ELECTRIC POWER SYSTEM ANALYSIS

NAVFAC MO-204

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FOREWORD

This publication is a practical guide for the assembly and preparation of information required for electric power system analysis studies. It is written specifically for engineers of the Public Works Centers, Public Works Departments, Naval Facilities Representatives, and Engineering Field Divisions.

This publication is certified as an official publication of NAVFAC and has been reviewed and approved in accordance with Secretary of the Navy Instruction 5600.16.

A. R. MARSCHALL
Rear Admiral, CEC, U.S. Navy
Commander
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CONTENTS

Page

CHAPTER 1. INTRODUCTION

1.1 Purpose 1
1.2 Scope 1
1.3 Computer Capability . . . . . .
1.4 System Analysis and Data Assembly 1
1.4.1 One-Line Diagram 1
1.4.2 Impedance Diagram 1
1.4.3 Line Impedance Calculation 2
1.4.4 Load Survey 2
1.5 Data Accuracy 2
1.6 Benefits of System Analysis 2

CHAPTER 2. SYSTEM SURVEY

2.1 Purpose 3
2.2 Two Phases Involved 3
2.3 Survey Requirements 3
2.3.1 Plot Plan 3
2.3.2 Circuit Routing Plan 3
2.3.3 One-Line Diagram 3
2.3.4 Impedance Diagram 3
2.3.5 Load Survey 4
2.3.6 Utility (Source) Impedance 4
2.3.7 Utility Voltage Regulation 4
2.3.8 Operating Problems 4
2.3.9 Equipment Inventory 4
2.4 Small System Survey 4

CHAPTER 3. ONE-LINE DIAGRAM

3.1 General 17
3.2 Checklist 17
3.3 Future Projects 18

CHAPTER 4. IMPEDANCE DIAGRAM DEVELOPMENT

4.1 Essentiality 21
4.2 100,000 KVA Base for Impedances 21
4.3 Example of Transformer Impedance Calculation Using Tables 4 and 5 23

CONTENTS (Continued)

Page

CHAPTER 5. DETERMINATION OF ELECTRIC LINE IMPEDANCES

5.1 Line Impedance Calculations 27
5.2 Impedance Tables 27
5.3 Use of the Line Impedance Tables 27
5.3.1 Underground Cable Impedance 27
5.3.2 Overhead Line Impedances 27
5.3.2.1 Example No. 1 28
5.3.2.2 Example No. 2 29
5.3.2.3 Example No. 3 29
5.3.2.4 Example No. 4 30

CHAPTER 6. LOAD SURVEY

6.1 Accuracy Requirements 81
6.2 Definitions 81
6.3 Documentation of Load Data 82
6.3.1 Load Calculation 82
6.3.2 Historical Demand Data 84
6.3.3 Distribution of Load 84
6.3.3.1 Example 85
6.3.4 Impact Loading 85
6.3.5 Future Load Data 86
INDEX Index-1

FIGURES

Figure No.	Title	Page
1	Typical Daily Voltage Regulation (Utility) . . .	5
2	Voltage Regulation Summer/Winter	6
3	Transformer Inventory	7
4	Circuit Breaker Inventory	8
5	Voltage Regulator Inventory	9
6	Reactor Inventory	10
7	Motor Inventory (Over 100 HP)	11
8	Generator Inventory	12
9	Relay Inventory	13
10	Recloser Inventory	14
11	Switch and Fuse Inventory	15
12	Partial One-Line Diagram	19
13	Partial Impedance Diagram	25
14	KW, KVAR, KVA, Pf Angle Relationship	82
15	Typical Feeder with Distributed Loads	85
16	Typical Feeder with Loads Consolidated	85
17	Hourly Demand Summer/Winter	87
18	Annual Peak Demand	88
19	Partial Load Diagram	89

TABLES

Table No.	Title	Page
1	Ohms to Percent Conversion Factors	21
2	Typical Reactance Values for Synchronous Machines Per Unit Values on Machine KVA Rating	22
3	Typical Reactance for Induction Motors Per Unit Values on Machine KEVA Base	23
4	Insulation Levels for Oil - Immersed Transformers	23
5	Typical Impedances for Transformers	24
6	Reserved for Future Use	
7	Impedance Tables for Underground Cable	31
7.1	Type 5KV 3/C Rubber and XLP	31
7.2	15KV 3/C CU Rubber and XLP.	31
7.3	5KV 3/C CU PILC	32
7.4	15KV 3/C CU PILC	32
7.5	23KV 3/C CU PILC	33
7.6	35KV 3/C CU PILC	34
7.7	5KV 3/C CU VC	34
7.8	15KV 3/C CU VC	35
7.9	5KV 3-1/C CU PILC	36
7.10	15KV 3-1/C CU PILC	41
7.11	23KV 3-1/C CU PILC	45
7.12	35KV 3-1/C CU PILC	48
7.13	5KV 3-1/C Cu VC	52
7.14	15KV 3-1/c CU VC	57
7.15	5KV3-l/C CU Rubber or XLPE	62
7.16	15KV 3-1/C CU Rubber or XLPE	66
8	Reserved for Underground Aluminum Cable Impedances (to be published when developed)	
9	Impedance Tables for Overhead Lines	70
9.1	Three Phase Copper	70
9.2	Three Phase ACSR	73
9.3	Three Phase Aluminum	76
10	Power Factor KW Conversion Tables	83
11	Power Factor KVA Conversion Tables	83

CHAPTER 1. INTRODUCTION

1.1 PURPOSE. This manual establishes guidelines for assembling electrical power system characteristics necessary to conduct a thorough engineering analysis of an electric power distribution system.

1.2 SCOPE. The manual provides step-by-step procedures for gathering information which is necessary for computerized analysis of an electric power distribution system. This information, some of which appears to be highly technical, is developed by following "cookbook" procedures which can easily be followed by personnel with the most rudimentary knowledge about electric power systems.

