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A Data Base for Simulating Electrical System Growth

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MASTER OF ARCHITECTURE

A DATA BASE FOR SIMULATING
ELECTRICAL SYSTEM GROWTH

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A DATA BASE FOR SIMULATING ELECTRICAL SYSTEM GROWTH

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B.A., Boston University, 1969

THESIS

Submitted in Partial Fulfillment of the
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A DATA BASE FOR SIMULATING
ELECTRICAL SYSTEM GROWTH

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Franklin Marshall Fine

ABSTRACT OF THESIS

Submitted in Partial Fulfillment of the
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ABSTRACT

The thesis describes and discusses the methodology developed and used by the author for producing an input load data base for the Westinghouse Distribution System Planning Program (DSP), a computer simulation model for planning electrical subtransmission and distribution systems. The Public Service Company of New Mexico's electrical system in Albuquerque is first described as is the DSP model. The methodology used is then discussed: first the estimating procedures for establishing the base year load, and then the techniques used for projecting future load. Possible improvements in these methods are offered and the ultimate limitations of such a data base are discussed.

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ABBREVIATIONS

BLA - Basic Load Area

COG - Middle Rio Grande Council of Governments

DAD - Data Analysis District

DASZ - Data Analysis Sub-Zone

DAZ - Data Analysis Zone

DSP - Distribution System Planning Program

KV - Kilovolt

KVA - Kilovoltampere

KW - Kilowatt

KWH - Kilowatthour

MVA - Megavoltampere

MW - Megawatt

MWH - Megawatthour

SIC - Standard Industrial Classification

INTRODUCTION

This thesis is concerned with the problems of developing a data base to be used for a computer simulation model. It describes a methodology and its application used to transform raw data into useable input data. It deals with the electrical subtransmission and distribution system in Albuquerque, New Mexico.

The simulation model, called The Westinghouse Distribution System Planning Program (DSP), is an attempt to integrate the planning, programming and budgeting functions of an electric utility company into a well designed process. It is a cost sensitive simulation model for electrical subtransmission and distribution systems. The user develops a data base from which DSP simulates system growth. The data base includes a description of the existing electrical system, the operating practices of that system, the policies for its expansion, the costs of expanding or reinforcing the various components of the system, scheduled expansions, a description of the existing load on the system by small geographical areas (one quarter square mile) called Basic Load Areas (BLAs), and projections for the expansion of that load for up to 20 years. The program, then, determines the most efficient expansion of the system one year at a time.

DSP is being developed by the Advanced Systems Technology Department of the Westinghouse Electric Corporation Power Systems Company. Development began in 1962, and DSP was first marketed in 1972 on an experimental basis. It remains in the development stage.

In 1973, the management of Public Service Company of New Mexico decided to include DSP in its planning process for its Albuquerque Division on a trial basis. In doing so, it became the first American company to attempt to use this Westinghouse service. The only other users at that time were smaller Canadian utilities having less complex distribution systems.

1972 was designated as the base year for data collection and is the same as the DSP year one. Since the Public Service Company plans a 10 year program, it was decided to run DSP through 1984, or for 13 study years.

The data base required is both large and complex.[1] Public Service Company's execution of the model in summer, 1974, represented the culmination of nine months of designing a data base system, collecting data, and synthesizing it into an input data base meeting the rigid requirements of DSP. It is the first attempt at developing a system from which to develop a comprehensive DSP data base. Most of that effort, including all that is the subject of this thesis, was done by or under the direction of the author.

It is the purpose of this thesis to describe the method and process developed by the author to assemble certain

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[1]Typical computer runs of DSP require 565K core on an IBM 370 system, or over twice the size of the largest user available partition in the University of New Mexico's 2000K core system.

portions of that data base, namely the load data. The load data consists of the load base (a description of the existing load) and load projections. This data was developed for the service area of the Albuquerque Division: the metropolitan Albuquerque area including the East Mountains area of Bernalillo County, the far North and South Valleys, Rio Ranchos and Corrales. This thesis does not attempt to analyze or make comment about DSP itself, or the role it may or may not play in the electric utility's planning process. The author is concerned with the data base for DSP, not the simulation model itself.

It is hoped that this thesis will serve as a manual and provide a framework for future users of DSP, both with Public Service Company of N.M. and with other electric utilities, for the development of sound and comprehensive data bases.

The thesis is in three parts. Part I gives the necessary background information for an understanding of the DSP data base and its formation. Chapter One offers an overview of an electrical system, measuring electric power and some of the quantitative tools used in electrical system planning. Certain aspects of the electrical system have been purposely simplified so that all material should be clear to the layman with no training in electricity or electrical engineering.

Chapter Two gives an overview to DSP, its data requirements and the method the model uses for its system expansion.

Part II describes the methods used for development of the two parts of the load data. Chapter Three describes the processes used for developing the load base - first for commercial and industrial customers, and then for residential customers. Chapter Four is concerned with developing land use projections and relating them to the load base.

Part III looks at the status of putting together a DSP data base. Chapter Five looks at techniques that can be used to improve the residential demand estimates. Chapter Six sets forth a possible systems approach to establishing the load base and then discusses the limitations in the data base.

PART I

Part I provides the necessary background information for an understanding of the DSP data base and its formation. There are two chapters, the first providing a general description of an electrical subtransmission and distribution system and methods used in its planning, the second providing a description of the Westinghouse Distribution System Planning Program for which the load base is to be developed.

CHAPTER 1

AN ANATOMY OF ELECTRICAL DISTRIBUTION PLANNING

This chapter gives background information concerning electrical system planning. It first describes a typical electrical system, looking at the system in Albuquerque, New Mexico. It then defines kilowatthour consumption and kilowatt demand. The last section describes some of the tools used in analyzing the load on electrical systems. These tools will be referred to in the sections concerned with developing the load base.

The Electrical System

Most of the electrical power used in the Albuquerque area is generated in the Four Corners area of northwestern New Mexico. From there it is transmitted at 345,000 volts (345 kilovolts) to the West Mesa switching station or bulk station just northwest of the I-40, Coors Road interchange (Figure 1). Transformers at this station reduce the voltage to 115 kilovolts. From there the current is sent over transmission lines to six additional switching stations, four of which form a loop around the city. The remaining two are on spurs going into the city.

Each of the six switching stations contain transformers and voltage maintenance equipment. From them go subtransmission lines at either 115 KV (kilovolts) or 46 KV to some

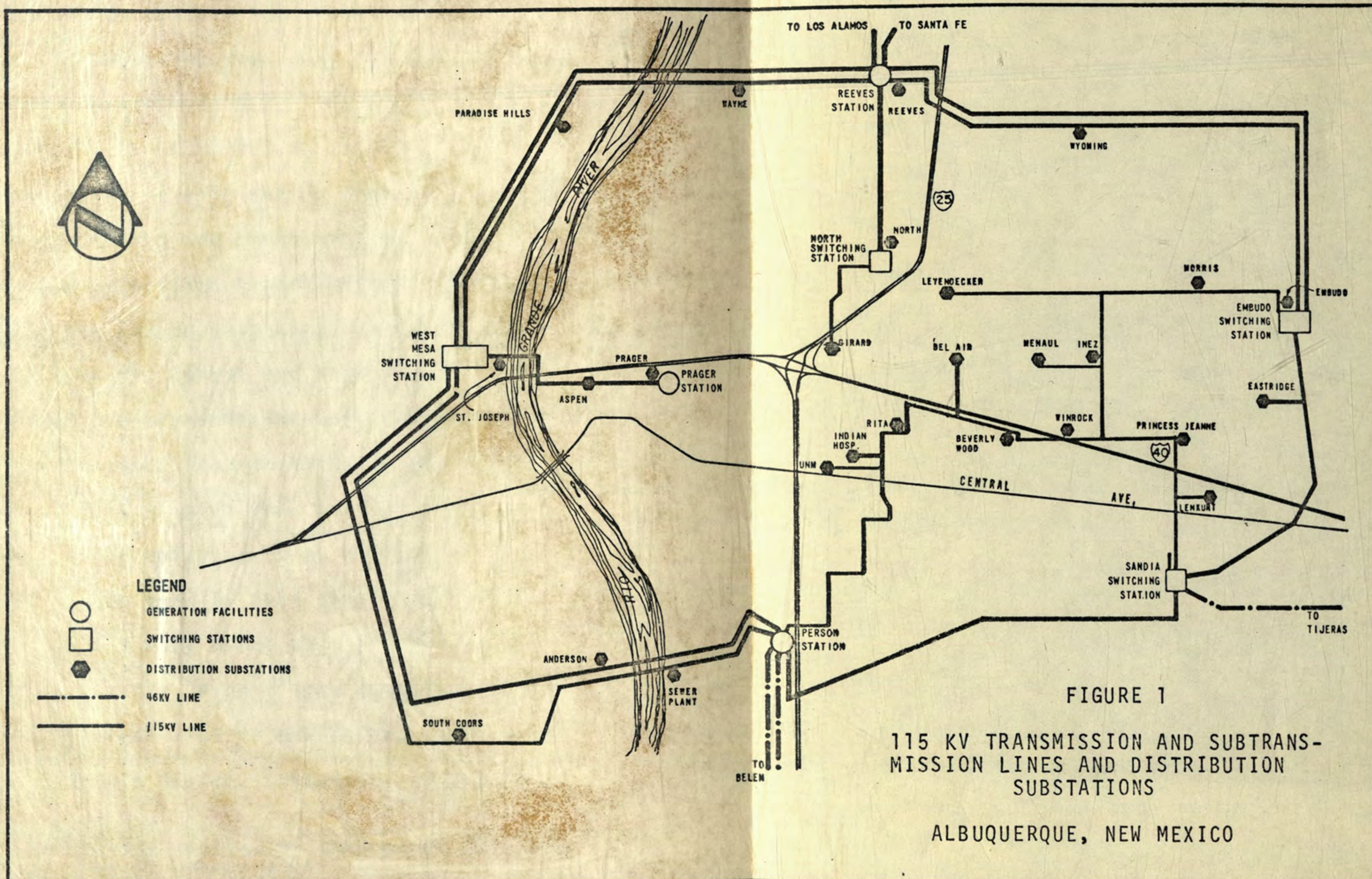

FIGURE 1

115 KV TRANSMISSION AND SUBTRANSMISSION LINES AND DISTRIBUTION SUBSTATIONS

ALBUQUERQUE, NEW MEXICO

60 distribution substations scattered throughout the service area (Figure 2).

These substations serve as the nucleus of the neighborhood electrical distribution system. Each of them contains transformers reducing the voltage to 12,470 volts, or, in some cases, to 4,160 volts. One such substation is Princess Jeanne substation located near the intersection of Constitution Ave. and Eubank Blvd. N.E. (Figure 2; it can also be found in Figure 1).[1] It is served on its high side by a 115 KV subtransmission line originating from the south at the Sandia switching station and continuing past the Princess Jeanne substation tying into several other substations and eventually reaching the Embudo switching station in the far Northeast Heights. As the Embudo and Sandia bulk stations are connected as part of the transmission loop previously mentioned, we now have an inner loop on which is the Princess Jeanne substation. This is a common configuration for a subtransmission network, often referred to as a loop system.

It is designed to meet single contingency failure criteria. This simply means that the system will be able to continue operating even if one component such as a subtransmission line goes out of operation, or is down. In the case of the Princess Jeanne substation, if the line is cut between

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[1]To provide continuity throughout the paper in the examples cited, reference will usually be made to the Princess Jeanne substation. This station, located in the Northeast Heights, is fairly typical of the stations used by the Public Service Company of New Mexico.

FIGURE 2

THE PRINCESS JEANNE DISTRIBUTION SUBSTATION it and the Sandia substation, it can be alternatively served with power from the Embudo substation.

From the low side of the substation go up to four feeders (at 12.47 KV from the Princess Jeanne substation). These feeders are the distribution system, sometimes referred to as primary distribution. Most of these can be seen going from pole to pole throughout the city, although much new construction of primary circuits are buried underground. These feeders go to small transformers that are cylindrical shaped containers that hang on poles (Figure 3), or for underground circuits, are usually box shaped and located on concrete padmounts (Figure 4). The distribution network for the Princess Jeanne substation can be seen in Figure 5.

These distribution transformers once again reduce the voltage, this time to the voltage level with which individual customers are served. For residential customers this would be 110 volts and 220 volts. From these transformers go secondary distribution circuits from which the individual residences or businesses are served.

Electrical Demand and Consumption

There are two different although related types of units used for measuring electricity in designing or planning for the various components of the electrical system. One is kilowatt hours (KWH). Most people are at least nominally familiar with KWH as that is what is measured by the meters on virtually all homes and most businesses. It is a

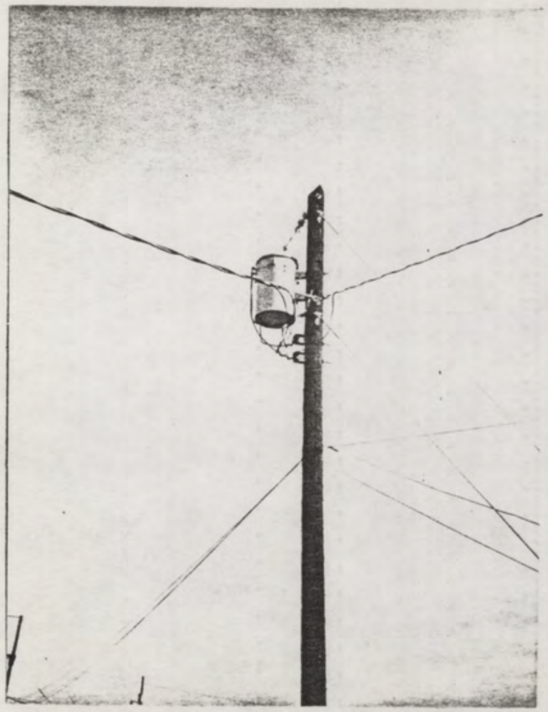

FIGURE 3

A TYPICAL OVERHEAD
DISTRIBUTION TRANSFORMER

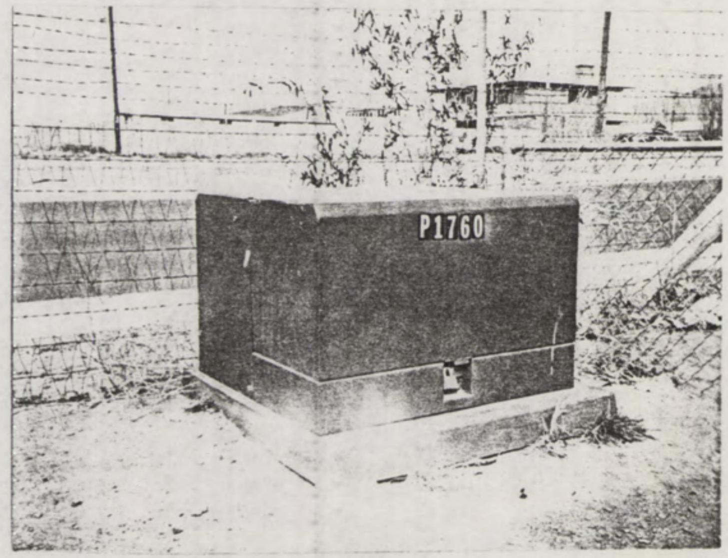

FIGURE 4

A TYPICAL PADMOUNT
DISTRIBUTION TRANSFORMER

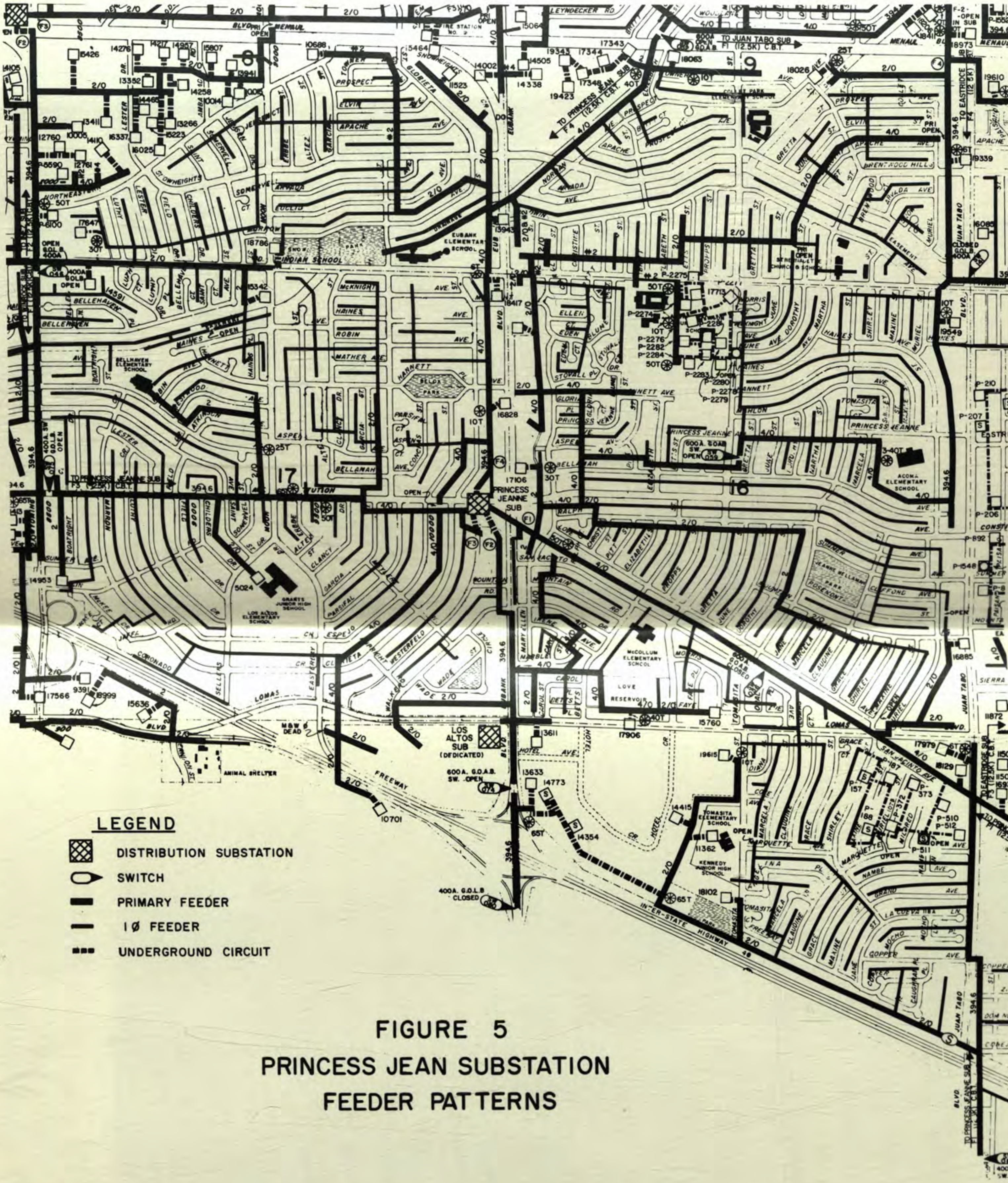

FIGURE 5
PRINCESS JEAN SUBSTATION
FEEDER PATTERNS

measurement of the consumption of electricity. Electric companies sell kilowatt hours.

