diversified Demands. Figure 11 depicts relationships between customers' annual energy use and their diversified maximum demands for average weekdays around the peak period of the residential class (more fully defined at the end of this chapter). The quantitative significance of these

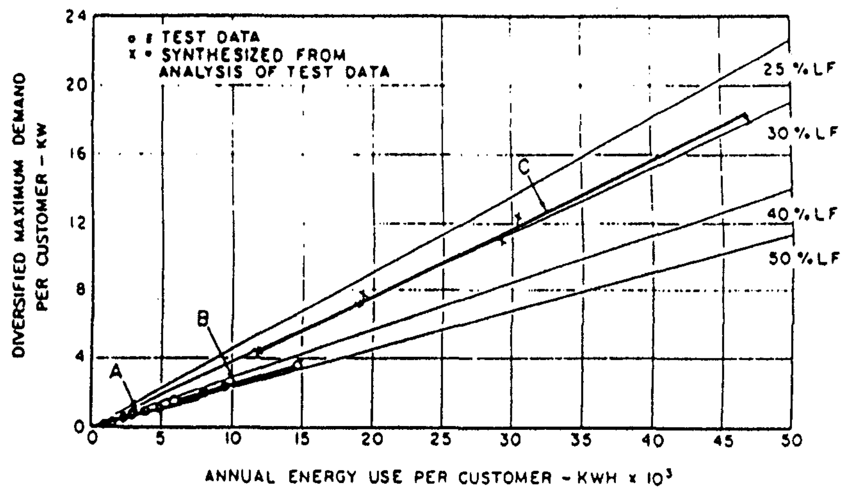

Figure 11. Illustrative relationship of energy uses *versus* average weekday diversified maximum demands of residential customers
A. "Base use" comprising lighting and miscellaneous appliances
B. "Base use" plus electric cooking and water heating (uncontrolled)
C. "All-electric home" (reflecting B plus electric cooling and heating)

relationships is constantly undergoing changes, and undoubtedly will continue to do so in the future. It, thus, behooves us *to be alert to any significant changes in these relationships.* One such change looms over the horizon: studies indicate that by projecting data into the conditions of an all-electric home, which would include electric space heating and air conditioning (under uncontrolled methods of operation), the energy *versus* group demand relationship, shown in Figure 11, will not only move into a much higher energy and diversified maximum demand region, but at the same time, into a band of much lower annual load factors than is obtained now with the load of a full-use home, before the introduction of electricity for the performance of the heating and cooling jobs.

Coincidence Factors versus Load Factors. Figure 12 depicts an empirical relationship between group coincidence

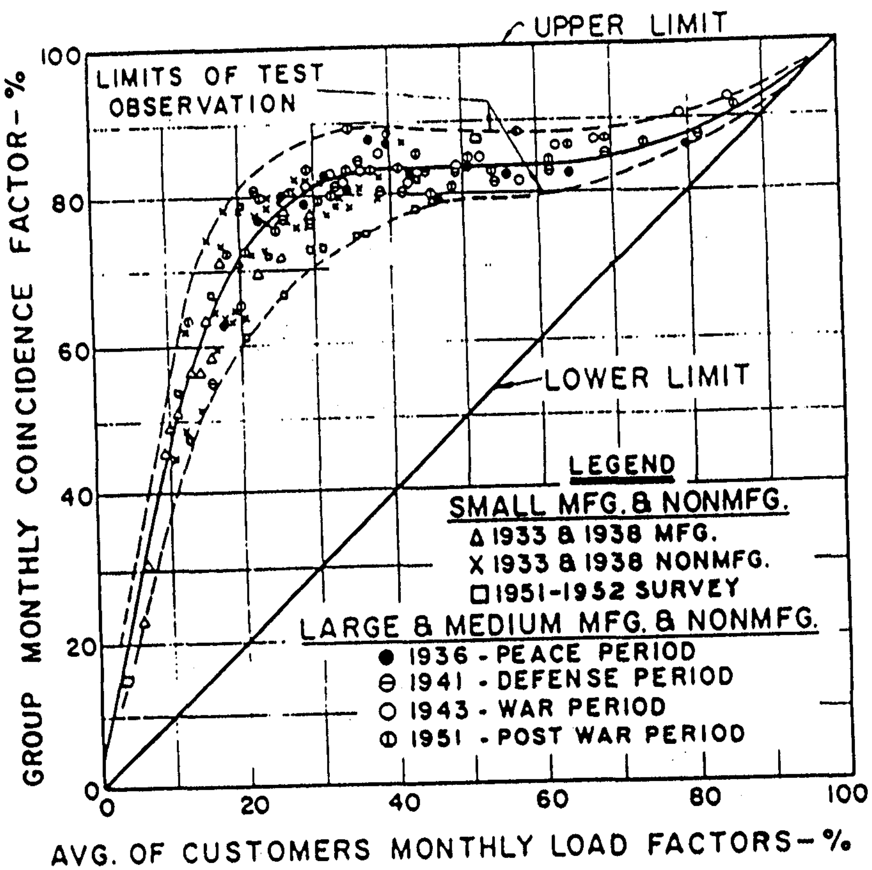

Figure 12. Empirical relationship between coincidence factors and load factors—based on integrated 30-minute demands in December for groups of 30 customers

factors for customers of the manufacturing and nonmanufacturing classes and individual customers' monthly load factors. This relationship and its underlying theory have been described in detail by me in 1945[2] and were first outlined in my 1937 presentation to the Association of Edison Illuminating Com-

[2]Constantine W. Bary, "Coincidence-Factor Relationships of Electric Service Load Characteristics," *AIEE Transactions*, LXIV (1945), 623.

panies (AEIC).[3] It has been studied in a thorough manner and verified first in 1939 by a subcommittee, F. M. Terry chairman, of the Special Committee on Load Studies of AEIC,[4] and then again in 1952 by a subcommittee, B. P. Dahlstrom chairman, of the Load Research Committee of AEIC.[5] H. E. Eisenmenger rationalized and verified the shape of the empirical curve in a classical manner, from mathematical considerations, in his 1939 paper before the 55th Annual Meeting of AEIC.[6] It has become known as the Second Law of Load Diversity,[7] or the "Bary" curve. It provides conveniently the means for obtaining the probable diversified maximum demands per customer for a given set of customers' monthly energy uses and their noncoincident maximum demands, which are the necessary ingredients for computing customers' load factors.