1.3 COMPUTER CAPABILITY. NAVFAC Engineering Field Divisions (EFDs) have computerized capability for solving complex electric power system problems. EFD Utility Division engineers can assist activities solve simple or complex problems involving their electric power system. Typical problem areas which can be quickly solved with computerized accuracy and documentation are capacity voltage levels, power factor, short circuit currents, effects of proposed construction and optimized benefits from system reinforcement.

1.4 SYSTEM ANALYSIS AND DATA ASSEMBLY. The initial step in electric power system analysis and evaluation is to prepare as complete and accurate a picture of the existing distribution system as is possible. System characteristics are assembled during a field investigation by activity personnel assisting NAVFAC Engineering Field Division (EFD) Utility Engineers or A&E's. This investigation encompasses a search of available engineering records and a system inventory and survey to validate the accuracy of the information which is developed. This information provides clear and concise documentation of the existing distribution system components and the operation of the system. Additional data is provided on future system requirements created by construction and normal load growth. Succeeding chapters in this manual provide guidelines for developing all necessary items to prepare an accurate composite picture of the electrical distribution system.

1.4.1 One-Line Diagram. The one-line diagram indicates, by means of a single line and symbols, the course and components or parts comprising an electrical distribution system and shows how these components are normally connected.

1.4.2 Impedance Diagram. The impedance diagram is a simplified

one-line diagram on which all significant equipment and line impedances are indicated.

1.4.3 Line Impedance Calculation. Simplified procedures and examples are provided showing how to calculate positive and zero sequence impedances per underground cables and overhead lines.

1.4.4 Load Survey. The load survey develops a composite picture of representative system loads for present and future conditions.

1.5 DATA ACCURACY. In system analysis, the adage "garbage in-garbage out" is especially accurate. Therefore, it is imperative that accuracy be stressed during the development of system characteristics. The development of these characteristics rests primarily with activity personnel because of their familiarity with the system. EFD engineers assist during this data gathering and provide guidance to make the task easier. In instances where activity personnel are not available for assembling system characteristics, EFD's can assist or the activity can obtain an A&E to assemble this information.

1.6 BENEFITS OF SYSTEM ANALYSIS. System analysis is a valuable tool in the efficient management of a utility system. Active participation in the periodic analysis of electric power distribution systems can provide the most reliable power to the Navy at the lowest possible cost. Some of the benefits derived through analysis are:

1. Identification and elimination of potential safety hazards.
2. Optimization of benefits from planned system improvements.
3. Improved system reliability.
4. Increased system efficiency.
5. Reduced operation and maintenance costs.
6. Increased activity knowledge about their power systems performance.

CHAPTER 2. SYSTEM SURVEY

2.1 PURPOSE. The purpose of the system survey is to assemble all data necessary to obtain a clear and concise picture of the electrical distribution system. This picture contains information about the physical plant and the normal operation of the distribution system.

2.2 TWO PHASES INVOLVED. The survey consists of two phases. First, available engineering records are gathered and examined. These records are then verified during the field investigation of the second phase. The field investigation also obtains system information which cannot be obtained in the records search.

The results of the analysis of an electrical distribution system are contigent upon the accuracy of all input data. It is therefore incumbent upon the personnel conducting the survey to insure the accuracy of input data is verified and, in so far as practical, that all required information is obtained and documented.

2.3 SURVEY REQUIREMENTS. The system survey shall be conducted to obtain the following items:

2.3.1 Plot Plan. The plot plan shows the geographical layout of an activity and includes streets and buildings.

2.3.2 Circuit Routing Plan. The circuit routing plan is a plot plan which has been annotated with the location of overhead circuits, underground circuits, substations, sectionalizing switches, and switching stations. Overhead circuits should be annotated with activity circuit designations. Underground circuits should be annotated showing activity circuits designations and how many spare ducts are available. Major substations, switching stations, and large loads should be identified by their names.

2.3.3 One-Line Diagram. A one-line diagram showing the normal operating configuration of all switches must be provided. Development of the one-line diagram is addressed in Chapter 3.

2.3.4 Impedance Diagram. The impedance diagram is a simplified one-line diagram which has been annotated with the positive and zero sequence impedances of system components. Development of the impedance diagram is addressed in Chapter 4.

2.3.5 Load Survey. Development of a system load survey is

2.3.6 Utility (Source) Impedance. The EFD will obtain the following source impedance information from the electric utility serving the activity:

1. Three-phase and phase-to-ground fault current availability at the activity metering point and, or,
2. Utility positive and zero sequence impedance from the activity metering point to the Utilities infinite bus expressed in ohms, or in percent on a specified base (e.g. 100MVA) , and,
3. Anticipated future changes to the above information.

This data should be accompanied with a simplified one-line impedance diagram showing positive and zero sequence impedances between the metering point and the utility infinate bus. This simplified impedance diagram is very important when the activity can be supplied from more than one source by the utility.

2.3.7 Utility Voltage Regulation. The typical daily voltage regulation of the utility should be provided if available. This data can be presented in the form of a graph similar to that shown in Figure 1 or as a listing of the nominal supply voltage and the typical daily maximum and minimum voltage. Data on typical summer and winter daily voltage regulation, Figure 2, should be provided if they are significantly different.

2.3.8 Operating Problems. Include a brief synopsis of system operating problems and outages caused by failure or malfunction of a component within the activity distribution system. Also include areas which activity personnel feel should receive particular attention during analysis to answer questions on system switching, future load capability, and system safety and reliability.

2.3.9 Equipment Inventory. Figures 3 through 11 provide sample formats which can be used to list information about the system. Transformer, circuit breaker, motor, generator, voltage regulator and reactor inventories provide data which are necessary for all system analyses. Relay, recloser and fuse inventories provide data which are required only if a system relay coordination study is going to be conducted.