To measure the KWH consumption of an electrical appliance, simply multiply its rating in watts times the length of time it is in use divided by 1000. For instance, a 75 watt light bulb that is on for 8 hours uses:

75 Watts x 8 hours = 600 watt hours = .6 KWH.

KWH, or the larger unit of megawatt hours (MWH) is used to plan how much electricity must be generated, as that is what is ultimately consumed.

The watts or kilowatts themselves represent the instantaneous load or demand. It can be thought of as the rate at which electricity is being demanded or delivered. It thus represents the amount of electricity at or passing through any component of an electrical system at an instant of time. The capacity of all systems components is measured in kilowatts. If its rated capacity is significantly exceeded, the component will most likely be damaged by the overload.

This dual measuring system of KWH and KW presents an interesting corporate planning problem. Most customers are billed according to their KWH consumption. Only the largest users are also billed for their KW demand. Thus system revenues are based upon KWH sales yet system design is based upon the highest KW demand anticipated. The relationship between these two parameters is discussed next.

Tools in System Load Analysis

LOAD FACTORS are quantitative relationships between KW and KWH. A load factor is a number between 0 and 1 inclusive representing a ratio of KWH to KW adjusted for time. One formula that can be used for calculating a load factor is

$$L.F. = \frac{KWH}{\text{peak KW x hours}} \quad (1)$$

where KWH is metered for the time period designated as hours in the denominator, and peak KW represents the highest KW demand experienced during that time period.

A load factor can tell us something about the regularity of a user's KWH consumption. Let us compare two hypothetical residential customers. One of them has a household member home most of the day who washes clothes and dishes, cooks, and perhaps has a television on between chores. At our second home, no one is home until returning from work in the late afternoon. Suddenly, all the electric appliances are going at once: washing, cooking, heating water, cooling air, etc. Both of these homes may have the same KWH consumption, but the second home, with all of its appliances operating at once, had a much higher peak KW demand. Thus the latter will have a lower load factor. And while both customers pay for the same KWH consumption, the second home requires more capacity from the electrical system.

In order to determine the load on a particular system component, all of the individual loads that contribute to it must be considered. For instance the load on the Princess

Jeanne Substation Feeder Number Two may comprise 1000 different customers. Perhaps 900 of them are residential customers and the remaining are commercial customers. (Apartment buildings in which different units are metered together, so called master metered apartments, are considered commercial customers.) It may appear that by summing the loads for each customer we could arrive at a feeder peak, but this is not the case. For different types of customers experience their respective peaks at varying times during the day. A residential customer will typically reach his peak in late afternoon or early evening, an office building during the day and a movie theatre in the evening.

In order to estimate the COINCIDENT PEAK for a group of heterogeneous customers, LOAD PROFILES are developed for different groups of similar customers. A load profile graphically displays a typical customer's demand throughout the day in relationship to his peak demand. The abscissa is labeled with the time of the day from midnight to midnight and the ordinate represents percentages of peak demand. The highest point of the curve will necessarily be at exactly 100% and at the time of peak demand. Figure 6 illustrates three such curves.[2]

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[2]The reader should note that the load profiles in Figure 6 are labeled "summer." Patterns in electrical demand change seasonally. Winter peaks usually are related to early evening lighting while summer peaks are largely due to mid-afternoon air conditioning. In Albuquerque the summer peak is higher than the winter peak and we will accordingly limit our concern to summer conditions.

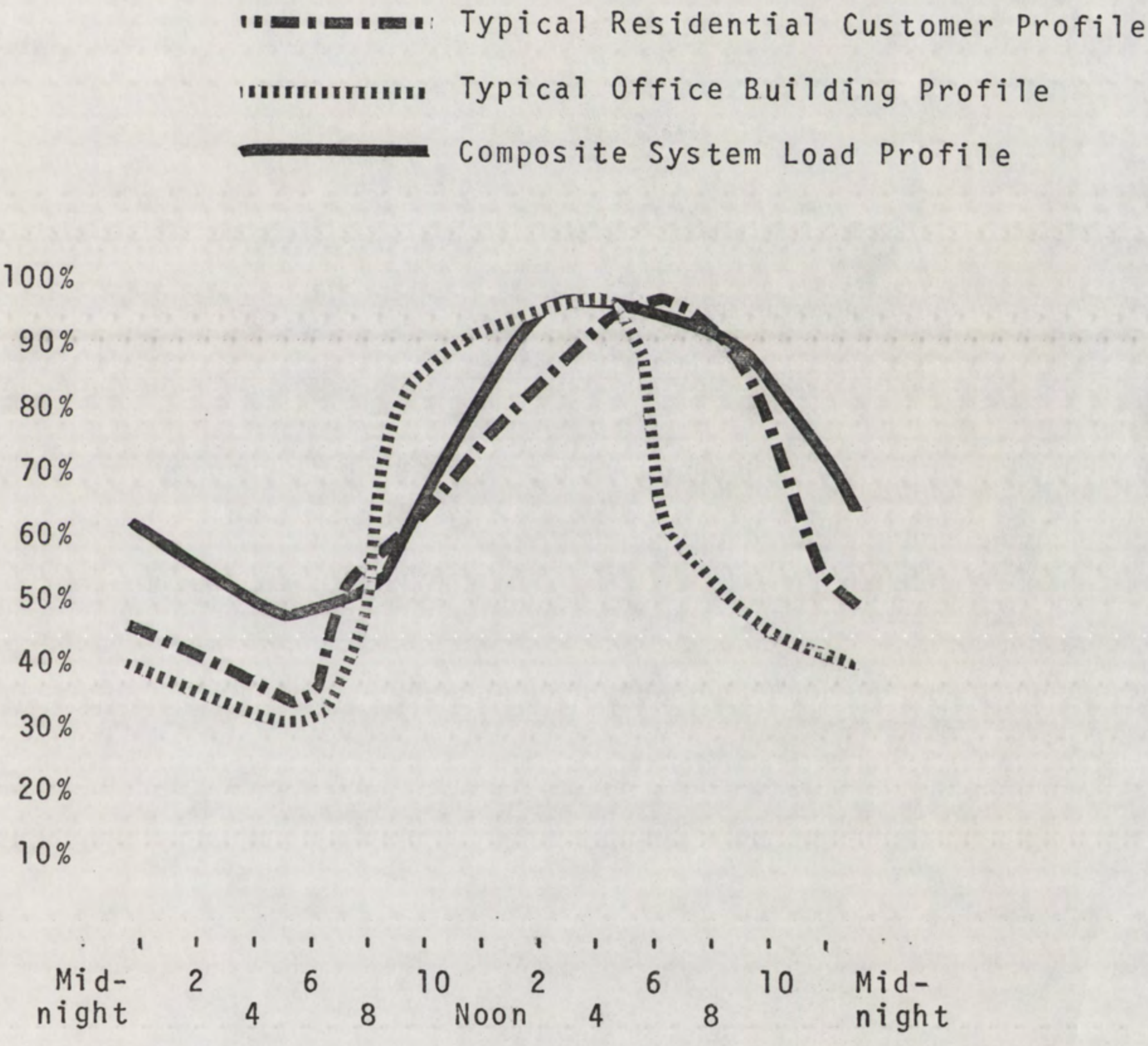

FIGURE 6

TYPICAL LOAD PROFILES - SUMMER

If we know the time of peak for the system or that portion of the system which we are examining, we can determine the COINCIDENCE FACTOR for a group of customers from their load profile. For instance, if peak is at 3:00 P.M., we can see looking at Figure 6 that the office customer is also at peak at that time and therefore has a coincidence factor of 100%, or 1.0. The residential customer, on the other hand, does not peak until about 6:00, and his demand at 3:00 is about 75% of his peak demand at 6:00. Thus his coincidence factor is .75. Thus when computing the load on the feeder in question or any other system component, one would multiply the residential customers' loads by .75 before adding them to the other loads on the feeder. And, of course, all other customer loads would have to be treated similarly.

While coincidence factors account for differences in load profiles between different types of customers, DIVERSITY FACTORS account for differences between load profiles of customers of the same type. For example we can look at the two hypothetical residential customers we examined earlier in this section. While the first customer, who performed household chores during the day, may peak in mid-afternoon, the second customer would peak about 6:00 upon coming home from work. Here we can determine a diversity factor by taking a sample of customers within a particular group (say residential customers) and measure their demands at different times during the day. Let us suppose that we have a group of five customers as in Table 1. We shall look at those times during the day that we would expect a peak to occur.[3] We can sum the demands at each time to determine the group's peak load and its time. We can then sum the individual peaks and divide this number into the group peak to get a diversity factor.

The calculated diversity factor can then be multiplied times the individual peak for each customer within a particular customer class. These DIVERSIFIED DEMANDS can then be summed to produce an estimated peak demand for that particular group of customers.

In this chapter we have described the major components of an electrical system and their relationship to each other, how power is measured, and a few of the tools used for analyzing electrical demand. These will all be called upon as we see how the DSP data base is set up. But first, Chapter Two will give an overview of what DSP is and what it does.

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[3]When actually metering customers for sampling purposes, demands are recorded and computed for every 15 minutes.

KW DEMAND AT

	NOON	2:00	4:00	6:00	8:00	PEAK	AT
CUSTOMER 1	.60	.58	.72	.90	.85	.90	6:00
CUSTOMER 2	1.42	1.42	1.42	1.68	1.56	1.68	6:00
CUSTOMER 3	.80	1.12	1.23	1.09	.95	1.23	4:00
CUSTOMER 4	.75	.80	.95	.85	1.03	1.03	8:00
CUSTOMER 5	1.50	1.60	1.65	1.78	1.75	1.78	6:00
	5.07	5.52	5.97	6.30 (1)	6.14	6.62 (2)	

(1) DIVERSIFIED PEAK IS 6.30 KW AT 6:00 P.M.

(2) SUM OF THE INDIVIDUAL PEAKS IS 6.62

THE DIVERSITY FACTOR IS 6.30 ÷ 6.62 = .95

(ALL DATA IS HYPOTHETICAL FOR ILLUSTRATIVE PURPOSES ONLY.)

TABLE 1

COMPUTING A DIVERSITY FACTOR

CHAPTER 2

AN ANATOMY OF DSP AND THE INPUT DATA

The first section of Chapter One described in a broad sense the nature of an electrical subtransmission and distribution system (Figures 1 and 5). DSP is concerned with a portion of that system: the switching stations, subtransmission lines, distribution substations and the primary feeders. In this chapter we shall examine the two parts of the input data required of the user: the system parameters and the load data. Then we shall see how DSP expands the system.

The Input Model - The System Parameters

The input model consists of all the data the computer program needs to operate successfully. First, the system parameters are outlined. The type of equipment used throughout the system and the operating voltage levels are established. Different types of feeders, substations, subtransmission circuits and switching stations are described. And the basic load area (BLA) grid dimensions are defined (one such BLA is outlined in Figure 12). DSP will use this data to simulate the system and later on, to simulate its expansion.

A complete description of each component of the existing system in the base year (1972) is made. Each substation is identified by name and number, located on the BLA grid and associated with a type number as described below. The feeders going out from each substation are likewise associated with a feeder type. The feeder configurations themselves are not described as the program simulates feeder patterns to serve most efficiently the load assigned to each substation.

There are 21 different types of substations and switching stations described in the input model. One such description, for Substation Type 2, can be seen in Figure 7. In this figure 18 different data items are listed, plus a description of the possible "Capacity Expansion Steps" available for a substation of this type. Several of the data items are coded references to other data input items. For instance "Feeder Type Number" 1 refers to the Feeder Type Data Table (Figure 8). Here we see that Feeder Type Code 1 refers to an overhead feeder (OH) with a 5.00 MVA capacity. (MVA, megavoltampere, is a measuring unit akin to, but not exactly equal to, megawatts).

The Princess Jeanne Substation is a Type 2 Substation. Various characteristics of it are described in Figure 9. It is located at BLA 76-58, the X and Y coordinates of the BLA at which we find the substation. The "Initial Bus Type" is a designation of the configuration of the subtransmission lines serving the substation. "Capacity Expansion Step" Number 4 shows that the station configuration is initially that described on the line for Step 4 in Figure 7: 4 feeders allowed, with a total firm MVA capacity of 16.00. Other data inputs in the substation description include Spot Loads, to

FIGURE 7

DISTRIBUTION SUBSTATION TYPE 2

NO. OF CAPACITY EXPANSION STEPS	MAXIMUM SUBTRAN CIRCUIT TERM.	FEEDER TYPE NUMBER	FEEDER REG. CODE	FEEDER VOLTAGE CONTROL CODE	MAXIMUM LINE REG. PER FEEDER	NOMINAL LOW VOLTAGE (KV)	NOMINAL HIGH VOLTAGE (KV)
4	1	1	2	1	0	12.470	115.000

NEW SUBSTA LAND COST $/1000	COST OF FEEDER POSITION ADDITION $/1000	COST OF ASSOCIATED EQUIP. FOR ADDITIONAL CAPACITORS $/1000	COST/MVAR CAPACITOR INSTALLED ON BUS $ /1000	COST OF SUBTRAN CIRCUIT TERMINAL $ /1000	MIN. PU VOLTAGE L-V BUS SYS PEAK LOAD	BUS REGULATOR RAISE WHEN ADDED PER UNIT
1.0	0.0	0.0	0.0	17.0	1.040	0.006

IF S(T)-D SUBSTATION

CONVERSION CAPITAL INVEST. $/1000	CONVERSION NON-CAP COST $/1000	FIRM MVA T-D AFTER CONV.
0.0	0.0	0.0

CAPACITY EXPANSION STEPS

EXPANSION STEP NUMBER	MAXIMUM FEEDERS ALLOWED	H-V BUS TYPE	FIRM CAPACITY MVA	NEW CAPITAL INVEST. $ /1000	NEW BUS REGULATOR COST $ /1000	P.U. IMPEDANCE ON SYSTEM BASE R	P.U. IMPEDANCE ON SYSTEM BASE X	NO LOAD LOSS KW	MAGNETIZING KVAR
1	2	DD	9.00	226.4	0.0	0.0	0.660	19.4	174.7
2	3	DD	9.00	0.0	0.0	0.0	0.660	19.4	174.7
3	4	DD	12.00	1.6	0.0	0.0	0.660	19.4	174.7
4	4	DD	16.00	4.2	0.0	0.0	0.660	19.4	174.7

FIGURE 8

FEEDER TYPE DATA

EXT. TYPE CODE	NORMAL MVA CAPCITY	CKT. COST NOT INCL. GETAWY CABL $/FOOT	GET-AWAY CABLE $/FOOT	FEEDER CAPACITOR COST/MVAR $/1000	FEEDER REG. COST $/1000	P.U. FEEDER REGUL. RAISE	FEEDER EXPRESS CIRCUIT OHMS/1000FT R	FEEDER EXPRESS CIRCUIT OHMS/1000FT X	FEEDER LATERAL CIRCUIT OHMS/1000FT R	FEEDER LATERAL CIRCUIT OHMS/1000FT X	MAX. PWR. FACTOR-FEEDER LOAD RELIEF PER UNIT
1 OH	5.00	3.3	10.0	11.0	0.0	0.0	0.045	0.111	0.045	0.111	1.000
2 OH	1.50	3.3	10.0	11.0	0.0	0.0	0.045	0.111	0.045	0.111	1.000
3 UG	5.00	5.0	0.0	11.0	0.0	0.0	0.055	0.058	0.055	0.058	1.000
4 OH	4.00	3.3	10.0	11.0	0.0	0.0	0.045	0.111	0.045	0.111	1.000
5 OH	2.50	2.3	10.0	11.0	0.0	0.0	0.134	0.147	0.134	0.147	1.000
6 OH	1.00	2.3	10.0	11.0	0.0	0.0	0.134	0.147	0.134	0.147	1.000
7 OH	3.00	2.3	10.0	11.0	0.0	0.0	0.134	0.147	0.134	0.147	1.000
8 OH	1.00	2.0	10.0	11.0	0.0	0.0	0.267	0.151	0.267	0.151	1.000
9 OH	4.00	3.3	10.0	11.0	0.0	0.0	0.045	0.058	0.045	0.058	1.000
10 OH	3.00	3.3	10.0	11.0	0.0	0.0	0.045	0.058	0.045	0.058	1.000
11 UG	5.00	5.0	0.0	11.0	0.0	0.0	0.055	0.058	0.055	0.058	1.000