It will be noted from the actual test data shown, that over nearly two decades of observations, covering pre-war, defense, war, and post-war conditions, the probable average relationship of test observations remain unaltered.

(Recently completed studies of 1961 data on load patterns of customers of the manufacturing and nonmanufacturing class, which resulted in 118 test-observations spread over a wide range of monthly load factors, again substantiate the qualitative and quantitative nature of the relationship between monthly coincidence factors and load factors established for the month

[3]Constantine W. Bary, "Economic Significance of Load Characteristics as Applied to Modern Electric Service," Minutes, 53d Annual Meeting (New York, Association of Edison Illuminating Companies, 1937, unpublished).

[4]"Report of Subcommittee on Coincidence Factors of the Special Committee on Load Studies of the AEIC," Minutes, 55th and 56th Annual Meetings (New York, Association of Edison Illuminating Companies, 1939 and 1940, unpublished).

[5]"Report of General Subcommittee on Nonmanufacturing and Manufacturing Customers of Load Research Committee of the AEIC," Minutes, 69th Annual Meeting (New York, Association of Edison Illuminating Companies, 1953, unpublished).

[6]H. E. Eisenmenger, "Study of the Theoretical Relationship between Load Factor and Diversity Factor," Minutes, 55th Annual Meeting (New York, Association of Edison Illuminating Companies, 1939, unpublished).

[7]The first law of load diversity is the relationship which exists between group coincidence factors and the number of customers in the group, described in my 1945 AIEE paper (see footnote 2).

of December. From a recent compilation of equally comprehensive data for customers of this class for the 1961 summer period, a similar relationship has been established for the warmest month which reflects heavy use of air conditioning equipment. The qualitative nature and the quantitative magnitudes of this relationship are virtually the same as for the month of December, and the new test-observations follow the patterns of dispersion outlined by the limits of observation shown in Figure 12.)

This relationship can be considered, therefore, as of a fundamental nature in the general behavior of electric loads. But being of an empirical nature the following qualifications must be kept in mind:

1. It is an empirical relationship and is based on the conditions and experience of one utility system supplying a given community. Other communities with different population habits, different definition as to what constitutes a class of service, different weather and other climatic conditions, may differ in the actual magnitudes of the coincidence factors shown throughout the entire load-factor range.

2. The relationship is confined to consumers of substantially the same size, taking the same class of service, operating at the same load factors, and always taken in sufficient numbers for each type, size, and load factor to produce representative results on a coincidence factor of the group. It is obvious that, unless these qualifications are observed fully, different coincidence factors may be obtained.

3. The coincidence factors obtained from Figure 12 are those for individual consumers within a group applied to monthly conditions. There will be additional coincidence factors between different groups of any one class of service, for longer periods than a month, and between different classes of service of a system.

INTERGROUP AND INTERCLASS COINCIDENCE FACTORS

Experience with the two probable relationships just described has shown that no matter which of the controlling characteristics is used for arranging individual load elements by groups, the major effects of load diversity within a general class are captured and retained in the load characteristics of the groups, whether they be expressed in terms of diversified maximum demands or group coincidence factors. But it is known that additional effects of load diversity exist between groups of a given class and between classes. Their measures are called "intergroup," and "interclass" coincidence factors, respectively. Table 2 provides an indication of the general magnitudes of the intergroup, and interclass coincidence factors obtained on the illustrative utility system.

TABLE 2. ILLUSTRATIVE INTERGROUP AND INTERCLASS COINCIDENCE FACTORS

Intergroup	
Between all groups of present-day residential customers (without ranges and water heaters)	0.98
Between all groups of present-day residential customers (with ranges)	0.99
Between all groups of present-day residential customers	0.96
Interclass	
Between two classes at secondary voltage level	0.99
Between four classes at primary voltage level	0.92
Between all eight classes at production system level	0.87

The establishment of probable trend relationships between certain parameters of load characteristics at the group level of the load model is susceptible to actual determination through the statistical method of averages, because of the large mass of individual elements which can react to the laws of chance. But at other levels of the model, say that of the classes, there are so few individual things to be dealt with that, from mathematical considerations, they cannot produce trend relationships, but only individualized spot values.

Distribution of Load Diversity Benefits. Obviously, the establishment of any classification carries with it the implications regarding the applicability of load diversity benefits which exist on a modern electric utility. Much has been written on this subject in terms of the allocation of demand-related costs of an electric utility enterprise. An excellent critical résumé by P. Schiller of the better-known methods is contained in the 1943 Technical Report K/T 106 of the British Electrical and Allied Industries Research Association,[8] and an "Im-

[8] P. Schiller, "Methods of Allocating to Classes of Consumers or Load the Demand-Related Portion of the Standing Costs of Electricity Supply," Technical Report Reference K/T 106 (London, The British Electrical and Allied Industries Research Association, 1943).