2.4 SMALL SYSTEM SURVEY. For small systems, a detailed equipment inventory can be eliminated and all pertinent information can be shown on the "one-line diagram."

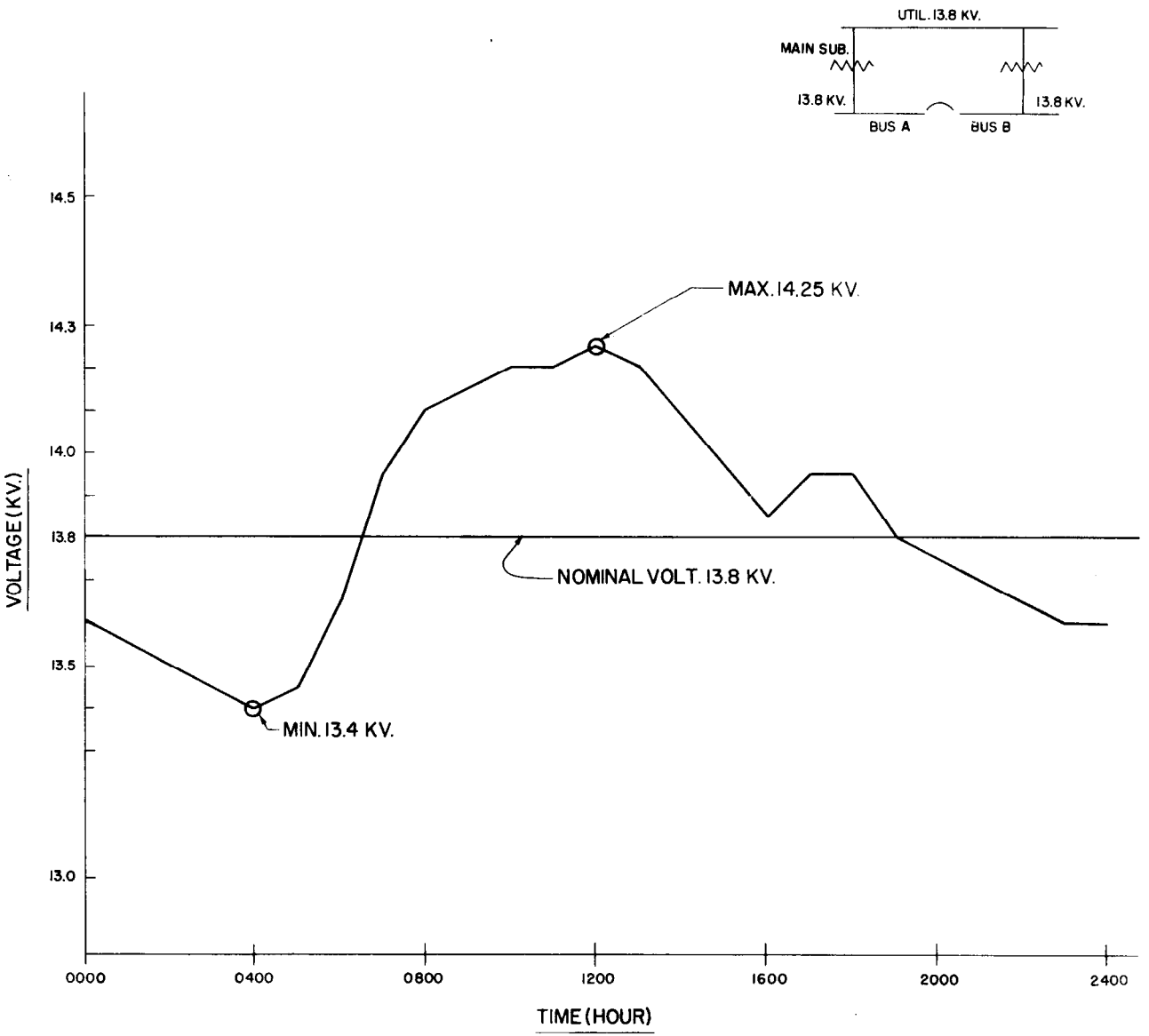


FIGURE 1
Typical Daily Voltage Regulation (Utility)