FIGURE 9

DESCRIPTION FOR
PRINCESS J. SUBSTATION NUMBER 540

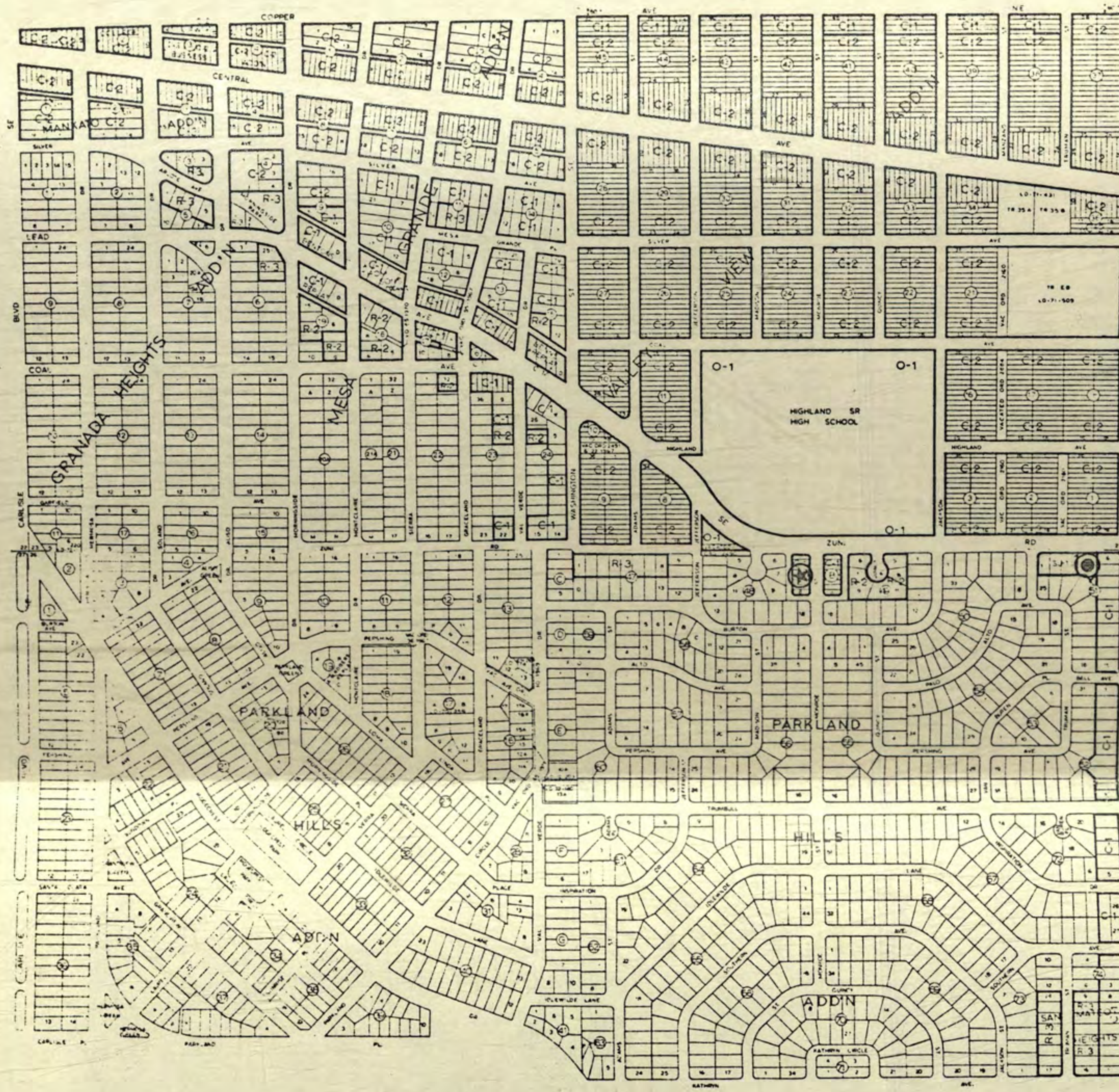
```
DESCRIPTION OF SUBSTATION                                            LOCATION
************************                                              76    58
                                                                ************************
NUMBER OF SUBTRANSMISSION CIRCUIT TERMINATIONS           2
NUMBER OF LINE REGULATORS ON FEEDERS                     0             SUB AREA NO.
PEAK LOAD VALUES                                                            1
  A) ACTUAL MW LOAD                                  12.70      ************************
  B) ACTUAL MVAR LOAD                                 5.00
CAPACITY EXPANSION STEP NUMBER                           4            SUBSTATION TYPE
MVAR OF CAPACITORS ON BUS                              0.0                  2
  -    -      -       -  FEEDER                        2.5      ************************
BUS REGULATOR RANGE P.U. RAISE                         0.1
FIXED TAP P.U.                                       0.0            SUBSTATION FUNCTION
T-D/S(T)-D SUBST. HIGH SIDE VOLTAGE                  0.0                   0
SPOT LOAD DATA                                                  ************************
  A) LOAD CLASS                                          0
  B) POWER FACTOR                                      0.0      HIGH VOLTAGE BUS NUMBER
  C) NETWORK LOAD FEEDER LOADING P.U.                  0.0                54
TYPE OF NEW SUBST. BUILT TO RELIEVE THIS SUB             2      ************************
NEW SUBST. FUNCTION CODE                                 0
SUBAREA FOR NEW SUBST. BEFORE CONV.                      1           INITIAL BUS TYPE
  -      -     -     -    AFTER    -                     1                 AA
TYPE NO. SUBTRANS. CIRCUIT EXT. SUPPLY                   1      ************************
TYPE OF T-D SUBST. AFTER CONV.                           0
COST OF TRANS. SUPPLY TO T-D SUBST.                    0.0
UG OR OH TRANSMISSION
TYPE OF SUBSTATION AFTER CONVERSION                      0
SUB AREA AFTER CONVERSION                                0
INITIAL NUMBER OF FEEDERS                                4


SPOT LOAD MW DEMAND FOR EACH YEAR OF STUDY
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
```

be described below (there are none for the Princess Jeanne substation), and Expansion Policies.

The expansion policy inputs give alternative expansion plans to be implemented if the substation is overloaded, and allow them to be placed in a hierarchy. The types of expansion policies allowed include expanding the station by going to the next Capacity Expansion Step Number, transferring load to an adjacent substation, and expanding an adjacent substation or building a new one and then transferring the overload to it. Princess Jeanne substation is already at its maximum capacity step (Number 4 in Figure 9) so the first relief action that will be tried when it is overloaded is a load transfer to a nearby station with excess capacity. A similar process of system component descriptions and expansion policies is used for switching stations and subtransmission circuits.

There are always certain expansions of the system planned and/or under construction by the Public Service Company of New Mexico, or for that matter, by most any electric company. Truman substation is one such planned system expansion (Figure 10). Like the Princess Jeanne substation, it is a Type 2 station (Figure 11), and is scheduled to be put on line at "Capacity Expansion Step" 4, 16 MVA. It is located near the smaller Monroe substation which is served by a 46 KV subtransmission line. Truman, with its larger capacity, and served by a 115 KV line, is designed to relieve Monroe substation when it becomes overloaded.



⊛ MONROE 46 KV SUBSTATION

◉ TRUMAN 115 KV SUBSTATION

FIGURE 10

MONROE AND TRUMAN
SUBSTATIONS AREA

FIGURE 11

BUILD DESCRIPTION FOR

TRUMAN SUBSTATION NUMBER 625

INITIAL DESCRIPTION OF SUBSTATION
****

CAPACITY EXPANSION STEP	4
NUMBER OF SUBTRANSMISSION CIRCUIT TERMINATIONS	0
NUMBER OF LINE REGULATORS ON FEEDERS	0
MVAR OF CAPACITORS ON BUS	0.0
MVAR OF CAPACITORS ON FEEDERS	3.7
BUS REGULATOR RANGE, PER UNIT RAISE	0.100
FIXED TAP SETTINGS, PER UNIT	0.0
IF T-D OR S(T)-D, PER UNIT HIGH SIDE VOLTAGE	0.0
CAPITALIZED COST OF BUILD, THOUSANDS OF DOLLARS	163.0
COST OF LAND FOR BUILD, THOUSANDS OF DOLLARS	0.0

****

DATA FOR POSSIBLE STATION RELIEF
****

TYPE OF STATION TO RELIEVE THIS STATION	2
NEW STATION FUNCTION CODE	0
NEW STATION SUB AREA	1
NEW STATION SUB AREA AFTER CONV., IF S(S)-D	0
TYPE OF SUBTRANSMISSION	1
IF THIS STATION IS S(S)-D,	
NEW SUB AREA AFTER CONVERSION	0
SUBSTATION TYPE AFTER CONVERSION	0
IF THIS STATION IS S(T)-D,	
TYPE OF T-D STATION	0
COST OF TRANSMISSION SUPPLY	$ 0.0E3

LOCATION
62 50
****

YEAR OF BUILD
0
****

SUBSTATION TYPE
2
****

SUBSTATION FUNCTION
0
****

SUB AREA
1
****

HIGH VOLTAGE BUS NUMBER
97
****

While the "Year Of Build" may be designated, the zero appearing in Figure 11 instructs the program to build the station only when load conditions warrant it. In the program run, Monroe became overloaded and Truman was built in Year 3 (1974). In actuality, the Truman substation is expected to be on line in spring, 1975.

If there are planned substation builds, then there must be subtransmission lines planned to serve them. A "Branch Build Table" allows entries for such lines. It has input requirements similar to those for the substation and scheduled switching station builds.

The reader will recall that DSP simulates the system expansion in a cost efficient manner. To do this, the program must be able to calculate the projected costs of any and all possible types of expansion. This includes three different types of cost data. All types of equipment, from distribution transformers to subtransmission circuitry, must be assigned a cost that includes installation. The price of energy is called for in dollars per megawatt hours as well as the cost of the losses which occur as power goes through transmission, subtransmission and distribution. Carrying charges must also be estimated. The carrying charge is a rate reflecting a minimum rate of return considered acceptable by the company, insurance, depreciation and taxes. Carrying charge rates must be entered for 13 different cost accounts associated with different system components and land charges (Table 2). Costs calculated by DSP may then be adjusted for inflation by the user.

TABLE 2

ANNUAL COST SUMMARY CONTENTS

****

I LAND
1. DISTRIBUTION SUBSTATIONS
2. T-S SUBSTATIONS

II T-S SUBSTATIONS
1. NEW T-S BUILDS
2. T-S EXPANSIONS
3. CIRCUIT TERMINATIONS
4. CAPACITORS

III UNDERGROUND SUBTRANSMISSION
1. SCHEDULED BUILDS
2. PROGRAM BUILDS
3. T-S RELIEF

IV OVERHEAD SUBTRANSMISSION
1. SCHEDULED BUILDS
2. PROGRAM BUILDS
3. T-S RELIEF

V PEAKING GENERATORS

VI DISTRIBUTION SUBSTATIONS
1. SCHEDULED BUILDS
2. PROGRAM BUILDS
3. SCHEDULED EXPANSIONS
4. PROGRAM EXPANSIONS
5. SUBTRANSMISSION TERMINATIONS
6. S(T)-D TO T-D CONVERSION
7. S1(S2)-D TO S2 CONVERSION
8. TRANSFER FOR T-S RELIEF
9. BUS REGULATORS
10. BUS CAPACITORS
11. SWITCHGEAR FOR CAPACITORS
12. NEW FEEDER POSITIONS

VII UNDERGROUND DISTRIBUTION
1. AREA RELATED LOAD TRANSFERS
2. EXPRESS FEEDERS
3. GET-AWAY CABLES

VIII OVERHEAD DISTRIBUTION
1. AREA RELATED LOAD TRANSFERS
2. EXPRESS FEEDERS

IX FEEDER CAPACITORS

X UNDERGROUND TRANSMISSION
1. SCHEDULED BUILDS
2. PROGRAM BUILDS
3. SUPPLY S(T)-D TO T-D CONVERSION

XI OVERHEAD TRANSMISSION
1. SCHEDULED BUILDS
2. PROGRAM BUILDS
3. SUPPLY S(T)-D TO T-D CONVERSION

XII UNDERGROUND DISTRIBUTION TRANSFORMERS
1. TRANSFORMERS
2. FEEDER REGULATORS

XIII OVERHEAD DISTRIBUTION TRANSFORMERS
1. TRANSFORMERS
2. FEEDER REGULATORS

NOTE -- IF NO PRINTOUT FOLLOWS FOR ANY OF THE ABOVE, NO COSTS WERE INCURRED FOR THAT ACCOUNT

The Input Model - The Load Data

Having established all the system parameters, it is necessary to develop an analysis of the KW load on the system for the base year, and projections of that load. A sample of this input data is to be found in Table 3. Load data is required by BLA, and within BLA, by class. Each class represents a group of customers with relatively similar load characteristics: load factors and load profiles. The 17 classes developed for the study are shown in Table 4. The breakdown of the residential customer classes (1 through 5) will be discussed in Chapter Three.

Each class is assigned a load profile. These profiles are used by the program to calculate peak demands as described in Chapter One. The "Load Class Code," column (5) in Table 3, refers the program to coincidence factors taken from a load profile. The "Initial Class Peak Demand," column (6), is the KW peak for that class of customers in that BLA. The program can multiply the figure for KW demand times the coincidence factor it finds for that class at the time of system peak. It thus calculates class peak coincident with system peak. Table 5 lists the coincidence factors for different classes at different times of the day.

Column (2) in Table 3 designates the substation from which the particular load is served. In our example, it is number 540, the Princess Jeanne substation. Lines 1 through 7 on Table 3 represent BLA 72-58 (Figure 12). This area is bounded by Constitution Ave., Moon St., Indian School Rd.,

TABLE 3

BLA LOAD DATA

Line	Basic Load Area X & Y Coordinates (1) X - Y	Substation From Which BLA Is Initially Served (2)	Time Shift Before Commencing Load Growth Trend (3)	Load Growth Trend Code (4)	Load Class Code (5)	Initial Class Peak Demand (KW) (6)
1	72 - 58	540		4	10	19
2	72 - 58	540		1	11	23
3	72 - 58	540		1	15	64
4	72 - 58	540		8	9	24
5	72 - 58	540		5	3	865
6	72 - 58	540		12	5	11
7	72 - 58	540		9	7	357
8	74 - 56	540		6	3	199
9	74 - 56	540	10	14	7	100
10	74 - 56	540		12	5	7
11	74 - 56	540		11	17	35

TABLE 4

DSP LOAD CLASSES

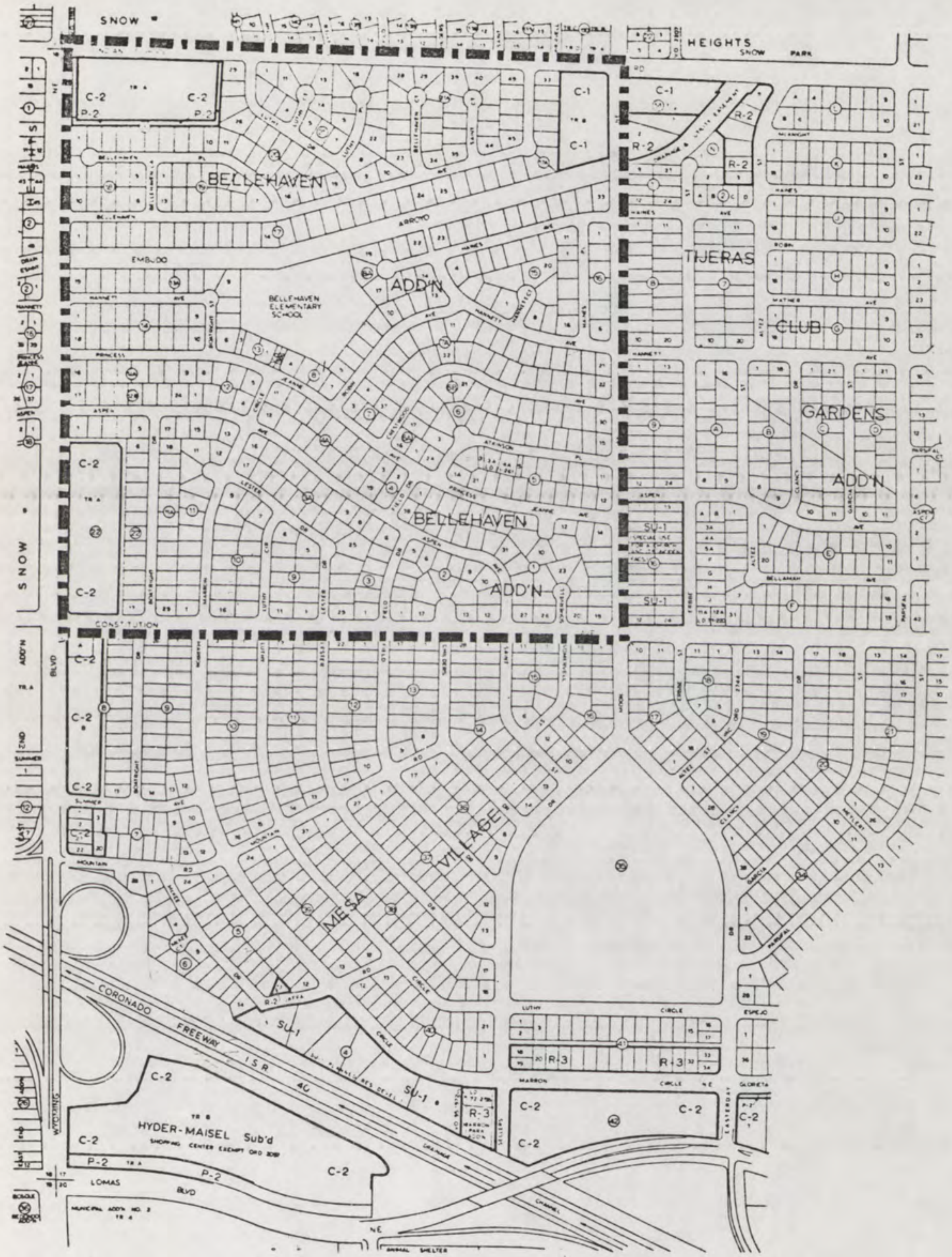
CLASS NUMBER	DESCRIPTION
1	Residential
2	Residential
3	Residential
4	Residential
5	Residential
6	Master Metered Apartments
7	Typical 8 Hour Businesses
8	Typical 12 Hour Businesses
9	Typical 16 Hour Businesses
10	Schools
11	Service Stations, Billboards
12	Industrial & 24 Hour Businesses
13	Water Pumping Stations
14	Agricultural (Not Used)
15	Eating & Drinking Places
16	Hotels & Motels
17	Theatres, Entertainment Places & Churches

TABLE 5

LOAD PROFILE CALCULATIONS

CLASS NUMBER	POWER FACTOR	HOURLY LOAD AS PER UNIT OF CLASS PEAK 1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.830	0.670	0.780	0.800	0.780	0.820	0.790	0.840	0.850	0.860	0.980	1.000	0.910	0.990
2	0.830	0.740	0.860	0.840	0.900	0.880	0.860	0.920	0.900	0.880	1.000	0.920	0.820	0.860
3	0.830	0.640	0.700	0.700	0.720	0.760	0.800	0.820	0.860	0.940	1.000	0.980	0.940	0.900
4	0.830	0.700	0.720	0.680	0.700	0.760	0.760	0.840	0.840	0.800	0.820	0.880	0.940	1.000
5	0.830	0.860	0.810	0.770	0.750	0.750	0.780	0.770	0.820	0.780	0.810	0.860	0.830	0.800
6	0.830	0.470	0.510	0.550	0.570	0.590	0.620	0.650	0.680	0.710	0.790	0.900	0.980	1.000
7	0.830	0.950	0.980	0.990	1.000	1.000	0.990	0.980	0.930	0.870	0.700	0.680	0.700	0.700
8	0.830	0.920	0.950	0.970	0.980	0.990	1.000	1.000	1.000	1.000	0.990	0.980	0.950	0.780
9	0.830	0.920	0.940	0.970	0.980	0.980	0.990	1.000	1.000	1.000	1.000	0.990	0.960	0.910
10	0.830	1.000	1.000	1.000	0.970	0.900	0.850	0.800	0.780	0.770	0.740	0.710	0.690	0.680
11	0.830	0.320	0.330	0.340	0.350	0.380	0.390	0.400	0.430	0.500	0.700	0.920	1.000	0.990
12	0.830	0.610	0.680	0.840	0.900	0.940	0.970	0.990	1.000	1.000	0.980	0.950	0.860	0.740
13	0.830	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
14	0.830	0.870	0.950	0.990	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.950	0.850
15	0.830	0.600	0.660	0.680	0.680	0.680	0.690	0.700	0.720	0.750	0.800	0.900	1.000	0.960
16	0.830	0.890	0.880	0.870	0.860	0.870	0.900	0.910	0.930	0.950	0.980	1.000	0.990	0.860
17	0.830	0.380	0.420	0.500	0.550	0.630	0.700	0.820	0.900	0.940	0.980	1.000	1.000	0.990
18	0.830	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Note: Time periods 1 through 13 refer to different specified times of the day, not hours.



BLA 72-58 Boundary

FIGURE 12

BLA 72-58 AND SURROUNDING AREA

and Wyoming Blvd., N.E., and is served solely by the Princess Jeanne substation. There is a load designated for each class represented in the BLA, seven in all. "Load Class Code" number 3, on line 5, has the largest load: 865 KW. This load is for some 800 homes. The system peak occurred at time number 7 (4:00 P.M.). Thus on Table 5, we can find the coincidence factor for class 3 at time number 7: .820. 865 KW times .82 equals 709.3 KW, the demand for class 3 in BLA 72-58 coincident with system peak.