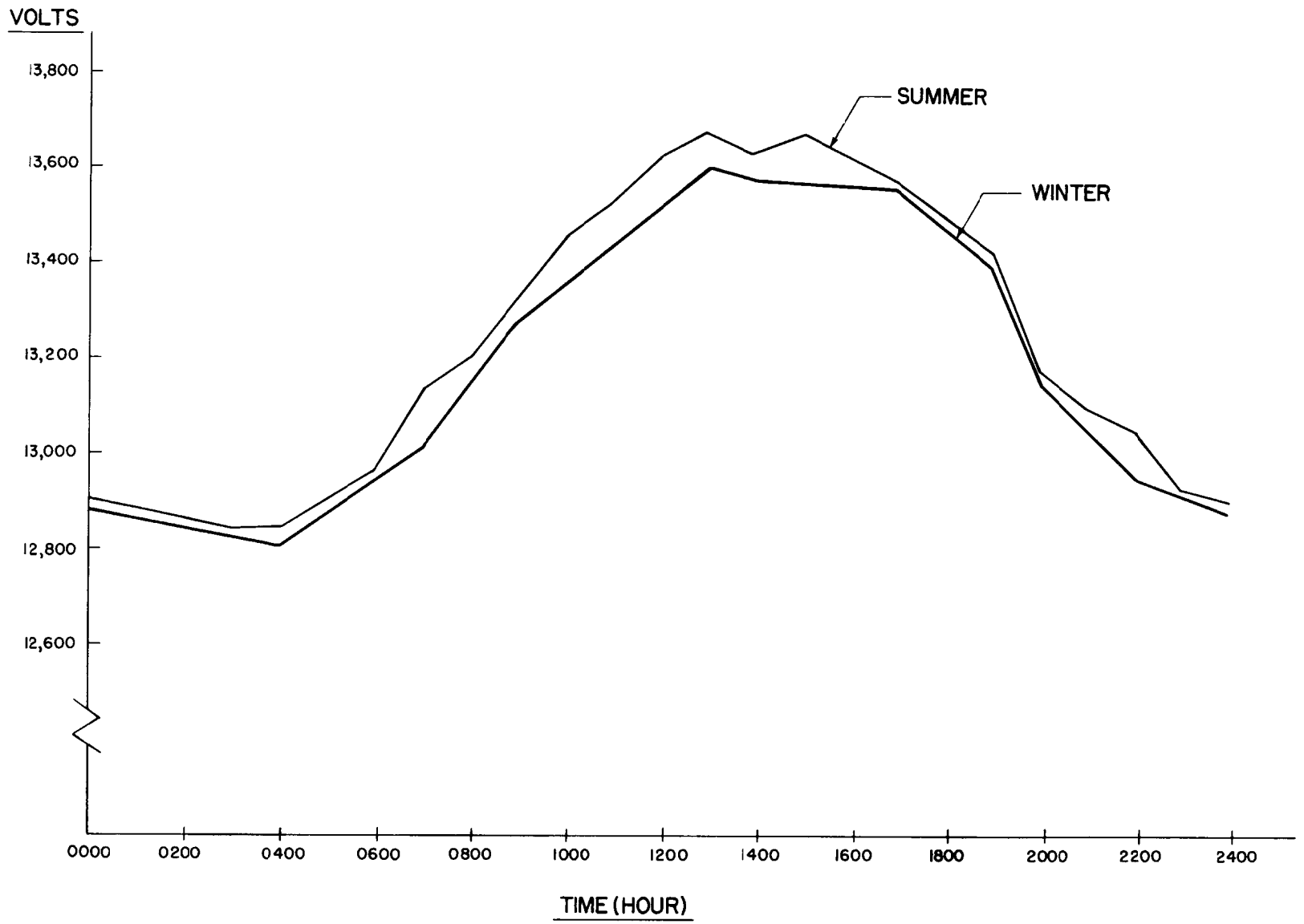


FIGURE 2
Voltage Regulation Summer/Winter

TRANSFORMER INVENTORY

ACTIVITY : _____ DATE: _____

TRANSFORMER LOCATION : _____

ACTIVITY TRANSFORMER NO: _____

MANUFACTURER, MODEL NO./TYPE: _____

RATING_____ KVA, (OA) (OA/FA) _____

VOLTAGES: Prim _____ KV/Sec. _____ KV phase: _____ Frequency: _____

WINDING CONNECTION: Primary _____ Secondary _____

IMPEDANCE : _____

PRIMARY TAPS

RANGE_____

EXISTING SETTING_____

AUTOMATIC LOAD TAP CHANGER RANGE_____

TYPE OF GROUNDING AND GROUNDING IMPEDANCE_____

REMARKS[1]

[1] Additional nameplate data, general condition, age.

FIGURE 3
Transformer Inventory

CIRCUIT BREAKER INVENTORY

ACTIVITY : _____ DATE : _____

BREAKER LOCATION : _____

ACTIVITY BREAKER NUMBER : _____

CIRCUIT NUMBER : _____

MANUFACTURER : _____

STYLE/MODEL NUMBER: _____

TYPE: (AIR) (OIL) (MOLDED CASE) (VACUUM) (GAS)

RATING :

CONTINUOUS CURRENT: _____

INTERRUPTING CAPACITY (AMPS OR MVA): _____

VOLTAGE :

RATED : _____

OPERATING : _____

EXISTING SETTING OF TRIP

REMARKS [1]

[1] Condition of Breaker; type, quality and rage of trip devices that are part of the breaker.

FIGURE 4
Circuit Breaker Inventory

VOLTAGE REGULATOR INVENTORY

ACTIVITY: _____ DATE : _____

REGULATOR LOCATION: _____

ACTIVITY VOLTAGE REGULATOR NUMBER : _____

CIRCUIT NUMBER : _____

MANUFACTURER AND MODEL NUMBER : _____

TYPE : (INDICATION) (STOP-VOLTAGE) _____

RATING : KVA , KV , PHASE _____

FREQUENCY HZ CURRENT AMPERES _____

CONTROL RANGE : % RAISE, % LOWER _____

TYPE OF COOLING: _____

REMARKS

FIGURE 5
Voltage Regulator Inventory

REACTOR INVENTORY

ACTIVITY: _____ DATE: _____

REACTOR LOCATION: _____

ACTIVITY REACTOR NUMBER : _____

MANUFACTURER AND MODEL NUMBER : _____

CIRCUIT NUMBER : _____

TYPE : _____ (AIR tom) (IRON CORE) _____

APPLICATIONS : (CURRENT LIMITING) (NEUTRAL GROUNDING) (DUPLEX) (SHUNT) _____

RATINGS : KVA , KV , VOLTS DROP, _____

AMP CONT. , AMP , SECONDS , _____

PHASE , OHM/PHASE , _____

TAPS : _____

Remarks :

FIGURE 6
Reactor Inventory

MOTOR INVENTORY (OVER 100 HP)

ACTIVITY: _____ DATE : _____

LOCATION: _____

ACTIVITY MOTOR NUMBER, DESIGNATION OR USE: _____

TYPE: (D.C.) (SYNCHRONOUS) (INDUCTION): _____

HORSE POWER: _____

VOLTAGE: _____ PHASE : _____ FREQUENCY: _____

CURRENT : _____

POWER FACTOR: _____

LOCKED ROTOR LETTER: _____

SPEED: _____

METHOD OF STARTING: (FULL LINE) (REDUCED VOLTAGE) _____

SUBTRANSIENT REACTANCE (XD"): _____

TRANSIENT REACTANCE (Xd'): _____

ZERO SEQUENCE REACTANCE (Xo): _____

Remarks

FIGURE 7
Motor Inventory (Over 100 HP)