The load projections are entered into the DSP input data base as percentages of growth on the base year load. (The development of the load projections is discussed in Chapter Four.) Twenty "load growth trend codes" have been designated (Table 6) ranging from no growth, "Trend Type Number" 1, to growth of 4000% in 13 years, "Trend Type Number" 20, a 36% annual compound growth rate![1] Table 6 is in growth per unit, so all first year figures are unity. Going back to our example of class 3 in BLA 72-58 (Table 3, line 5), a load growth trend code (in column (4)) of 5 is designated. Going to Table 6, we find a per unit growth trend in year 13 (1984) of 1.501. This time our calculated coincident demand of 709 KW yields a projected coincident demand for year 13 of 1064 KW.

Column (3) in Table 3 labeled "Time Shift Before

[1]Such large compound growth rates are necessary for areas just beginning to develop. Even though the magnitude of new load in such an area may not be so large, when compared to the small existing load, it represents a very large growth rate.

TABLE 6

LOAD GROWTH TRENDS

TREND TYPE NUMBER	YEAR 1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2	1.000	1.008	1.016	1.024	1.032	1.041	1.049	1.057	1.066	1.074	1.083	1.092	1.100
3	1.000	1.012	1.023	1.035	1.048	1.060	1.072	1.085	1.097	1.110	1.123	1.136	1.150
4	1.000	1.019	1.038	1.057	1.077	1.098	1.118	1.139	1.161	1.182	1.205	1.227	1.250
5	1.000	1.034	1.070	1.107	1.145	1.184	1.225	1.267	1.311	1.356	1.402	1.451	1.501
6	1.000	1.048	1.098	1.150	1.205	1.262	1.323	1.386	1.452	1.521	1.594	1.670	1.749
7	1.000	1.059	1.122	1.189	1.260	1.335	1.414	1.499	1.588	1.682	1.782	1.888	2.001
8	1.000	1.070	1.145	1.225	1.310	1.402	1.500	1.605	1.717	1.837	1.965	2.103	2.250
9	1.000	1.079	1.165	1.257	1.357	1.465	1.581	1.706	1.841	1.987	2.145	2.315	2.499
10	1.000	1.088	1.184	1.288	1.401	1.525	1.659	1.805	1.963	2.136	2.324	2.529	2.751
11	1.000	1.096	1.201	1.316	1.442	1.581	1.732	1.898	2.080	2.280	2.499	2.738	3.001
12	1.000	1.110	1.232	1.368	1.518	1.685	1.870	2.076	2.304	2.558	2.839	3.152	3.498
13	1.000	1.122	1.260	1.414	1.588	1.782	2.000	2.245	2.520	2.829	3.176	3.565	4.002
14	1.000	1.144	1.309	1.497	1.713	1.959	2.242	2.564	2.934	3.356	3.839	4.392	5.025
15	1.000	1.161	1.348	1.565	1.817	2.109	2.449	2.843	3.301	3.832	4.450	5.998	5.998
16	1.000	1.212	1.469	1.780	2.158	2.615	3.170	3.842	4.656	5.643	6.840	8.289	10.047
17	1.000	1.253	1.570	1.967	2.465	3.089	3.870	4.849	6.076	7.613	9.539	11.952	14.976
18	1.000	1.284	1.649	2.117	2.718	3.490	4.481	5.754	7.388	9.486	12.180	15.639	20.081
19	1.000	1.328	1.764	2.342	3.110	4.130	5.485	7.284	9.673	12.846	17.060	22.656	30.087
20	1.000	1.360	1.850	2.515	3.421	4.683	6.328	8.605	11.703	15.917	21.646	29.439	40.037

Commencing Load Growth Trend" allows us to project, for a class not previously represented in the BLA, a load to come on line sometime in the future. This feature is used in line 9. (This is a new BLA for us, 74-56). This class 7 load of 100 KW is not projected to come on line until year 10 of the study (1981). At that time it will begin to grow at the rate designated by Load Growth Trend Code 14, a 14.4% annual compound rate of growth.

The base load and the load projections can be designated in one additional way. Sometimes very large customers require the use of an entire feeder or even an entire substation. University of New Mexico, Kirtland Air Force Base and the Albuquerque International Airport are cases in point. These can be designated as "Spot Loads" at a particular substation or switching station and the projected load specified for each year of the study. Such a Spot Load would be designated at the bottom of Figure 9.

The Working Model

Now that we have seen what data the user must provide before DSP can be run, we will now turn to the model's execution. Each expansion year begins with the addition of any scheduled builds to the system representation (Step 1 in Figure 13). This might include a new substation planned by the company, where, unlike the Truman substation mentioned above, the Year of Build is specified. The load model for the system for the new year is then calculated using

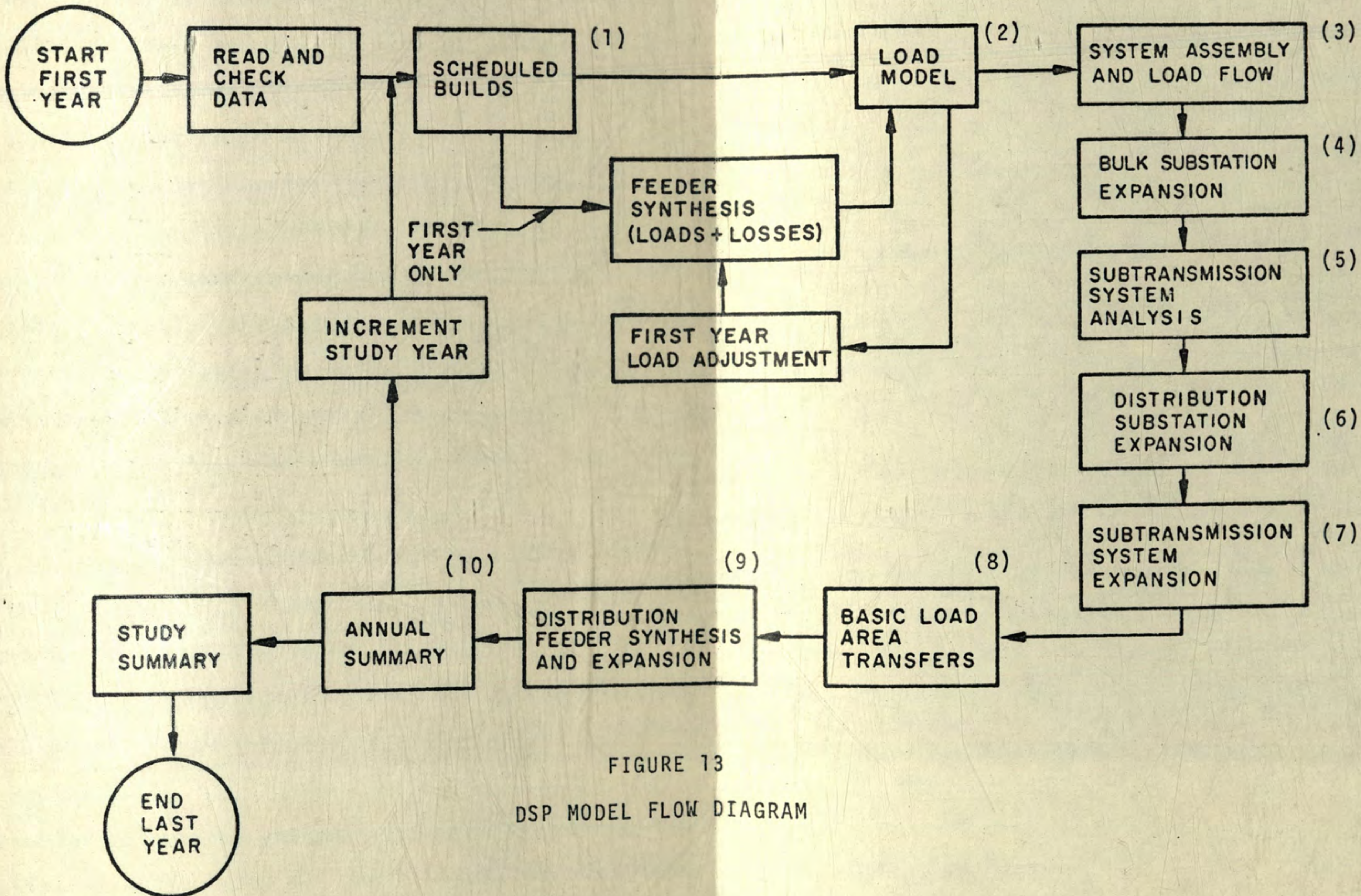


FIGURE 13

DSP MODEL FLOW DIAGRAM

the Load Growth Trends and adding in the Spot Loads (step 2).

All loads are assigned to substations and a "load flow" is performed (step 3). With a load flow, the model simulates the flow of power from the bulk stations through the subtransmission system to the distribution substations. First the bulk station loads are analyzed for overload conditions. If there is an overloaded bulk station, relief action is taken (step 4). Load could be transferred to another bulk station by changing the routing on the subtransmission lines. This would simply involve opening and closing switches on the lines. Peaking generators could be built at the switching station site increasing the station capacity. The station's capacity could be increased by adding additional equipment in the same manner that a distribution substation is expanded. Or a new subtransmission line could be built to allow load to be transferred to another switching station.

Not only are the bulk stations analyzed under normal conditions, but emergency conditions are considered as well. Each transformer at a bulk station is taken out of service in turn and the stations are then analyzed. This test allows the bulk stations to be designed to meet single contingency failure criteria.

A similar process of analysis is performed for the subtransmission circuits (step 5). Both normal and emergency conditions are considered, and the overloaded circuits are noted. Those with excess capacity are also noted. However relief action is deferred until the distribution substation expansions are performed.

The distribution substations are now considered (step 6). Each station is examined for either overloads or excess capacity. Then relief action is taken for the overloaded stations. Types of relief action for distribution substations have already been mentioned (page 25). The order of the possible relief action may be specified, or the program may calculate the most efficient relief action. Much of the time there will be an adjacent substation with excess capacity. Then the load can easily be shifted. But if there is no such alternative and the substation in question is at its maximum capacity step, then the program must determine the most cost efficient relief action: expand some other station and transfer the load, or build a new station and transfer the load. And if a new station is to be built, it must determine the best location for it.

When the substation relief action is completed, the model returns to the problem of the subtransmission system expansion (step 7). As there have been load transfers from substation to substation, the loading on the subtransmission system has changed. In addition, new circuits must be built to serve any new substations. For these reasons, the subtransmission system expansion had to wait until the substation relief actions were completed.

The first order of business here is building lines to serve the new substations. A list of tentative correction actions is produced with potential lines to serve the substation and their costs. The least expensive solution is tried first. A load flow is run for the new circuit and the circuits it directly effects to check for overload problems. If this action is unsuccessful, a different solution (the next least expensive) is tried. If it is successful, then a load flow is run on the entire system under both normal and emergency conditions. If there are no new overload problems when compared to the load flow run before the substation expansion, the new line is incorporated into the subtransmission system.

When all of the line build requirements for new substations have been satisfied, the originally overloaded lines are relieved. The process here is little different from that which built lines to the new substations. The circuit with the greatest problem (i.e. most overloaded) is taken first. A list of tentative correction actions is composed and the least expensive solution is tried first. If it can be added to the system successfully and without creating any new overload problems, it is incorporated into the system representation.

When the subtransmission system expansion is completed, the BLA loads are transferred in accordance with the transfers planned in the substation expansion step (step 8). Those transfer plans designated the size of the load to be transferred, but not which BLA loads are to be transferred. This is determined in the BLA transfer logic. The objective is to transfer between two substations that BLA load which is farthest from the sending substation and closest to the receiving substation. A ratio is calculated for this purpose:

$$\frac{s}{r} = \frac{\text{distance from BLA to sending substation}}{\text{distance from BLA to receiving substation}}$$

The BLAs with the highest s/r ratio are transferred first. This is continued until sufficient load has been transferred.

The final procedure is the distribution feeder synthesis and expansion (step 9). This involves two steps: building the feeders and assigning load to them. A "center of load" is calculated for each feeder. The number of feeders for a substation has been determined from the substation type data and capacity step (Figure 7). For Princess Jeanne substation, there are four feeders. Four separate centers of load are determined and feeders are routed directly through them. Load in each of the ten BLAs served by Princess Jeanne substation is assigned to one of the feeders using a cost obtimization technique.

A load density plot in year 4 (1976) for Princess Jeanne substation is in Figure 14. Table 7 gives data on the substation's feeder synthesis, also in year 4. In the center of the page is the feeder breakdown. This includes the load in MVA and the BLAs served by each feeder. Note the load summary labeled "Next Year." The peak loads are calculated for each of the thirteen times during the day for the substation in the following year. This will be used for

YEAR 4 MVA LOAD DENSITY PLOT FOR SUBSTATION 540 PRINCESS J

EACH STAR REPRESENTS 0.25 MVA OR LESS

** UNABLE TO ENTER ALL LOAD IN BLA (74, 56) --- THE DIFFERENCE NOT SHOWN IS 0.596 MVA

STATION CAPACITY = 16.000 MVA --- STATION LOAD = 14.821 MVA --- POWER FACTOR = 0.9257

STATION CAPACITORS = 0.0 MVAR --- FEEDER CAPACITORS = 2.550 MVAR

"S" DESIGNATES THE SUBSTATION LOCATION

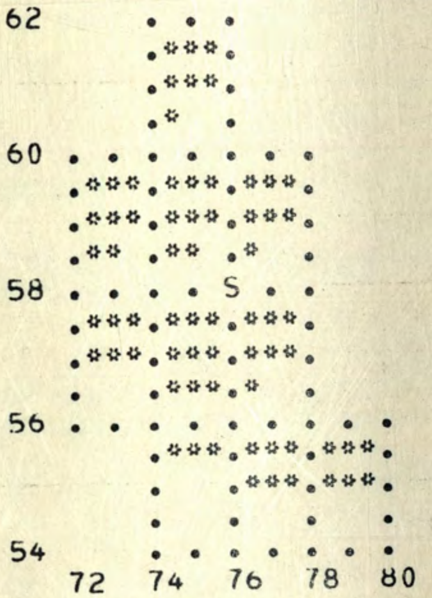


FIGURE 14

PRINCESS JEANNE SUBSTATION LOAD DENSITY PLOT

TABLE 7

PRINCESS JEANNE SUBSTATION FEEDER SYNTHESIS

SUBSTATION 540 -- PRINCESS J TYPE 2 STEP 4 16.00 MVA LOCATION = 76. 58. 10 BLA

FEEDER DATA

TYPE = 1 - OH
CAPACITY # 5.0 MVA
CAPACITORS = 2550.KVAR

MAX.NO. LINE REGS = 0
LINE REGS IN SUBSTA= 0
LINE REG.RAISE(PU) =0.0
LOAD RELIEF MAX PF = 1.00

REGULATOR CODE = 2 (INCLUDE EXP.FEEDER DROP)
VOLTAGE CONTROL = 1 (CAPS ONLY)
EXPRESS CIRCUIT IMPED.(R) = 0.045 OHMS/1000FT
EXPRESS CIRCUIT IMPED.(X) = 0.111 OHMS/1000FT
LATERAL CIRCUIT IMPED.(R) = 0.045 OHMS/1000FT
LATERAL CIRCUIT IMPED.(X) = 0.111 OHMS/1000FT

SPOT LOADS (NONE)

THE SUBSTATION LOAD CENTER OF GRAVITY IS AT 74.6 56.7
NARCS = 55

FDR NO.	VOLTAGE DROP(%)	LOAD MVA	LOAD PF	LOSSES KW	LOSSES KVAR	FT/1000 EXP	FT/1000 LAT	KVAR CAPS	NO. REGS	BASIC LOAD AREAS X	Y	X	Y	X	Y	X	Y
1	0.941	4.9	0.86	15.	36.	6.	1.	0.	0	74	54	74	56	76	58		
2	1.375	5.0	0.86	27.	66.	6.	3.	0.	0	76	54	76	56	76	58	78	54
3	0.563	2.2	0.86	5.	13.	3.	2.	0.	0	74	58	74	60	76	58		
4	1.490	5.0	0.86	30.	73.	6.	3.	0.	0	72	56	72	58	74	58		

LOAD SUMMARY FOR SUBSTATION 540

THIS YEAR

12.1	12.7	12.8	12.9	13.2	13.6	13.7	14.0	14.5	14.7	14.7	14.5	13.9 SUBMW
14.0	14.7	14.8	15.1	15.4	15.8	16.0	16.2	16.8	17.1	17.1	16.9	16.2 SUBMVA
0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86 PF

NEXT YEAR

12.8	13.4	13.5	13.7	14.0	14.4	14.5	14.8	15.3	15.5	15.5	15.3	14.7 SUBMW2
14.9	15.6	15.7	15.9	16.3	16.7	16.9	17.2	17.8	18.0	18.0	17.8	17.1 SUBMV2
0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86 PF

calculating substation loads and planning relief actions.

With this overview of the Distribution System Planning Program, we will now look at the methodology used to establish the load data in Part II. Chapter Three will cover the load base and Chapter Four will deal with the load projections.

PART II

Part II describes the method used for the development of the DSP load data. Chapter Three deals with the load base and Chapter Four concerns itself with the load projections.

CHAPTER 3

THE LOAD BASE-ESTIMATING DEMAND

It will be recalled that the load data consists of two parts: the load base and the load projections. This chapter is concerned with the load base, while the load projections will be covered in Chapter Four.

The load base consists of estimates of KW demand by areas of the city and classes of customers for the base year. The areas are ultimately basic load areas (BLA), but we will work first with data analysis sub-zones (DASZ), as they are used for most of the geographically based demographic data available from public agencies. Only after the DASZ demand estimates are completed are they converted to BLA by dividing each DASZ load up into parts representing BLAs in that particular sub-zone. For a comparison of BLAs and DASZs see Figure 15.

In estimating demand for different classes of customers, two reasons warrant the separation of the residential from the commercial and industrial customers. The quantity of data available for each of these two groupings differs greatly, and the relative limits upon the types of residential loads offer additional parameters to be considered when estimating residential demands.