GENERATOR INVENTORY

ACTIVITY: _____ DATE : _____

GENERATOR LOCATION: _____

ACTIVITY GENERATOR NUMEER : _____

USE: (EMERGENCY) (STAND-BY) (PRIME POWER)

PRIME MOVER: (DIESEL) (GAS ENGINE) (GAS TURBINE)
(EXTRACTION STEAM TURBINE) (CONDENSING STEAM TURBINE)

VOLTAGE: _____

RATING (KW) : _____

POWER FACTOR: _____

FREQUENCE: _____ PHASE: _____

SPEED: _____

GEN. MANUFACTURER: _____

GEN. SERIAL NUMBER: _____

CONNECTION: (DELTA) (WYE)

GROUNDING: (NoNE) (soLID) (RESISTOR_____0HMS) (REACTOR_____OHMS)

REACTANCE :

SUBTRANSIENT (X″d) : _____

TRANSIENT (X′d) : _____

SYNCHRONOUS (Xd): _____

ZERO SEQUENCE (Xo): _____

REMARKS[1]

[1]0ther pertinent nameplate data; age and condition of gen; Hours on prime mover since last overhaul; etc.

FIGURE 8
Generator Inventory

RELAY INVENTORY

ACTIVITY: _____ DATE : _____

FEEDER: _____

LOCATION: _____

BREAKER NUMBER: _____

MANUFACTURER: _____

NAME OF RELAY: _____

RELAY TYPE: _____

STYLE NUMBER: _____

QUANTITY: _____

TAP RANGE: _____

INSTANTANEOUS RANGE: _____

CT RATIO: _____

PT RATIO: _____

EXISTING SETTING

TAP: _____

LEVER: _____

VOLTAGE: _____

INST: _____

REMARKS[l]

[l]Any additional nameplate data or settings not provided above.

FIGURE 9
Relay Inventory

RECLOSER INVENTORY

ACTIVITY : _____ DATE : _____

LOCATION : _____

ACTIVITY NUMBER : _____

CIRCUIT NUMBER : _____

MANUFACTURER : _____

VOLTAGE : _____

PHASES : (30) (l0)

C0NTINUOUS AMP RATING: _____

INTERRUPTING RATING : _____

TYPE CONTRoL: (MECHANICAL) (ELECTRONIC)

OPERATING SEQUENCE : _____

REMARKS[1]

[1] Settings of electronic control unit, condition of recloser

FIGURE 10
Recloser Inventory

SWITCH AND FUSE INVENTORY

ACTIVITY: _____ DATE : _____

CIRCUIT : _____

LOCATION : _____

CUTOUT/SWITCH

MANUFACTURER : _____

STYLE NO: _____

TYPE : (ENCLOSED) (DEPENDENT) (OIL) _____

VOLTAGE : _____

CONTINUOUS CURRENT RATING: _____

INTERRUPTING CURRENT RATING: _____

FUSE

MANUFACTURER : _____

TYPE : _____

SIZE, IN AMPERES: _____

INTERRUPTING RATING: _____

REMARKS

FIGURE 11
Switch and Fuse Inventory

CHAPTER 3. ONE LINE DIAGRAM

3.1 GENERAL. A one line diagram indicates, by means of a single line and simplified symbols, the course and component devices or parts comprising an electrical distribution system. In so far as is feasible, the approximate geographical position of substations and lines should be maintained on the diagram. Because this drawing is a diagrammatic shorthand, every line, symbol, letter and figure has a definite meaning and a definite purpose in conveying significant information. In the interest of simplicity, duplication of information should be avoided and standard symbols used to the maximum extent possible. For example, the abbreviation CT should not be used because the symbol for a current transformer conveys this information. The rating should be specified as 600/5.[1] The abbreviation AMPS is not necessary because current transformers are rated only in amperes. Any non-standard symbols which are used to show special features or equipment must be explained in the drawing legend to make their meaning entirely clear.

3.2 CHECKLIST. The following is a check list of items which should be included on a line diagram:

1. The EFD will obtain the available three-phase and phase-to-ground fault current of the utility supply at the activity metering point. This information can be presented in amperes, MVA, or as an impedance to the utility infinite bus (impedance in ohms or per unit on a specified base). The EFD should also request the utility to provide an estimate of future three-phase and phase-to-ground fault levels. These estimates will provide an indication of utility system changes which may affect the future interrupting capability of Navy switchgear.
2. Transformers - show winding connections, voltages, rating, impedance, neutral grounding and its impedance, if any, and activity transformer number, or substation name.
3. Underground cables - size, length, type of insulation, 3-phase or 3-single phase, operating voltage, and activity assigned circuit number.
4. Overhead lines - size and type of phase conductors, line length, equivalent delta spacing, operating voltage, and circuit number. If there is a ground wire indicate its size and type of conductor.
5. Circuit breakers - show type by appropriate symbol (for example, oil, air, drawout) and activity assigned circuit breaker

[1](Multiple ranges should be indicated and the range used should be underlined)

number. Also show if breaker is operated normally open.

6. Switches and fuses - show rating in amperes, type, size, interrupting of the fuse, activity assigned switch number and normal operating position (indicate only if normally open).

7. Motors and generators (over 100 HP or KW) - KW or HP rating, power factor, synchronous or induction type, voltage, and subtransient reactance. The following additional data is required for synchronous machines; transient reactance, synchronous reactance, zero sequence reactance and the impedance of any grounding resistor or reactor installed on generators, including switching of the ground resistor or reactor and the normal operating position of this switch.