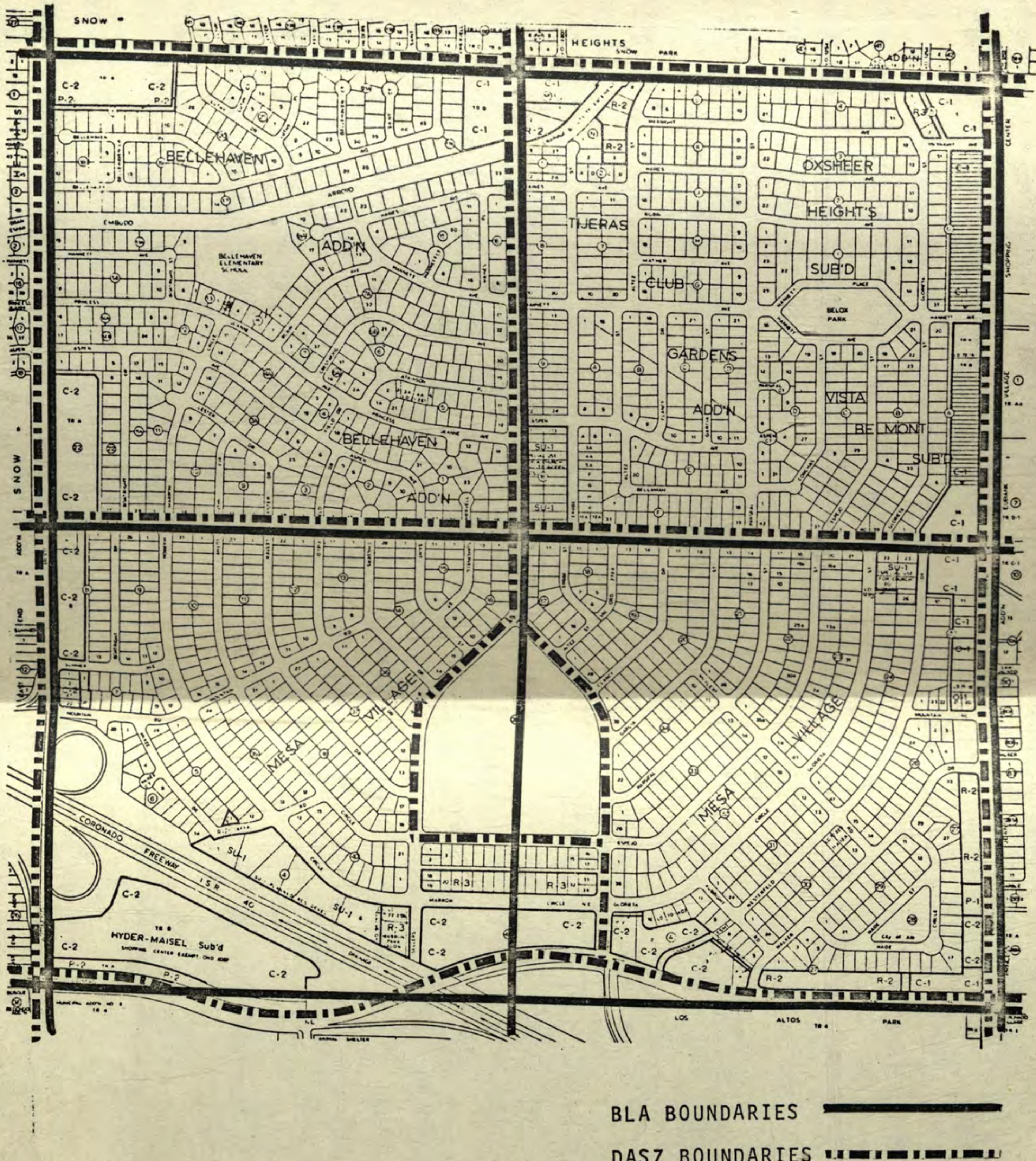


FIGURE 15

COMPARISON OF DASZs & BLAs

Estimating Commercial and Industrial Demand

DSP allows for the use of different load classes of customers for describing base year loads and assigning growth trends to fit the load projections. These load classes must be defined and customers assigned to them before the demand estimating procedure is begun.

Load classes are established by planning groupings that minimize the variance in load factors and coincidence factors and by including customers that reach peak at about the same time. Or it could be said that we want to put customers with similar load profiles together. Thus the hours of operation becomes the most significant factor to be considered.

The most commonly assigned load class immediately becomes apparent: the typical 9:00 A.M. to 5:00 P.M. operating business. Most such establishments turn on most of their electrical appliances in the morning and leave them on until the afternoon quitting time. Thus they will all peak in the afternoon as air conditioning units go on, and their profiles will have shapes similar to the office customer profile in Figure 6.

Three other load classes are established according to their typical hours of operation: typical 12, 16 and 24 hour businesses. Additional classes are established identifying special operating practices of different types of businesses. Restaurants receive their own group as their load profiles will usually show peaks at meal times. Hotels and motels are separated as they usually show higher evening and morning demands when travelers are in their rooms. Service stations have a significant evening peak due to high lighting loads, and billboards are grouped with them for the same reason. Schools receive special treatment as do master metered apartments (they are treated as commercial customers). Finally, we have an unusual grouping of customers that have high evening and weekend loads but tend not to peak during the weekday: theatres, entertainment places and churches. Table 8 lists the different commercial and industrial load classes and some of their characteristics.

The next step is to assign each customer to a load class. As it is not practical to examine each customer's attributes, Standard Industrial Classification Codes (SIC) are used as each customer's record shows its SIC assignment. Every SIC is assigned to the load class that best fits that type of business. It then becomes a simple matter to assign classes according to SIC.

This last step as well as the following step makes use of a customer data report known as PNM 558 (Figure 16). It lists for each DASZ, SIC and rate code the number of customers and their mean, standard deviation and total KWH. It also includes data on the peak KW for demand metered customers.

The page taken from PNM 558 reproduced in Figure 16 shows data for some of the customers in DASZ 7511 for July, 1972. DASZ 7511 is coterminous with BLA 72-58 (Figure 12). The 518 customers listed under SIC 00 are residential

TABLE 8

COMMERCIAL LOAD CLASS CHARACTERISTICS[1]

CLASS	NAME	LOAD FACTOR	DIVERSITY FACTOR	COINCIDENCE FACTOR	TIME OF DEAL
6	Master-metered apartments	.48	.95	.60	9:00 P.M.
7	Typical 8 hour business	.27	.80	1.00	3:00 P.M.
8	Typical 12 hour business	.48	.80	1.00	3:00 P.M.
9	Typical 16 hour business	.63	.80	.98	5:00 P.M.
10	Schools	.27	.60	.90	1:00 P.M.
11	Service stations, billboards	.46	.60	.38	8:00 P.M.
12	Industrial; 24 hour business	.48	.80	.85	4:00 P.M.
13	Water pumping stations[2]				
15	Eating and drinking places	.51	.85	.68	8:00 P.M.
16	Hotels and motels	.43	.90	.87	7:00 P.M.
17	Theatres, entertainment places and churches	.27	.80	.65	8:00 P.M.

[1]Residential customer class characteristics are discussed elsewhere.

[2]Water pumping station demand estimates are based upon horsepower ratings and an assumption of continual operation.

PUBLIC SERVICE COMPANY OF NEW MEXICO
MARKET RESEARCH DEPARTMENT
CUSTOMER DATA BY MAJOR GROUPINGS

FIGURE 16

TYPICAL PAGE PNM 558

DIV DASZ	SIC	RATE	KWH DATA: NUMBER OF CUSTOMERS	MEAN	STANDARD DEVIATION	MONTH TOTAL KWH	MAXIMUM KW DATA: NUMBER OF CUSTOMERS	MONTH MAX KW. MEAN	STANDARD DEVIATION
			2	13,911.00	992.03	27,822	2	93.00	43.00 ***
7511	00	010	516	708.66	318.64	365,669			.00
		040	1	2,370.00	.00	2,370			.00
		060	1	1,358.00	.00	1,358			.00
			518	713.12	327.51	369,397			.00 *
			518	713.12	327.51	369,397			.00 **
	15	200	3	1,382.33	551.75	4,147			.00
			3	1,382.33	551.75	4,147			.00 *
			3	1,382.33	551.75	4,147			.00 **
	48	200	1	49.00	.00	49			.00
			1	49.00	.00	49			.00 *
			1	49.00	.00	49			.00 **
	50	200	1	1,278.00	.00	1,278			.00
			1	1,278.00	.00	1,278			.00 *
			1	1,278.00	.00	1,278			.00 **
	52	230	1	47,369.00	.00	47,369	1	120.00	.00
		200	1	1,052.00	.00	1,052			.00
			2	24,210.50	562.25	48,421	1	120.00	.00 *
			2	24,210.50	562.25	48,421	1	120.00	.00 **
	54	230	1	11,422.00	.00	11,422	1	24.00	.00
			1	11,422.00	.00	11,422	1	24.00	.00 *
			1	11,422.00	.00	11,422	1	24.00	.00 **
	55	200	7	2,149.43	868.06	15,046			.00

customers. Each listing is assigned to a load class and all the customer KWH figures in each class within the DASZ are summed. But those lines of data giving customer KW demand are omitted from this process. The first entry for SIC 52 (Rate 230) is a case in point. There is one customer with 47,309 KWH and 120 KW. Since we have an actual demand figure for this customer, there is no need to estimate his demand. However, this data can be used to aid in determining load factors for estimating demand for other customers in that load class. The KWH and KW figures for all demand metered customers within a particular load class are summed, and then used to calculate a load factor using equation 1.

At this point the data is transformed to a listing of total KWH for each load class within each DASZ, and total KW for each load class within each DASZ for the demand metered customers. Load factors are applied to each KWH total to arrive at a KW demand estimate. These estimates are then added to the KW figure for the demand metered customers to arrive at the total class KW for that DASZ.

How are the load factors developed? Three techniques are used. The first is mentioned above. The KWH sales and KW demand for a group of demand metered customers are summed and from them a load factor is calculated. The second technique calls upon a random sample of customers who are metered with special magnetic tape recording devices to get a detailed load profile on them. The KWH and KW readings from these meters allow us to calculate load factors for customers considered typical of a particular load class.

The third technique calls for developing load factors from load profiles drawn to represent the typical customer of a load class. The load factor to be used for a particular class is then chosen from an analysis of these three estimates.

Let us look at an example of a class load estimating procedure for DASZ 7511, load class 7. Summing of all the KWH entries for the non-demand metered customers from PNM 558 yields 54,400 KWH. Summing of all the KW entries for the demand metered customers yields 176 KW. Using equation 1 we estimate demand for the former group:

$$KW = \frac{54.400}{.27 \times 744} = 270.81$$

where .27 is the class load factor and 744 is the number of hours in the time period metered. The demands for the two groups are summed,

$$176 + 270.81 = 446.81$$

to arrive at the total estimated demand for the load class. This is multiplied by the diversity factor found on Table 8 (developed from an analysis of test metered customers), 446.81 x .80 = 357.45 KW to arrive at a total estimated diversified demand. This figure becomes the KW demand for class 7 of DASZ 7511. As DASZ 7511 and BLA 72-58 are coterminous, this figure, rounded to 357, can be found in the BLA load data (Table 3) as the Initial Class Peak Demand on line 3.

Estimating Residential Demand

While estimating commercial and industrial demand relied upon load factors and diversity factors, a more accurate process is involved in estimating residential demand. The major components of residential load can easily be identified. They include lights, electric heaters, electric hot water heaters, air conditioners, electric ranges, dishwashers, electric clothes dryers, televisions, refrigerators and freezers. By estimating the saturation of some of these appliances for a particular area and applying these estimates in a logical manner, estimates of demand can be developed more accurately than by simply using load factors.

Appliance saturation coefficients are used for defining ownership levels of appliances. They are calculated by dividing the number of units of the appliances in question owned by a group of households, by the number of households. For example a .50 coefficient for electric ranges means that half of the households in a sample or an area have electric ranges (the other half undoubtedly have gas ranges). The appliance saturation level for televisions is often greater than 1.0 as many homes now have more than one television.

Multiple regression analysis[1] is used to establish

[1]Multiple regression analysis is a statistical technique that fits a curve to a set data. The equation for that curve is used for estimating values of an unknown parameter that is a function of other parameters whose values are known.

For an introduction to regression see "Concepts and Applications of Regression Analysis," IBM. For more detailed discussion of regression theory and application, see the related references in the bibliography.

relationships between appliance saturation levels, KWH sales and KW demand such that

$$KW = f(KWH, \text{appliance saturation coefficients}). \quad (2)$$

This is in essence the same as using a load factor and adjusting the results to account for the existence of specific electrical appliances.

Regression analysis requires a data base of observations giving real values for both the independent variables (KWH and the saturation levels) and the dependent variable (KW demand). To obtain this data, 80 randomly selected households were demand metered using magnetic tape recording devices recording KW levels at 15 minute intervals. KWH sales were also recorded. Each household was interviewed to obtain information on their electrical appliances as well as certain socio-economic and demographic parameters.

Not only were KWH sales and appliance saturation levels tested as independent variables, but certain socio-economic and demographic variables that intuitively appeared likely to explain variance in load were tried as well. The parameters tested include people per home, age of the house, number of rooms in the house and age of the head of the household. Each of these parameters proved to be of little or no value in explaining variance between different demand observations and was ultimately rejected for use as an independent variable.

In testing appliance saturation levels for use in the multiple regression analysis, it was assumed that their coefficients must be positive for the results to be valid. For the whole idea behind their use is that, if a customer has a particular appliance, his potential demand is increased. While an intercept term was included in several of the test regression runs, the use of an intercept term was ultimately rejected as it seemed self-evident that as KWH approaches zero, so does KW demand. Test regression runs were attempted using both maximum demand and group coincident demand as the dependent variable. Both seemed of equal validity for use in the analysis.

All attempts to include multiple appliance saturations or including socio-economic or demographic parameters were unsuccessful. Consider the following result:

$$\text{MAX KW} = .0044\ \text{KWH} - .234\ \text{AC} + .261\ \text{ROOMS} + .533.^{2} \quad (3)$$

The negative coefficient for air conditioners renders this equation invalid even though its R^2 showed two-thirds of the variance explained.

Better results were obtained by limiting the independent variables to KWH sales and one appliance, but this caused other problems in certain instances. For example, with

$$\text{COIN KW} = .0027\ \text{KWH} + .109\ \text{AC} - .183 \quad (4)$$

the coefficients are positive and the R^2 is a "fair" 55%,

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[2]In this and the following equations, MAX KW = maximum demand, COIN KW = group coincident demand, ROOMS = rooms per house, COOK = saturation level for electric range and AC = saturation level for an air conditioning index of different types of air conditioners.

Customers with electric hot water heaters were treated in a separate regression analysis not considered herein. Thus water heater saturations do not appear in this discussion.

but the T-statistic for the air conditioner saturation variable is .86, or well below the 2.0 required for significance at the 95% confidence level. When the same variables were regressed without an intercept term, the T-statistic for the air conditioning variable went up to 1.19. This is still not significant, but represented the best obtainable result using the obvious load affecting air conditioner variable. The R^2 value increased to 72%. The equation is

$$\text{COIN KW} = .00245 \text{ KWH} + .147 \text{ AC}. \tag{5}$$

Somewhat better results were obtained regressing maximum demand against KWH sales and electric range saturation:

$$\text{MAX KW} = .0052 \text{ KWH} + 2.13 \text{ COOK}. \tag{6}$$

With both independent variables having satisfactory T-statistics and the equation yielding an R^2 of 89%, this equation looks good. But it seemed remiss to ignore air conditioning as a term that explains variance in summer KW peak. And since equation (5) estimates group coincident demand, its use does not require the additional step of applying diversity factors. Thus both equations (5) and (6) were selected for use in the residential demand estimation process.

This process required taking a mean of the two estimated values for KW demand. Since equation (5) is for maximum peak demand, its result must first be multiplied by a diversity factor of .296. This was developed through an analysis of the diversity between the test metered customers. The final equation used for residential demand estimation thus became

$$DEMAND = \frac{COIN\ KW + .296 \times MAX\ KW}{2} \qquad (7)$$

where COIN KW is the result of equation (5) and MAX KW is the result of equation (6).

Having established an equation for estimating demand, it is necessary to apply that equation to the residential customers throughout the study area. To that end, values are needed for each of the independent variables: KWH sales, electric range saturation and air conditioning saturation. KWH sales are available individually for each customer; the appliance saturations must be estimated.

In fall of 1971, the Public Service Company of N.M. conducted an appliance saturation survey of its residential customers. The responses were grouped according to their respective billing cycle. From these responses, mean saturation levels for several appliances were established for each billing cycle. These provided estimates for the equation's independent variables.

Problems can arise at this point. How does one rationalize the use of one set of appliance saturation estimates for potentially large numbers of often diverse customers? (There are, after all, only 21 billing cycles for the service area.) This problem is minimized when one considers that the estimating equation is not applied to individual customers, but to aggregates of customers in a DASZ. For example, we can examine the residential customers of DASZ 7511 (Figure 15).

There are a total of 518 residential customers (SIC 00) with a total KWH sales of 369,397. DASZ 7511 is in billing cycle 10, which has a mean electric range saturation of .774 and an air conditioning saturation of .253. Equation (5) becomes

$$\text{COIN KW} = .00245(369{,}397) + .147(.253 \times 518) = 924.3 \text{ KW}.$$

In this computation, the equation is used to calculate the demand for all 518 customers. Thus the sum of their KWH sales and the sum of their air conditioning saturations (.253 x 518) are used.

Similarly we compute using equation (6):

$$\text{MAX KW} = .0052(369{,}397) + 2.13(.774 \times 518) = 2774.8 \text{ KW}.$$

Applying these figures to equation (7):

$$\text{DEMAND} = \frac{924.3 + (.296 \times 2774.8)}{2} = \frac{924.3 + 821.4}{2} = 872.8 \text{ KW},$$

gives us our actual estimate for the group coincident demand for the residential customers of DASZ 7511.

There are two serious limitations to this process of estimating residential demand: the development of the regression equation and the appliance saturation estimates. These problems will be dealt with in Chapter Five. Chapter Four, however, will consider the development of the land use projections. They are very much dependent upon the load base just described, and together these two components constitute all of the load data.

CHAPTER 4

DEVELOPING THE LAND USE PROJECTIONS

Developing land use projections, and converting them to load projections, is undoubtedly the weakest link in putting together the DSP data base. They are, in essence, predictions of where, when and what, for all development in the area for a period of about 10 years.

It has been about 10 years since the last Master Plan was developed for Albuquerque. The assumptions upon which it was based may have seemed reasonable at the time, but in retrospect they proved to be far afield. It was developed at the apex of the city's burgeoning growth in defense related industries at the Sandia Labs and the Kirtland and Sandia bases. Albuquerque's population nearly tripled in the '40's, and better than doubled from 1950 to 1960. The end to its growth was no where in sight.

In 1960 Albuquerque's residential landscape was dominated by the single family home, making up 83% of all permanent year-round housing. But in the following 10 years only 64% of the new houses constructed were single family. Certain areas of the Northeast Heights, most notably along Montgomery Blvd., became havens for larger apartment buildings. The fibre of the residential fabric of the city began to change. The number of mobile homes sprouted. The development of the military bases leveled off. The completion of Interstate 40 opened up new areas for development, particularly on the West Mesa.

Thus by 1974, we find the City Planning Department preparing a new "701" Comprehensive Plan for Albuquerque. This time, however, there is no attempt to delineate specific land uses or densities for a particular time in the future. Nor are specific population projections made. Instead, a broader picture is painted based upon general objectives and goals.

It is in this context that the projections must be made for DSP. Controlled and uncontrolled events in the near future will significantly alter the patterns of development. Will the West Mesa airport be built? Will the Montano River Crossing be approved? Where will the Environmental Planning Commission be disposed to approve annexations? Will a mass transit system be implemented? What effect will interest rates have upon the rate and the nature of future development? These sorts of questions can be answered only with great uncertainty.

The load projection development begins with a control total: a KW demand projection for the study area for 1984. Another control total is also used: a population projection for 1984. In the three sections below we will examine the development and use of these control totals, the development of the residential projections, and the development of the commercial projections.

The Control Totals

Public Service Company of New Mexico, as part of its annual budgeting process, develops a load growth document including KWH sales and KW demand projections for a 10 year period.[1] These projections become the base for both construction and revenue planning. As this is "official company policy," it is attempted to use these projections for DSP.

As it was necessary to complete the DSP data base development before the 1975 budget hearings in July and August, 1974, preliminary figures were used. Thus there was a figure for 1984 KW demand which became our control total. In theory then, the problem before us is to disaggregate that projection geographically (by BLA), and by customer class.

Ignoring the problem of disaggregating by customer class for the moment, consider the problems of disaggregating by BLA. How does one get a perspective on the matter of how much load will be in each one?

To this end, the study area was divided into 30 separate geographic districts (Figure 17). As will be seen below, the control totals can first be disaggregated into these 30 districts, and each district projection then distributed among its respective BLAs.

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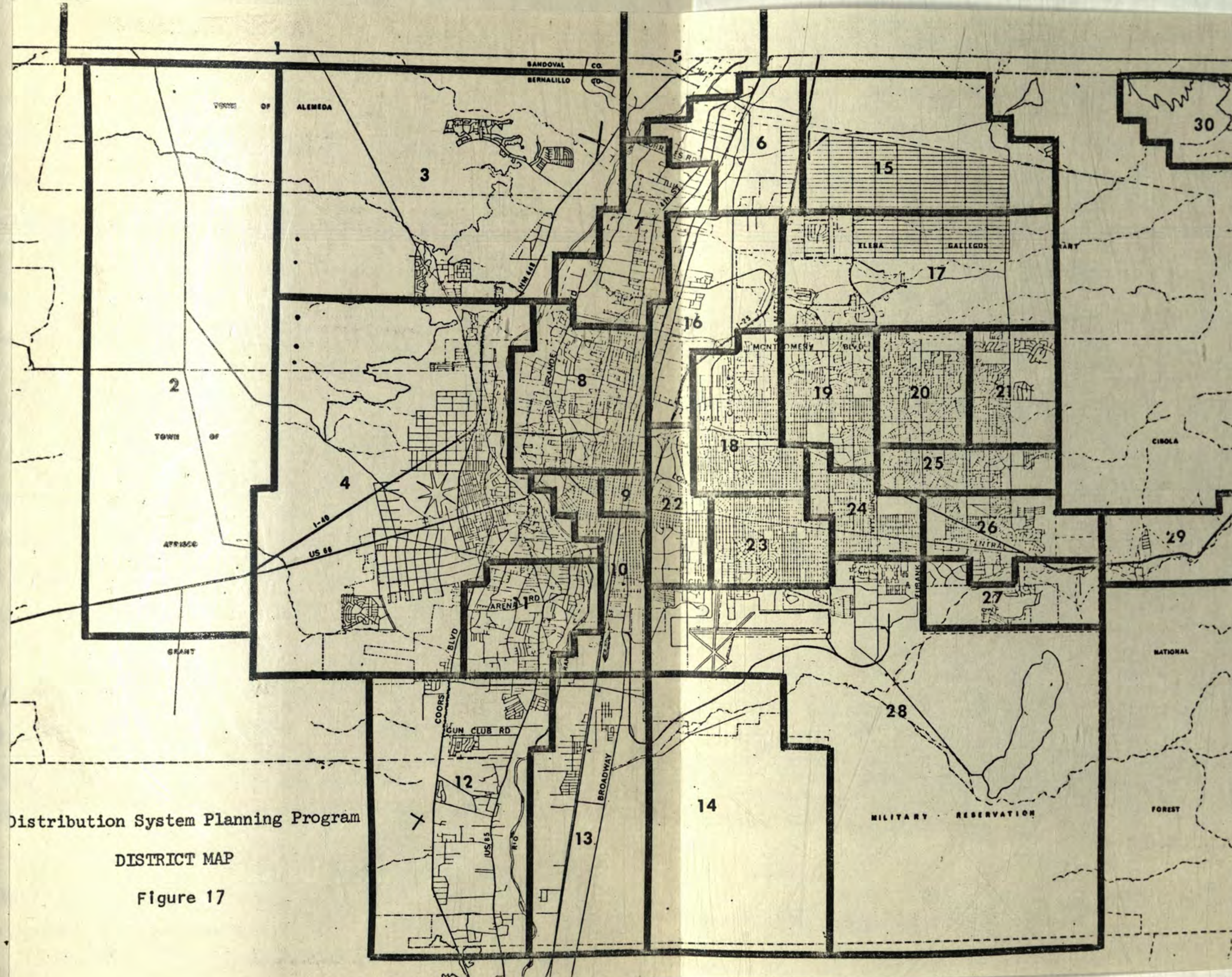
[1]The KW demand and KWH consumption projections were developed using multiple linear regression analysis. The equations are of the form KW (or KWH) = f(YEAR, POPULATION, PER CAPITA INCOME). Ten years of historical data were used for the observations.



Distribution System Planning Program

DISTRICT MAP

Figure 17

The Residential Projections

The first task was to determine what portion of that load was residential, assigning the balance as commercial. There are, of course, no figures on the historical breakdown as there is no way to meter different classes of customers in the aggregate. But a similar breakdown was available for KWH sales, and this was felt to be representative of the KW demand. A simple linear regression analysis was performed with the year and the respective total KWH sales used as the independent variables to estimate residential sales. (The residential sales projections came from the load growth document described above). The 1984 estimated residential sales is divided by the 1984 total sales projection to derive a residential to total sales ratio (Table 9). This ratio was then applied to the KW demand projection for 1984 to provide a residential demand projection and the residual as a commercial demand projection.

(While these projections, and all others mentioned herein, refer exclusively to the last year of the study period, 1984, similar processes were used for the intervening years. For the sake of brevity, such references are omitted.)

Unlike the commercial customers which are classified by their load characteristics, the residential customer classes are geographically based (with electric hot water customers in a separate class altogether). Thus the different residential classes are not a consideration

TABLE 9

ESTIMATES FOR RESIDENTIAL DEMAND PROJECTIONS

(1) YEAR	(2) RESIDENTIAL SALES (MWH)	(3) TOTAL SALES (MWH)	(4) RATIO (2)/(3)	(5) TOTAL MW DEMAND	(6) RESIDENTIAL MW DEMAND
1965	305.7	1189.1	.257	247.6	63.6
1966	330.2	1271.9	.260	255.3	66.4
1967	346.4	1365.6	.254	251.0	63.8
1968	380.1	1473.3	.258	264.4	68.2
1969	415.6	1611.9	.258	292.7	75.5
1970	456.3	1734.8	.263	320.0	84.2
1971	507.5	1908.0	.266	381.4	101.5
1972	553.0	2083.4	.265	406.7	107.8
1973	616.3	2233.7	.275	421.8	116.0
1974	681.4	2462.4	.277	480.2	133.0
1975	751.6	2683.1	.280	531.8	148.9
1976	821.2	2904.1	.283	581.2	164.5
1977	895.7	3138.3	.285	634.2	180.7
1978	976.6	3390.1	.288	691.8	199.2
1979	1061.5	3651.3	.291	752.7	219.0
1980	1151.1	3924.8	.293	816.8	239.3
1981	1245.4	4211.6	.296	883.7	261.6
1982	1345.2	4511.5	.298	954.9	284.6
1983	1451.9	4829.3	.301	1031.3	310.4
1984	1564.2	5160.0	.303	1112.1	337.0

Columns 2, 3, 4 and 5 are actual through year 1973. All others are projected and/or estimated.

Column 2, 1974-1984 figures, are estimated using linear regression analysis.

Columns 3 and 5, 1974-1984 figures, are from a preliminary study for the Public Service Company of New Mexico Load Growth Document, 1974. All other figures are calculated therefrom.

in the disaggregation process.[2]

The first step was to assign a portion of the total residential load projection to each district. To do this, population and housing unit distributions were used as representative of residential load distributions. The 1970 census figures were apportioned by the 30 DSP districts, and percentages of the totals for both parameters were calculated.

The only comprehensive demographic projections by areas of the city are the "1995 Development Patterns" summary report of the Middle Rio Grande Council of Governments (COG). Its projections are by DASZ and are developed for 1975, 1985 and 1995. It also includes actual statistics for 1970. By summing all of its DASZ projections in each of our DSP districts, 1985 (close enough to 1984) projections by district are developed.

But these projections leave much to be desired. The magnitude of the demographic projections is based upon the report "Albuquerque Area 1960-2000" by Kirschner Associates. More recent studies and current estimates show the Kirschner projections to be unrealistically high.[3] The land use distribution of the COG study is based upon the "City of

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[2]The geographically based classes were originally established on the premise that different load characteristics are identifiable by areas of the city.

[3]See, for example, "Population and Employment Projections, 1975-2020," Bureau of Business Research, UNM, 1973.

Albuquerque 1984 Master Plan" developed in 1963. Many of the premises of that plan have been denied by actual development. For example, that plan called for low density residential development along Montgomery Blvd., now one of the highest density corridors in the city.

The demographic distributions by district for 1970 and, projected, for 1985, are valuable statistical parameters for use in assigning 1984 residential load to district. But qualitative information that cannot easily be reduced to raw statistical data must ultimately be relied upon. Careful studies were made of the nature of the residential development in each district as well as the available developable land, the recent patterns of development, patterns of and plans for extensions of utilities, roads, etc. This basic understanding of the nature of the growth of the city became indispensible in applying the demographic parameters to the problem at hand.

The 1984 district demographic parameters were then calculated by considering the change in each district's share of the total load from 1973 to 1984. For example in 1970, District 25 had a population of 17,900, or about 5.7% of the study area's 314,000. By aggregating DASZ figures in the "1995 Development Patterns," the 1985 projected District 25 population of 29,900 is about 5.2% of the area's projected 580,000. The 5.2% figures was then reviewed on the basis of other data collected, and then applied to population projections developed using Public Service Company of

New Mexico data and the recent studies mentioned above.

A similar process was used for developing 1984 projections for housing units by district. Each district was then assigned a figure for KW per household according to the area of the city. These figures were developed from the residential base load analysis (Chapter Three) and adjusted for the increasing appliance saturations anticipated. For District 25, a figure of 5615 residential units was projected for 1984 (this does not include master metered apartments nor electric hot water heated customers). The per unit mean diversified demand, coincident to peak for that area is 1.443 KW, yielding a district residential load of 5615 x 1.443 = 8102 KW.

Having completed this process for each district it is necessary to assign the district load projections to the Basic Load Areas. As the area projection was disaggregated to districts, so shall each district projection be assigned to BLAs. However this process is not nearly so complicated. There are no BLA demographic projections nor BLA historical data.

Each BLA is examined and the potential number of new housing units (single family, multi-family and mobile home) is noted. Any potential loss in the housing stock is also recorded. The net new housing units foreseen for each BLA are added together to get a total housing increase for the district. If this is close to the increase projected in the district demographic calculations (described on page 68), we are in business. Otherwise, the BLA housing projections must be re-examined.

Once they are deemed satisfactory, the mean KW per unit is calculated. A portion of the load growth is attributed to increased appliance saturations for the existing household; the balance is divided by the number of new homes projected for the district. This figure times the number of new units in a BLA, plus the 1972 load, plus the appliance saturation growth allotment, yields the 1984 BLA residential load projection.

We can use a hypothetical example for clarification. Let us say that a district has 5 BLAs, a 1972 residential load of 300, and a projected 1984 residential load of 800. The base year data and the calculations are in Table 10. We will assume that there are only single family homes in our example.

The number of new homes projected for 1984 is developed (Column 2). An allowance is made for load growth by the existing households of 30% of their present load (Column 3).[4] This totals 90 KW, making 390 KW the total 1984 load accounted for by the original homes. Thus the projected 800 KW less the 390 KW leaves 410 KW to be attributed to new construction. 410 divided by 340 (new homes projected) equals 1.21 KW per unit, a reasonable expectation, so the new household

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[4]The 30% load growth is over a 12 year period. This represents a 2.21% annual compound growth rate which is representative of the typical household in Albuquerque. It is generally caused by purchase of additional electrical appliances, additions to the home, conversion from gas to electric appliances and installation of central refrigerated air conditioning.

TABLE 10

HYPOTHETICAL BLA RESIDENTIAL LOAD PROJECTION DATA

BLA	(1) 1972 LOAD (KW)	(2) 1984 PROJECTED NEW HOUSEHOLDS (UNITS)	(3) EXISTING HOMES NEW APPLIANCE LOAD (1) x 30% (KW)	(4) NEW HOUSEHOLD LOAD (2) x 1.21 (KW)	(5) 1984 TOTAL LOAD (1)+(3)+(4) (KW)
1	50	70	15	84	149
2	60	60	18	72	150
3	70	90	21	109	200
4	80	20	24	24	128
5	40	100	12	121	173
	300	340	90	410	800

projections are used. The new household load is calculated (Column 4) and added to the 1972 load (Column 1) and the new appliance load of the original homes (Column 3) to get the 1984 total residential projected BLA loads.

The Commercial Projections

There are eleven commercial customer load classes (Table 8). Certain of these classes are considered together for load projection purposes while the special type classes are considered individually. The latter are the master metered apartments, schools, large 24 hour activity industries, water pumping stations, and hotels and motels. For each of these classes, development patterns unique from the general commercial patterns exist, and can, to some extent, be identified.

The remaining classes, including the typical 8, 12, and 16 hour businesses, service stations and billboards, eating and drinking places, and theatres, entertainment places and churches all are to be found on C-1 and C-2 zoned lands, and follow a typical pattern of development in strip and cluster arrangements. They are therefore considered together.

Before developing the projections, the load base, by district and by load class, was derived. This allowed calculations of each class load as a percentage of the total commercial load. These percentages were then adjusted to reflect changing development patterns and became the basis for allocation of the 1984 commercial load projection.

For example, for class 16, hotels and motels, the 1972 diversified demand is 5,796 KW, or about 2.4% of the total diversified load of 246,804 KW. Only minor changes in the proportion of hotel and motel rooms to the size of the city (measured in population, bank clearings, employment or some other parameter) is anticipated over the next decade. So the 2.4% figure is used for 1984. .024 times the 1984 projected diversified load of 528,000 KW yields the approximate projected class diversified load of 12,763 KW.

Recalling the KW projections for 1984 (see Table 9), we had developed both total and residential demand figures. The difference, after adjustment for spot loads and other extraordinary loads, represents the commercial load projection. This projection is then broken down between the classes by their respective percentages as mentioned above.

With each commercial class load projection in hand, we will now look at the development of each class (or group of classes) district and BLA projections.

The term "master metered apartments" refers to larger apartment buildings or complexes with a minimum load of approximately 30 KW (usually about 20 dwelling units), and where all of the units are metered and billed together. Most new master metered apartments will be built at easily identifiable locations usually already having compatible zoning. This knowledge, coupled with an analysis of the 1972 master metered apartments, is the basis of this class projection.

The 1972 class load is taken and the percentage of the total for each district is calculated. Since the total number of units is known, it can be multiplied times the percentage just calculated to get an estimate of the number of apartment units in the district.

A projection was made for new apartment units along with the population and housing unit projection discussed above (page 67). This projection was broken down by district using the information on apartment locations. The projections were added to the estimates of existing units to arrive at district figures for the 1984 stock of master metered apartments units. The total number of units was divided into the projected class load, and the distribution of the units used to simulate the distribution of the load.

With the district master metered apartment loads projected, it remained to allocate them to BLAs. This simply involved assigning the loads among those BLAs with compatible zoning or compatible projected land use patterns.

Information from the Albuquerque Public Schools was depended upon for the school load projections. Fairly detailed plans for new school construction were available for the near future. And more general plans took us well into the 1980s.

Not only are new schools to be built, but existing schools are to be expanded. To account for this a percentage growth of each school's load was included in the projections.

Typical demands for elementary schools, junior high and mid-schools, and senior high schools were calculated. These means were then applied to the plans for new school development to arrive at the school load projections.

Of course, there are other schools to consider: the universities, trade and technical schools, and parochial schools. Here, future plans were not so available, and it was necessary to depend upon the trending of historical load growth patterns.

Projections for large industrial concerns similarly offered few problems. By necessity, such firms must locate in industrial parks in order to have the necessary services and for that matter, the proper zoning. Most such industrial parks are clearly defined, and potential locations for new parks are limited to locations with railroad sidings, good access to interstate highways, or both.

First, the existing industrial developments were identified, their loads were checked (nearly all industrial customers are demand metered), and the acreage of their plants approximated. With this information, average KW load per acre of industrial development was calculated. Next, projected industrial development was identified by BLA location and size in acres. By using the average demand per acre already calculated, projected industrial load was easily arrived at.

The information necessary for development of the water pumping station projections was obtained from the City of Albuquerque. The city's plans for future new tank sites including pump sizes allowed direct calculation of the projected class load from the pump motors horsepower ratings.

For the hotel and motel BLA projections, locations for future development were first identified. These included points along the major highways accessing the city, highway interchanges and present hotel and motel sites that have additional development potential. For each of these sites, a projection was made of the number of rooms to be developed. By working with number of rooms, the problems of working with hotels and motels of different sizes were largely dispensed with.

The room projections were then totaled and this figure divided into the total KW increase projected from 1972 to 1984 for the class. This KW per room ratio was then applied to the BLA room projections to arrive at class and BLA load projections.

With each of the special classes projection methods examined, we arrive at the task of developing the projections for the general commercial classes: 8, 12 and 16 hour businesses (classes 7, 8 and 9), service stations and billboards (class 11), eating and drinking places (class 15), and theatres, entertainment places and churches (class 17).

Each of these classes tend to develop in standard cluster or strip developments. The patterns as well as the respective zoning form a clear pattern in Albuquerque and allow relatively easy locational decisions in developing the projections.

We have already seen how the class load projections were developed (page 72). Here we assume that the general commercial loads remain a constant proportion of the total load. This gives us a 1984 load projection that must be broken down first by district and then by BLA.

Like the residential district projections, area studies such as COG's "1995 Development Patterns" can be used, but a good understanding of the area's historical growth and current development patterns must ultimately be relied upon. The COG report includes DASZ projections of employment by SIC major groupings as well as acreage by zoning, vacant and in use. The employment figures are useful for developing percentages of total commercial activity for each district. As population and other parameters were used in developing the residential district projections, so employment parameters are used for developing the commercial district projections. The percentages so derived are adjusted to reflect the most recent information on development patterns and are then applied to the commercial load projection control totals to arrive at the district projections. Each class then receives a load allocation in proportion to its 1972 share of the load.

The remaining task is to assign the district and class load projections to the BLAs. As was done for the residential projections, the available and likely to be developed acreage is identified. For each district it is summed and the total acreage divided into the district load projection to determine the BLA load allocation.

This concludes the examination of the load projection process, the second part of the load data. Part III will look toward future use of the Distribution System Planning Program including improving the way in which the load base is developed.

PART III

Part III considers the possibilities and the limitations of the DSP load base. Chapter Five deals with the methodology used for developing the residential demand estimations. Chapter Six considers an information system for developing the load base and concludes with comments on the inherent limitations built into the structure of the DSP load data.