8. Location(s) where power purchased from a utility company is metered.

9. Reactors, capacitors and voltage regulators - show their KVA or KVAR rating, current rating, type of connection, tap range, phases, and activity assigned numbers. The following information is required if a relay coordination study is to be conducted:

a. Locations of potential and current transformer. For CTs show rating.

b. Relays and metering - show location, quantity and types of relays by standard IEEE device numbers (such as 51 for overcurrent relays, 67 for directional overcurrent relays.

3.3 FUTURE PROJECTS. An additional copy of the one line diagram should be annotated with all proposed projects which will reinforce, expand or modify the existing electrical distribution system. This diagram should show the length of new overhead and underground circuits and the size of new substations or new substation transformers. All projects should be identified by their assigned MILCON or repair project number. Figure 12 is an example of a one line diagram.

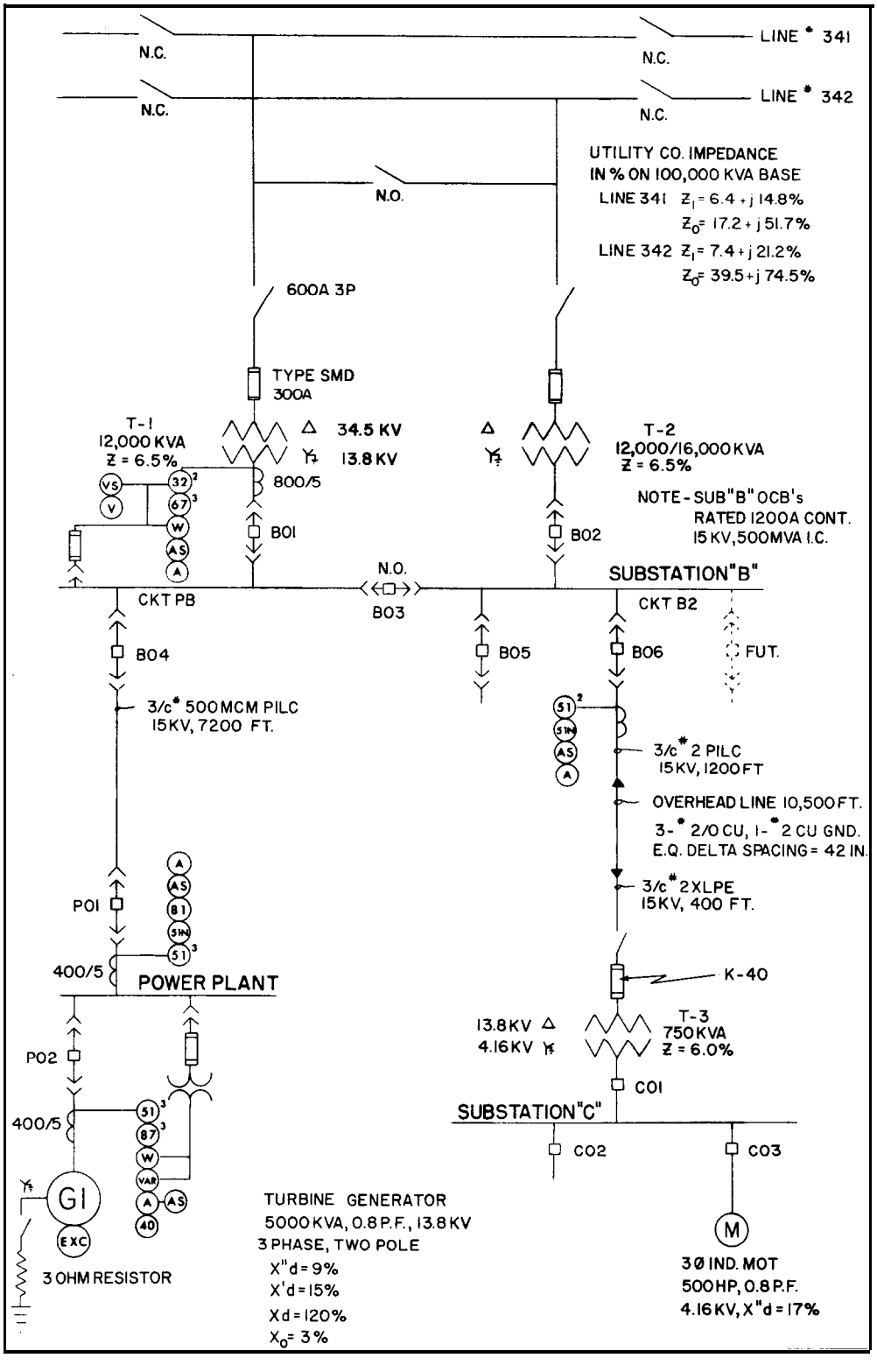


FIGURE 12
Partial One-Line Diagram

CHAPTER 4. IMPEDANCE DIAGRAM DEVELOPMENT

4.1 ESSENTIALITY. An impedance diagram is essential for any analysis of an electric power distribution system. It is in effect, a road map in one-line diagram format on which all significant equipment and line-impedances are indicated.

4.2 100,000 KVA BASE FOR IMPEDANCES. The first step in developing an impedance diagram is to convert the information contained on the one-line diagram and system inventory sheets into impedances on a pre-selected base. A base KVA is selected to simplify the calculations required to enter system analysis data into the computer. It is recommended that all impedances be converted to percent on a 100,000 KVA base. The following formula can be used for converting a resistance or reactance to percent on a chosen KVA base is:

$$\text{Percent Resistance} = \frac{(^{R}\text{OHMS})}{10} \quad \frac{(^{KVA}\text{BASE})}{(\text{KV})^{2}}$$

where: ohms are line-to-neutral values (single conductor)
KVA base is the chosen 3-phase base KVA (100,000 KVA)
KV is the line-to-line voltage (kilovolts)

Table 1 provides conversion factors for converting ohms to % on a 100,000 KVA base. Some equipment reactance are expressed in percent on their own rated KVA base (Tables 2 and 3). (For example, transformers, generators, motors.) To convert to percent on the chosen base from the equipment rating base KVA, the following formula applies:

$$\%\ x\ @\ \text{New Base} = \%x@\ \text{Old Base} \times \frac{\text{New Base KVA}}{\text{Old Base KVA}}$$

Impedance of motor on 100,000 KVA base

$$\%Z@\ 100{,}000\text{KVA} = 16.8 \times \frac{100{,}000}{500} = 3360\%$$

TABLE 1
Ohms to Percent Conversion Factors

Line to Line Voltage in KV	Line to Neutral Voltage in KV	(For Converting Ohms to % on a 100,000 KVA Base)
2.2	1.27	2066

TABLE 1 (Continued)
Ohms to Percent Conversion Factors

Line to Line Voltage in KV	Line to Neutral Voltage in KV	(For Converting Ohms to % on a 100,000 KVA Base)
2.3	1.33	1890
2.4	1.39	1736
4.0	2.30	630.1
4.16	2.40	578.7
4.8	2.77	434.0
6.0	3.45	277.9
7.2	4.16	192.9
11.0	6.35	82.64
11.5	6.64	75.76
12.0	6.94	69.44
12.47	7.20	64.31
13.2	7.62	57.41
13.3	7.97	52.52
22.0	12.70	20.66
23.0	13.28	18.90
26.4	15.25	14.35
33.0	19.05	9.18
34.5	19.90	8.40
44.0	25.40	5.17
46.0	26.56	4.73
66.0	38.10	2.29
69.0	38.9	2.10

% ohms on 100,000 KVA Base = (ohms) x (K)
Example: 13.2 KV System Voltage.
Z_1 = 0.5 + j.75 ohms
Z_1 = (0.5 + j.75) (57.41) = 28.71 + j 42.99% on 100,000 KVA Base

TABLE 2
Typical Reactance Values for Synchronous Machines
Per Unit Values on Machine KVA Rating*

	x"d	X'd
**Turbine Generators		
2 Pole	0.09	0.15
4 Pole	0.014	0.23
**Salient Pole Generators		
Without Damper Windings		
12 Poles or less	0.25	
14 Poles or more	0.35	
With Damper Windings		
12 Poles or less	0.18	
14 Poles or more	0.24	

TABLE 2 (Continued)
Typical Reactance Values for Synchronous Machines
Per Unit Values on Machine KVA Rating*

	X"d	X'd
Synchronous Motors		
6 Pole	0.15	0.23
8-14 Pole	0.20	0.30
**Synchronous Condensers	0.27	
**Synchronous Converters		
600 volts direct current	0.20	____
2500 volts direct current	0.33	____

*Use manufacturers specified values if available.
**X'd not normally used in short-circuit Calculations.

Note: Synchronous motor KVA bases can be found from motor horsepower ratings as follows:
0.8 pf motor - KVA base = hp rating
1.0 pf motor KVA base = 0.8 x hp rating

TABLE 3
Typical Reactance for Induction Motors Per Unit Values
On Machine KVA Base (Horsepower Rating)*

	X"d	X'd
Above 600 volts	0.20	____
600 volts and below	0.28	____

Per Unit Z of induction motor on its own KVA

$$\text{Base} = \frac{1}{\text{L.R. KVA/HP}^{**}}$$

*KVA base is assumed equal to machine HP
**See Locked Rotor indicating Letter Table in NEC (usually between 5 and 6)

4.3 EXAMPLE OF TRANSFORMER IMPEDANCE CALCULATION USING TABLES 4 AND 5.

5000/5750KVA 30 power transformer
34.5-4.16KV
HV BIL - 200
LV BIL = 60

From Table 5 z = 6.00% on 5000KVA BASE

Note: Transformer impedances are based upon their air cooled rating or 5000 KVA for the above example.
The impedance on a 100,000 KVA base is:

$$6.00 \times \frac{100,000}{5000} = 120\%$$

As a general rule transformer resistance will be 20% of the reactance. Therefore, the impedance of the example transformer is:

$$\%Z = 24 + J120 \text{ (on 100,000KVA base)}$$

Figure 13 is an impedance diagram developed from the one-line diagram.

TABLE 4
Insulation Levels for Oil - Immersed Transformers

Nominal System Voltage	Distribution Levels BIL	Power Levels BIL
KV	KV	KV
.24	30	45
.48	30	45
2.4	45	60
4.8	60	75
7.2	75	95
12.0	95	110
14.4	95	110
23.0	--	150
34.5	--	200
46.0	--	250
69.0	--	350

TABLE 5
Typical Impedances for Transformers (On Transformer KVA Rating)

HV BIL*	LV BIL*	Impedance - Percent
KV	Kv	
110	45	5.75
	60-110	5.5
150	45	5.75
	60-110	5.5
200	45	6.25
	60-110	6.0
	150	6.5
250	45	6.75
	60-150	6.5
	200	7.0
350	45	7.25
	60-200	7.0
	250	7.5

*Use manufacturer's specified values if available or refer to Electrical Transmission and Distribution Reference Book or General Electric, Electric Equipment Specifiers Guide, Book I - Power Distribution Apparatus if manufacturer's specified values are not available. BIL Levels may be obtained from TABLE 4.