CHAPTER 5

IMPROVING THE RESIDENTIAL DEMAND ESTIMATIONS

The methodology used for residential demand estimation was discussed in the latter half of Chapter Three. That chapter ended on the note that there are serious limitations in that process. It is the purpose of this chapter to examine two areas that can be improved: the development of the regression equation and the appliance saturation estimates.

The Regression Equation

The development of residential load estimates described in Chapter Three allowed certain conclusions to be made concerning the independent variables. First, that KWH sales are unexcelled as a tool is estimating demand. That is, the load factor reigned supreme in the estimating process. But three appliances demonstrated significant roles in affecting residential demand: hot water heaters, air conditioners and ranges. The question then becomes: how can they best be introduced into the estimating process?

Until recently, Public Service Company of N.M. has offered a special, promotional rate to homes with electric hot water heaters in an effort to attract their use. As a result, every residential customer's rate code identifies the existence of such equipment. This can best be accommodated in the regression equation by including a yes or no variable for electric hot water heaters.

There is no similar record to identify customers having air conditioners. The problem is further compounded by the existence of different types of air conditioning units (evaporative coolers, window mounted units, and central refrigerated units). The value for the variable used in Chapter Three takes into account the different potential loads of each of the three units. But this compounds the opportunity for error when the equation is applied using <u>estimates</u> of appliance saturation.

An alternative method would consider "weather sensitive load" rather than that particular class of appliances: air conditioners. If one takes a customer's load during a period of time when there are no heating or cooling requirements, that would be considered a "base load." Any demand above and beyond that figure during the summer (or winter) would represent the weather sensitive load.

Obviously, we do not know the weather sensitive load if we don't know the load itself. But there is a possible substitute: a ratio of the peak month KWH sales to a relatively weather insensitive month KWH. For 1974, that proves to be June and April. What else other than cooling could cause a dramatic rise in the KWH consumption from April to June? Only the unlikely addition of significant new connected load. And using this method, that new load would be properly accounted for. The larger the KW rating of the cooling equipment, the larger the weather sensitive load and the larger the peak month KWH sales in relation to the off-peak sales.

No such alternative is available for estimating electric range saturations. Yet the effect of electric ranges upon residential load is undeniable. To improve its usefulness in estimating demand will require improved methods of estimating range saturation levels. This will be discussed below.

To repeat the question: how can these variables best be introduced into the estimating process? We can now offer a possible solution. The functional relationship was stated earlier as equation (2). The specific form to be tested using multiple linear regression is

$$KW = a_1 \times KWH + a_2 \times EHWH + a_3 \times AC + a_4 \times RANGE \quad (8)$$

where $a_1, \ldots, a_4$ are regression coefficients whose values should be greater than 0, EHWH is 1 if the home has an electric hot water heater and 0 if not, AC is the ratio of the peak month to the off peak month KWH sales, and RANGE is 1 if the home has an electric range, 0 if not, and a value between 0 and 1 representing the range estimated saturation level when the equation is being applied to groups of customers.

The Appliance Saturation Estimates

A need still remains for appliance saturation estimates. At minimum, electric range saturations are needed. Air conditioning saturations are useful for testing the weather sensitive load theory outlined above. Other appliances may be considered as well. And an array of other uses for such estimates exist for the electric utility.

A utility is in an excellent position to conduct such a study. The survey can be conducted as part of the billing process. That is, sending out and receiving back questionnaires with the monthly bill. Traditionally the percentage of responses is lower for surveys disseminated with bills rather than in separate mailings. However, surveys could be sent to all customers rather than to a sample of customers and without incurring the costs of a separate mailing.

Statistically biased samples could be avoided in this manner. In Public Service Company's most recent appliance saturation survey, conducted in October, 1973, this presented a problem. About 5% of the residential customers were surveyed, about half of them responding. However, it was necessary to develop statistically significant results for several different rate codes, some of which have proportionately few customers. Thus it was necessary to survey a larger percentage of these rate codes, and in some cases, the entire population was surveyed.

But when the results are analyzed for demand estimation purposes, some of these special rate codes need not be segregated out, therefore biasing the data. This causes the need for complicated data transformations in order to meet the assumption of unbiasness required by regression analysis. When the entire population is surveyed, the sample bias problem is eliminated (unless one determines a bias in the pattern of responses).

It will be recalled that the saturation estimates are made by geographical areas (as described in Chapter Three, by the 21 billing cycles). Larger sample sizes allow an increase in the number of geographical areas used for the estimations while maintaining a statistically significant sample size. The greater the number of areas within fixed boundaries, the smaller they must be. And the smaller they are, the greater the likelihood for homogeneity between the households. This in turn means that the sample variance will be reduced, in effect improving the accuracy of the estimates.

Thus an appliance saturation survey of the entire population of residential customers is both feasible and, statistically, an improvement over the sampling methods currently employed. But the analysis of such a survey, as well as so much of the data that is employed throughout the development of the load data begs for a solid and rational system of data selection, manipulation and transformation. Chapter Six will, in part, deal with that problem.

CHAPTER 6

LIMITATIONS OF THE DATA BASE

As we have now seen, developing the DSP data base can be a complex chore, and a potentially rather onerous one at that. Raw customer data must be collected, analyzed and transformed. Demands must be estimated requiring surveys, test metering and statistical analysis. Projections must be made requiring insight (and foresight) into the workings and growth trends of the city. And data must be organized and transformed to meet the model's rigid input requirements.

This chapter will deal with the issues of improving the user's ability in dealing with these tasks and pointing out the ultimate limitations one must run into. First, a systems analysis approach will be developed for the entire process from raw customer data to a coded load base. Next, we will examine how, through the use of minor changes in the DSP program, the user's latitude in inputting the load data will be significantly improved. Finally, the ultimate limitations of the load data will be considered.

Developing the Load Base - A Systems Approach

Chapter Three described the process used to develop the load base. Starting with data from the report "PNM 558" (Figure 16) data was transformed and estimating procedures were incorporated until the properly formatted "BLA Load

Data" (Table 3) was arrived at. This process was completed manually, allowing additional errors to enter the process.

By computerizing this process, more accurate results can be obtained with less man time. The master customer records of the company can be tapped to get exactly the data needed in the format desired. A description of seven programs designed to meet this end follows.

Program #1 selects data from the customer master records for the month of peak demand. The data selected includes the customer account number, number of days in the billing period under consideration, DASZ, SIC code, KWH sales, KW demand for demand metered customers, and rate code. There would be records for about 120,000 customers.

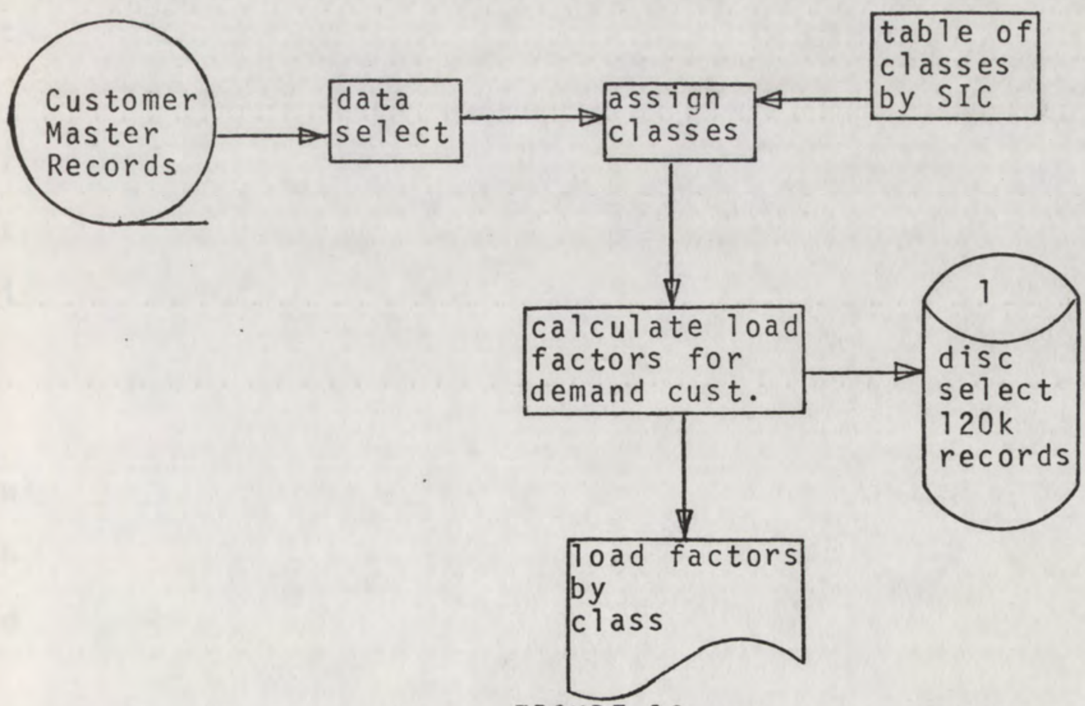

FIGURE 18
FLOW DIAGRAM FOR PROGRAM #1

Each customer record is then assigned to a load class. A table assigning a load class to each SIC code is called upon by the program for this purpose. For residential customers, the rate code may be used for class assignment purposes.

A load factor is then calculated for each of the demand metered customers using equation (1) (page 14). Then a report is listed giving the means of the calculated load factors for each class along with other statistical indicators. The data selected, along with the load class assignments, are stored on disc for use by succeeding programs.

Program #2 assigns demands and diversifies demands for each customer. There are three parts to the program: (1) assigning demand to non-residential customers, (2) assigning demand to residential customers, and (3) diversifying the demands of the demand metered customers.

(1) A list of diversified load factors for each non-residential customer class is read in. For each non-residential customer that is not demand metered, a demand is calculated using the formula:

$$\text{KW Demand} = \frac{\text{KWH}}{\text{CDLF x days x 24}} \qquad (9)$$

where CDLF (class diversified load factor) has been computed by adjusting the class load factors listed by program #1 and dividing them by appropriate diversity factors.

(2) Demand is estimated and assigned to residential customers by using the demand model developed by multiple

regression analysis. The variables to be used in the regression equations may be included in the customer record (KW sales, or rate code for identifying electric hot water heaters). Or a table of additional variables such as appliance saturation levels by DASZ or DAZ may be called upon by the program. If the equation used is of the form of

$$KW = a_1 \times KWH + a_2 \times EHWH + a_3 \times RANGE + a_4 \times AC, \qquad (10)$$

the April KWH sales can be included in the original data selected for computing AC, the air conditioning saturation coefficients (see page 81). If KW is not a diversified demand, then the results of the equation must be multiplied by a diversity factor.

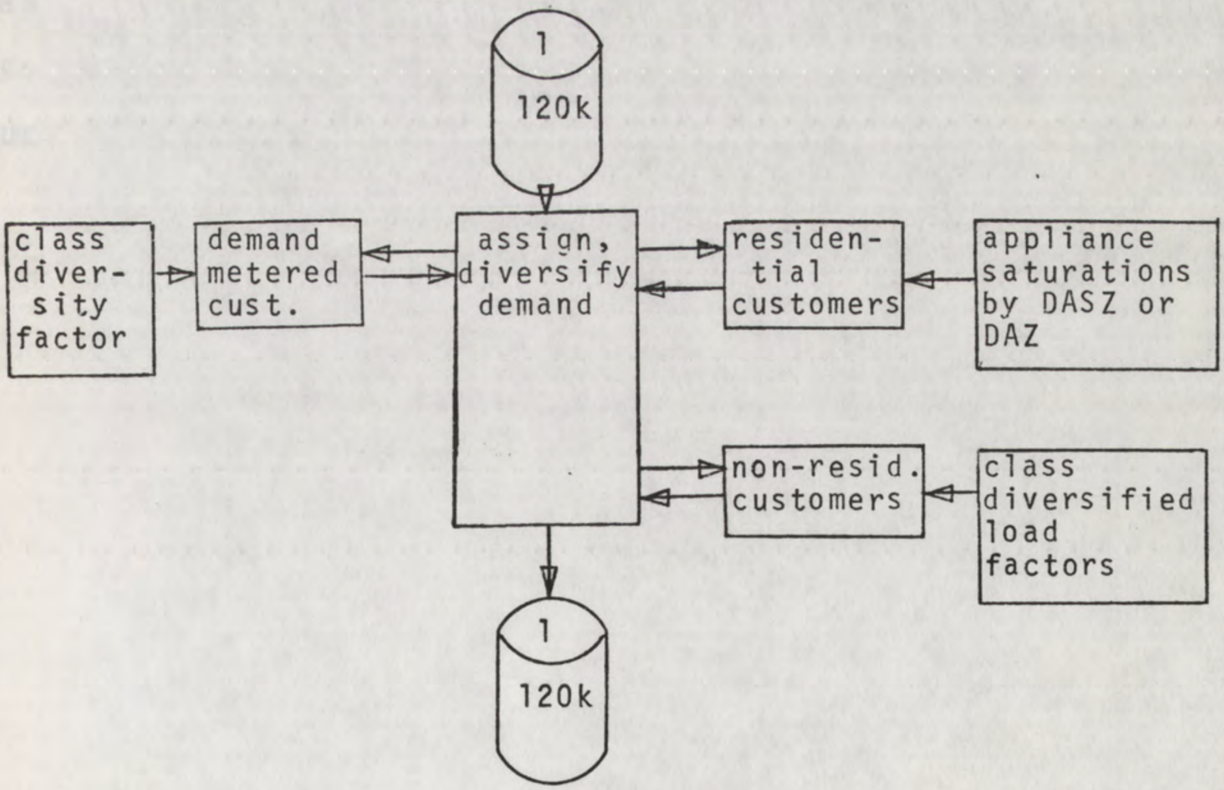

FIGURE 19
FLOW DIAGRAM FOR PROGRAM #2

(3) A table of diversity factors by class is called upon by the program. Then the loads for each demand metered customer are multiplied by their appropriate diversity factors.

Each customer record, now complete with a diversified demand, is returned to disc storage.

Program #3 sorts and sums records by class and DASZ. A sort is first performed by DASZ. Within each DASZ the demand for each class is summed. This produces a maximum of 8000 records (400 DASZs by 20 classes). Each record contains DASZ, class, and diversified KW demand. A report is printed with this information and the same data is stored on a newly created disc file (number 2). At this point it is no longer necessary to maintain the original 120,000 record disc file (number 1).

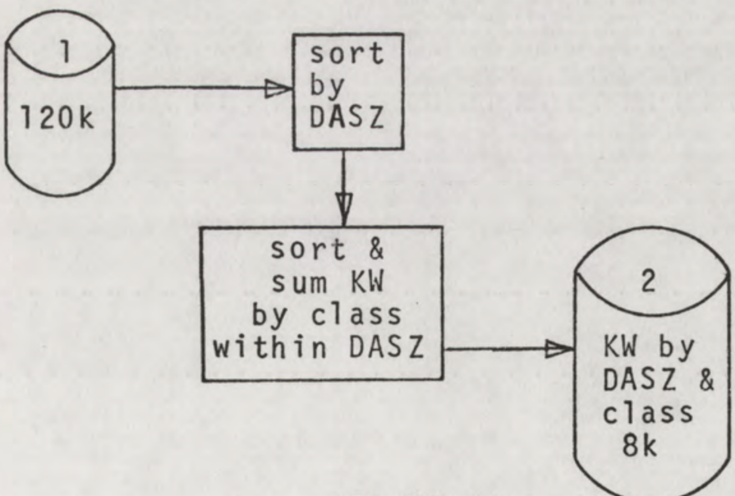

FIGURE 20
FLOW DIAGRAM FOR PROGRAM #3

Program #4 converts the demand data from a DASZ base to the BLA base required for input into DSP. A table of considerable size is read in containing the information necessary for the conversion to BLAs. It is of the form of a 400 x 20 matrix[1] with each location on the matrix containing a breakdown of the demand attributed to that particular DASZ and class. Specifically, it is a list of BLAs with the percentage of the demand in question that is to be assigned to it.

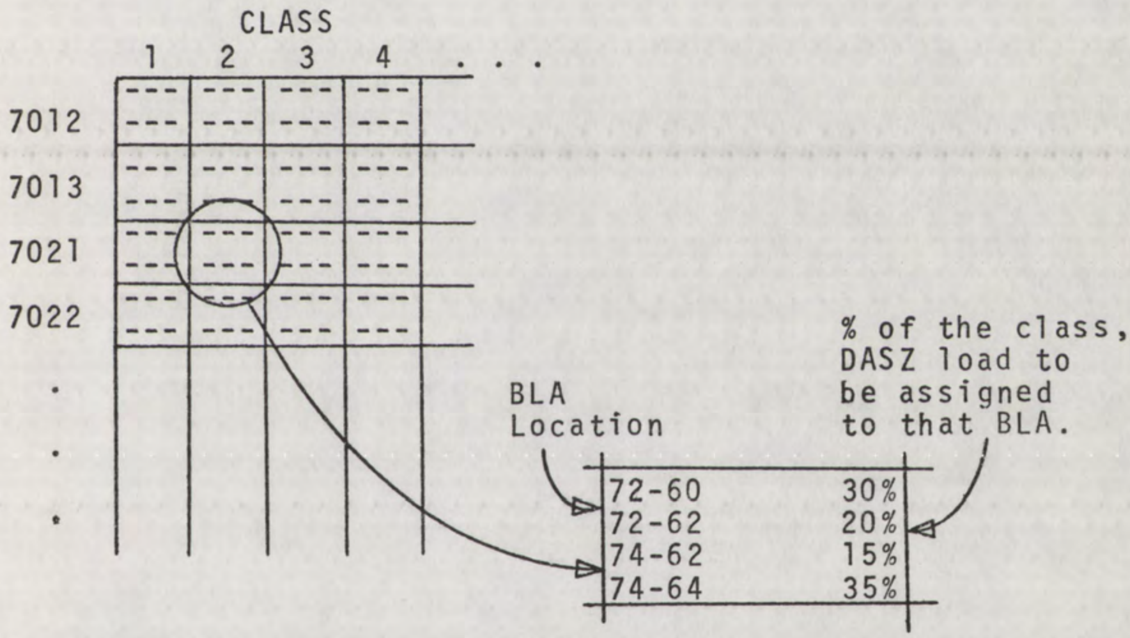

FIGURE 21
DASZ TO BLA CONVERSION TABLE MOCK-UP
SHOWING % ALLOCATION BY BLA

This program will produce a maximum of about 20,000 records containing demand by BLA and class. A new disc file (number 3) is created for this information and the old disc file (number 2) is purged.

[1]The 400 x 20 matrix represents loads for up to 20 load classes for each of approximately 400 DASZs.

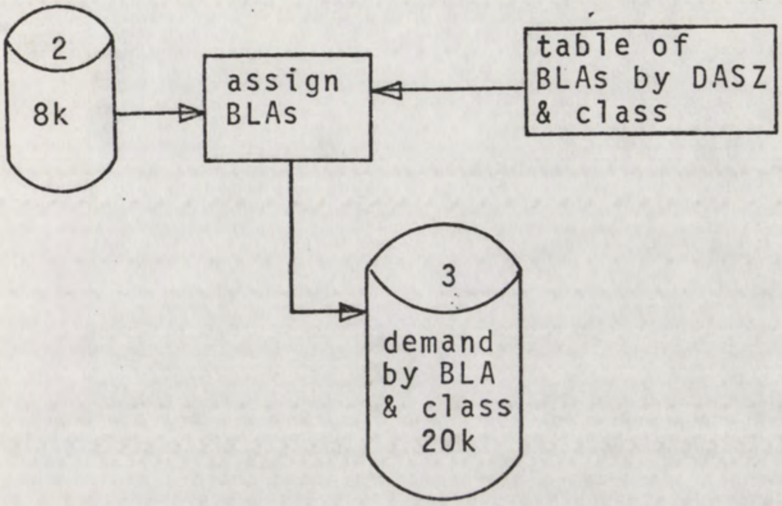

FIGURE 22
FLOW DIAGRAM FOR PROGRAM #4

<u>Program #5</u> sorts the records by BLA and, within BLA, by class. Multiple records for BLAs and class are summed. A new disc file (number 4) is created for this data with a maximum 10,000 records, and the old disc file (number 3) is purged.

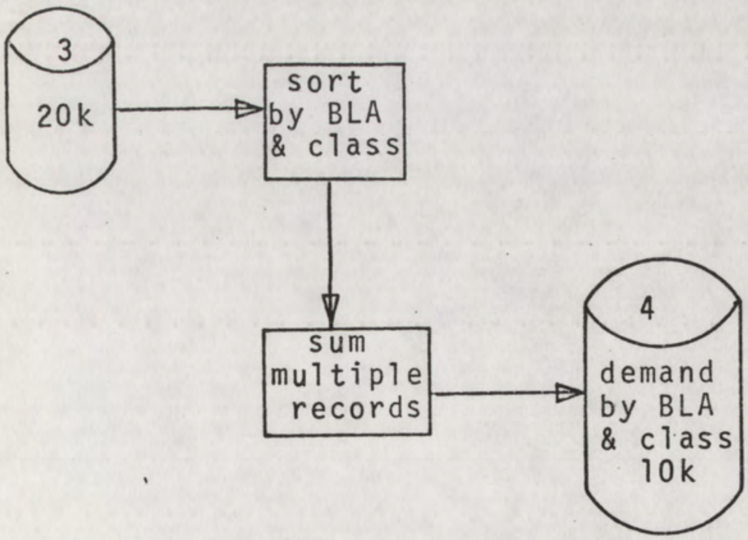

FIGURE 23
FLOW DIAGRAM FOR PROGRAM #5

At this point we have diversified demands by BLA and class as required for the input data. However, before listing it out, the data can be manipulated to give us a base useful for developing the load projections.

<u>Program</u> <u>#6</u> calls upon a table of coincidence factors by class and applies them to each BLA class load. Each of these loads, now calculated coincident to system peak are

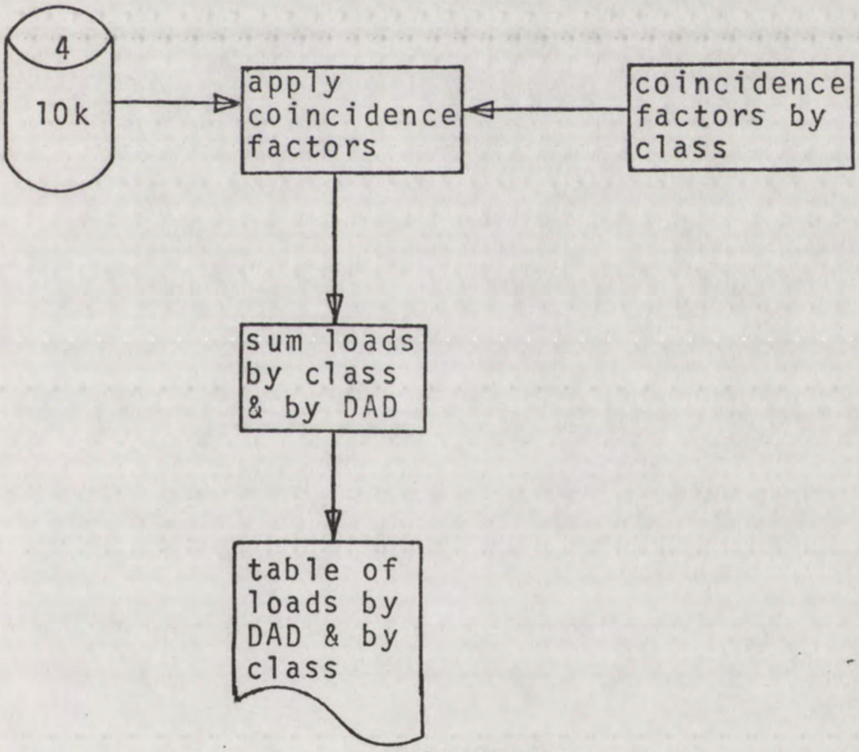

FIGURE 24
FLOW DIAGRAM FOR PROGRAM #6

summed by DAD and are printed out in a table of loads by Data Analysis District (DAD) and class (see "The Control Totals," Chapter Four).

<u>Program</u> <u>#7</u> is used to list the load data by BLA and class. It has two options, allowing either a hard copy

listing or having the data punched onto cards ready for input into the DSP program.

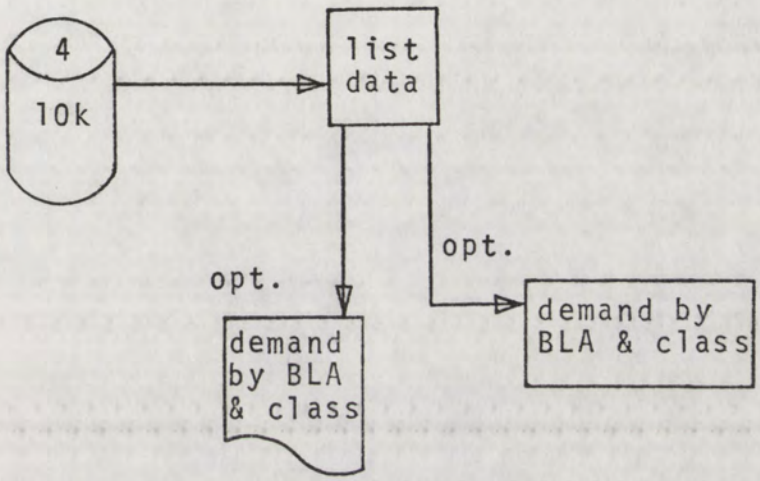

FIGURE 25
FLOW DIAGRAM FOR PROGRAM #7

<u>Latitude for the Load Data Input</u>

The load data is prepared for input into the computer in a format similar to that found in Table 3, "BLA Load Data." Each BLA class load may be described individually allowing for an accurate description of the load as it is estimated. However, this format is limiting when the time comes to describe the projections.

Two parameters must be considered when describing the load projections: the overall magnitude of growth, and its timing. Twenty Load Growth Trends (Table 6) are permitted by the program. For our study, each trend represents a different annual compound rate of growth.

This representation is satisfactory in describing the magnitude of the growth, but not its timing. For example, two areas may have the same development possibilities.

Area One, being in a part of town presently experiencing rapid and substantial growth, is expected to be developed in the next couple of years. Area Two is in a "younger" part of town, not yet extensively developed, but due to blossom within a decade. Both of these areas will most likely be described by the same Load Growth Trend Code. If Area Two has no load within a particular class, the time shift feature may be used. But an initial small existing load may rule out that possibility.

At present, only one line of load data input is allowed by DSP for each load class in each BLA. By eliminating that restriction, better representation of the timing of future development would be possible. For example, a class load could be assigned a Trend Code to account for a portion of the load projection; and the balance could be represented using the time shift feature to delay the inclusion in the electrical system.

Alternatively, the number of Load Growth Trends allowed could be increased. This would give the user the latitude to account for the timing of the new load as well as its ultimate size.

Either way, a significant problem could be avoided: projected load being simulated either earlier or later than intended, causing an imbalance in the geographical load distribution anticipated. This could cause equipment builds or delays beyond those that more accurate input devices would permit.

Ultimate Limitations in the Load Data

While the Distribution System Planning Program is potentially a useful tool in the electric utility's planning process, its value is limited by the accuracy of the load data. In the final analysis the limitations on the load data's accuracy are not due to the program but to the estimating and projecting methods employed by the user.

As long as any estimation must be used, the load base is compromised. Small users are not likely to be demand metered in the near future due to the additional expense that would be required for the meters and their installation. The estimation process for residential customers has potential for greatly improved accuracy, as we have seen in Chapter Five. But commercial customer load estimation procedures haven't such potential. The diversity in their types of appliances and patterns of use prohibit it.

Even considering these limitations, the load base can be developed to be a reasonable representation of the actual load experienced. However, making ten years of load projections look like the load that will actually be experienced ten years hence is another problem. No seers are we, and anything less renders us imperfect at this task. The hazards of making such projections have already been discussed (Chapter Four) and need not be repeated here.

Are these problems so severe that they render the model useless? Can they be worked around? No, not that severe, and yes, there are ways around the problems.

There are two major kinds of errors made in the small area projections. One is anticipating the wrong kind of development in an area. This may result in a larger or smaller projection than that which is ultimately experienced. More often the problem will not be with the type of development projected, but with the second kind of error, the timing of its construction. Thus the projections may not show load in an area for years after it is actually built up (or vice versa). Such errors would tend to bias the timing of the electrical system's expansion, but not necessarily its ultimate configuration.

Let us suppose that the original system load projection control total was accurate, but the geographical dispersion of that load varied from year to year. DSP would still account for the approximate expansions required and their associated costs, and substations and other equipment would be assigned BLA locations, only the year of build would be in error. In short, the simulated results would still be valid planning parameters.

Thus, while there are limitations in the load data, they neither render the model inoperable nor the results unusable. For a rough model, with bandages and open sores, is more useful than no model at all.

To argue that these limitations in the data base are death blows to DSP denies so much of our day to day experiences. An architect's program must anticipate the needs of his client decades into the future. A student must gaze into his imaginary crystal ball to decide what course may directly apply to his future career. Choosing from a lunch menu may require guessing what is for supper 6 hours later.

Our lives are filled with decisions that must be made by anticipating future outcomes. Sometimes those anticipations are wrong and therefore the decisions are wrong. But more often than not that gaze into the future enables us to better plan present actions.

And that is what DSP is all about. We do not deny the limitations of our knowledge of future load growth; but we fervently uphold that what knowledge we do have should be put to the best possible use, and a model such as the Distribution System Planning Program offers that opportunity.

GLOSSARY

GLOSSARY

ADJACENT SUBSTATIONS - Substations whose feeders are connected by switches allowing transfer of load between them.

APPLIANCE SATURATION LEVEL or COEFFICIENT - The probability that a customer has a certain appliance, or the mean appliance ownership for a group of customers.

BASE LOAD - That portion of a load not caused by weather sensitive equipment, i.e. heaters and air conditioners.

BASE YEAR - That year represented for the DSP input model; in this case, 1972.

BASIC LOAD AREA (BLA) - The name for the grid cells into which the study area is divided.

BILLING CYCLE - An accounting device whereby all customers are assigned to one of twenty one cycles on a geographic basis. Each cycle is billed once a month, as there are usually 21 working days a month.

BULK STATION - A station that recieves power from a transmission line, may or may not reduce voltage, and send power on to another bulk station or a distribution substation. Also called <u>switching station</u>.

BUS - Connecting points on circuits, e.g. where a subtransmission line connects to a distribution substation.

CAPACITY - The load for which an electrical apparatus is rated. If exceeded, the equipment could be damaged.

CIRCUIT - A conductor, or line, through which power flows.

CLASS - See <u>Load Class</u>.

CLASS PEAK - The peak load for a class of customers at the time of their peak, not necessarily the same time as system peak.

COINCIDENCE FACTOR - A customer's or group of customers' peak divided into its load at system peak. The ratio is usually used to calculate load coincident with system peak from a class peak.

COINCIDENT PEAK or LOAD - Load for a customer or group of customers at the time of system peak.

CONSUMPTION - Kilowatthours used.

CURRENT - The flow of electricity.

CYCLE - See Billing Cycle.

DATA ANALYSIS DISTRICT (DAD) - A geographic area in a system dividing the Albuquerque area into approximately 30 areas.

DATA ANALYSIS SUB-ZONE (DASZ) - A geographic area in a system dividing the Albuquerque area into approximately 400 areas, or about 3 DASZs per data analysis zone.

DATA ANALYSIS ZONE (DAZ) - A geographic area in a system dividing the Albuquerque area into approximately 150 areas, or about 5 DAZs in each data analysis district.

DATA BASE - See Input Model.

DEMAND - Kilowatt load.

DEMAND METERED CUSTOMER - A customer for whom a kilowatt demand reading meter is installed. For small customers this is usually for sampling purposes.

DEPENDENT VARIABLE - In regression, that parameter to be estimated, by making it a function of one or more known independent variables.

DISTRIBUTION SUBSTATION - A station that receives power from a subtransmission circuit, transforms it to a lower voltage, and sends it out over feeders in the distribution system.

DISTRIBUTION SYSTEM - That part of the electrical system including the distribution substations, primary feeders, distribution transformers and secondary feeders.

DISTRIBUTION SYSTEM PLANNING PROGRAM (DSP) - A computer simulation model developed by Westinghouse for use in planning electrical sub-transmission and distribution systems.

DISTRIBUTION TRANSFORMER - A transformer on a primary feeder lowering the voltage to that with which the customer is served.

DIVERSITY FACTOR - A ratio of the peak demand for a group of customers divided by the sum of their individual peaks.

EMERGENCY CONDITIONS - The operating conditions when one component of the system is out of operation. Ratings of equipment are often somewhat higher under emergency conditions than under normal conditions.

EXCESS CAPACITY - When the load on a component is significantly less than its rated capacity under normal conditions.

FEEDER - A circuit emanating from a distribution substation and serving distribution transformers and individual customers.

FEEDER SYNTHESIS - That process used by DSP to design the pattern of and load on individual feeders.

FINAL YEAR - The last DSP study year for which there is load data input. For this study, it is year 13, or 1984.

GENERATOR - A machine which transforms mechanical energy into electric energy.

HIGH SIDE - The receiving side of an electrical component, usually a bus and usually in reference to the receiving voltage level.

INDEPENDENT VARIABLES - In regression, the variables, whose values are known, that are used to estimate the value of a dependent variable.

INPUT DATA or INPUT MODEL - The body of information that is organized, coded and read into a computer for use by the DSP program.

KILOVOLT - One thousand volts.

KILOVOLTAMPERE - One thousand voltamperes.

KILOWATT - One thousand watts.

KILOWATTHOUR - The basic unit of electric energy equal to one kilowatt of power supplied to or taken from an electric circuit steadily for one hour.

LINE - See <u>Circuit</u>.

LOAD - A rate of kilowatts. See <u>Watts</u>.

LOAD BASE - That portion of the input model describing the KW demand on the system in the base year.

LOAD CLASS - A group of customers with similar load characteristics used for development and input of the load base and load projections.

LOAD DATA - The load base and load projections.

LOAD FACTOR - The ratio of KWH consumption to KW demand adjusted for time.

LOAD FLOW - A series of calculations determining the voltage level load on different system components under normal and/or emergency conditions.

LOAD GROWTH DOCUMENT - An annually produced document of the Public Service Co. of N.M. outlining its projections of demand and sales for a ten year period. It is used for budgeting and system planning purposes.

LOAD GROWTH TREND - A year-by-year series of growth rates, per unit used by DSP for input for load projections based upon the base year loads.

LOAD MODEL - The load base.

LOAD PROFILE - A representation of load at different times of the day on a per unit basis, with peak load equalling one unit.

LOAD PROJECTION - A projection or forecast of KW demand over a period of time. For this project, it is for 13 years and upon a base year load.

LOAD TRANSFER - A change in the source of power on a circuit from one station or substation to another.

LOW SIDE - The sending side of an electrical component, usually a bus and usually in reference to the sending voltage level.

MEGAVOLTAMPERE - One thousand kilovoltamperes.

MEGAWATT - One thousand kilowatts.

MEGAWATTHOURS - One thousand kilowatthours.

MULTIPLE REGRESSION ANALYSIS - See Regression.

NORMAL CONDITIONS - Those conditions under which all components of the system are properly operating.

OVERLOAD - When a system component's load exceeds its rated capacity.

PEAK LOAD - The maximum demand experienced over an established time period.

PEAKING GENERATORS - Generators used to supplement the system capacity during times of peak load.

POWER - The time rate of electricity, measurable in watts, or for apparent power, in voltamperes.

PRIMARY FEEDER - A circuit running between a distribution substation and a distribution transformer.

R^2 (R-SQUARED) - A measure of goodness-of-fit in regression analysis. If $R^2 = 0.78$, then 78% of the variance of y about its average is explained in terms of the independent variables.

RATE CODE - A code with which every customer is assigned for billing purposes. It can be further used for identifying certain customer types and characteristics.

REGRESSION - A method for getting the best formula relating y to one or more variables $x_1, x_2, \ldots, x_n$. A typical regression equation is of the form $y = a_1x_1 + a_2x_2 + \ldots + a_nx_n + b$.

RELIEF ACTION - Transferring load from a system component that is overloaded.

SALES - Kilowatthour consumption.

SECONDARY FEEDER - A circuit running from a distribution transformer and from which a customer is served.

SERVICE AREA - That geographical area served by the electrical system under consideration.

SINGLE CONTINGENCY FAILURE CRITERIA - That standard by which the system can continue to operate even though one system component is out of operation.

SPOT LOAD - A specific KW demand for which both its load base and load projections are individually itemized and assigned to a distribution substation independently of the rest of the load data.

STANDARD INDUSTRIAL CLASSIFICATION CODE (SIC) - A system for classifying establishments by type of activity in which they are engaged.

STATION - Any bulk station, distribution substation or distribution transformer.

STUDY AREA - That area included in the DSP data base, generally coterminous with the service area.

SUBSTATION - See Distribution Substation.

SUBTRANSMISSION CIRCUIT or LINE - A circuit extending from a bulk station to a distribution substation.

SWITCHING STATION - See Bulk Station.

SYSTEM - Any group or sub-group of circuits and stations.

SYSTEM PEAK - The maximum KW demand experienced by a system over a specified time period.

T-STATISTIC - In a regression equation, a coefficient of an independent variable divided by its standard error. If it is greater than 2, then one can be 95% confident that the independent variable is significant in explaining variance in the dependent variable. Also called Partial-F.

TRANSFER - See Load Transfer.

TRANSFORMER - A piece of electrical equipment that changes the voltage of electricity.

TRANSMISSION CIRCUIT or LINE - A circuit serving a bulk station, used primarily to move large quantities of energy.

VOLT - The unit of electric force analogous to water pressure in pound per square inch.

VOLTAMPERE - The basic unit of apparent power.

WATT - The electrical unit of power, or rate of doing work.

WEATHER SENSITIVE LOAD - That portion of a load caused by weather sensitive equipment, i.e. heaters and air conditioners.

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