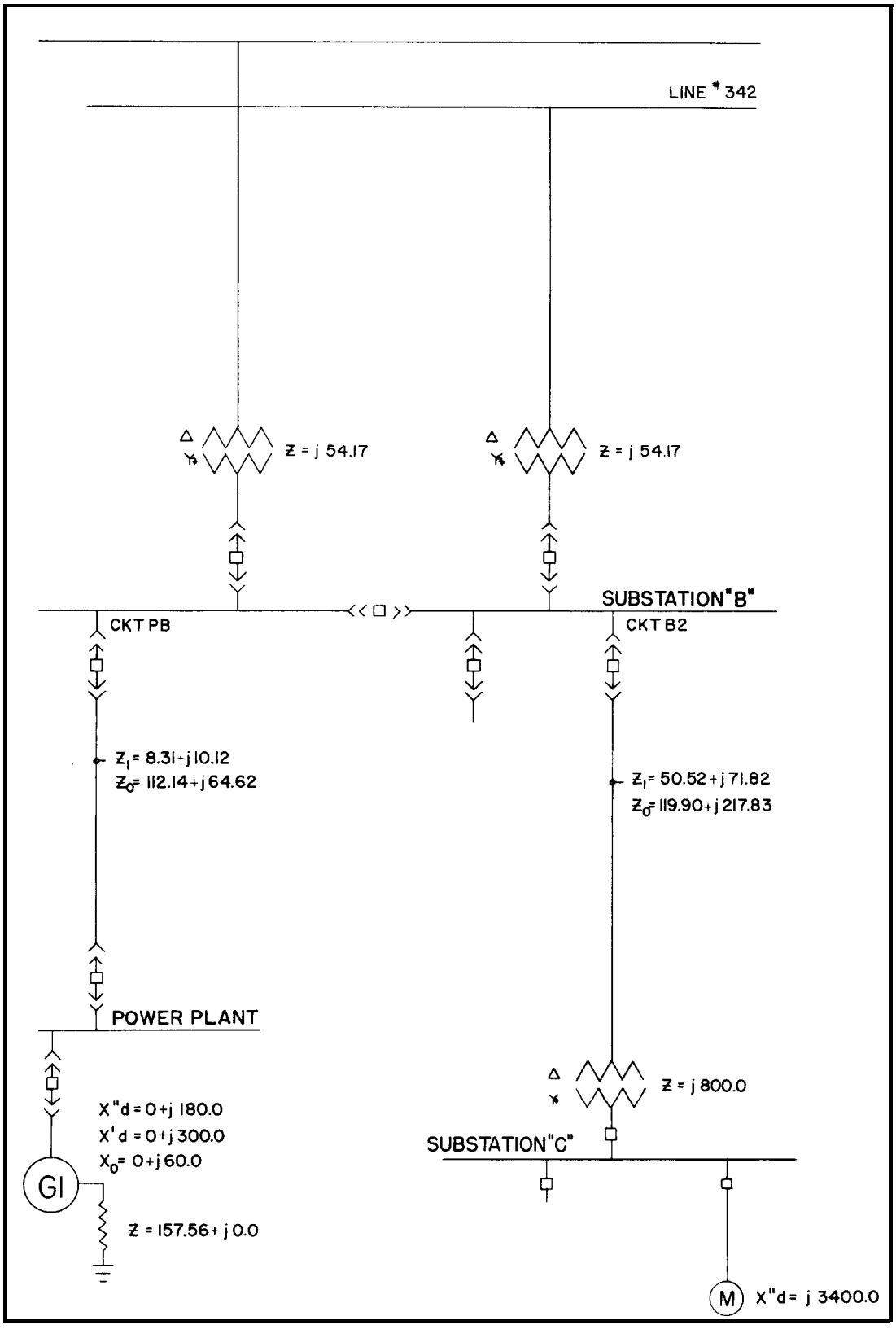


FIGURE 13
Partial Impedance Diagram

CHAPTER 5. DETERMINATION OF ELECTRIC LINE IMPEDANCES

5.1 LINE IMPEDANCE CALCULATIONS. The calculation of electric line impedances is a complex task dependent on many input factors such as ground impedance spacing of conductors, conductor stranding and construction, conductor insulation temperature, the size and effect of the neutral conductor, voltage, conducting material and size, frequency, location of other lines. All of these factors have some influence upon the actual impedance of a line. Some of these factors such as temperature and ground impedance are continuously in a state of change. Therefore, no matter how many input factors an engineer considers, his calculation of line impedance becomes a very good estimate of the actual line impedance.

5.2 IMPEDANCE TABLES. The positive and zero sequence Impedance Data contained in tables 7 and 9 is representative of line impedance in Navy systems. (Table 8 is reserved for underground aluminum cables and will be published when developed.) The purist may argue that these values are not accurate because the actual value of earth resistivity was not used to determine the zero sequence impedance of overhead lines or that standardized conductor constructions were used instead of including all actual construction, or that a delta-equivalent spacing was used instead of actual spacing. The standard equivalent delta spacing of overhead lines used for tables are: 34.5KV - 54″, 13.2KV - 42″, 2.4KV and 4.16KV - 30″. Compromises on the above data are common practice in network analysis and relay coordination studies and do not materially affect the final product which is effective analyses and coordination of the system. The Impedances are presented in the line impedance tables as ohms/1000 ft. at a fifty-degree centigrade conductor temperature.

5.3 USE OF THE LINE IMPEDANCE TABLES.

5.3.1 Underground Cable Impedance. Positive and zero sequence impedances for three single conductor copper cables and three conductor copper cable can be read directly from the impedance table for underground cable (Table 7).

5.3.2 Overhead Line Impedances. The impedance tables (Table 9) for overhead lines contain the positive and zero sequence impedances for three types of overhead lines: 30 copper, 30 ACSR and 30 aluminum lines. Each type of overhead line has five tables associated with it.

Positive Sequence Impedance (R and X) can be read from the first table. To locate the zero sequence Impedance, first you

must go to the proper table for the geographic area where the electrical system is located. Two tables are included each for coastal area and inland area locations. Going to the tables with the proper geographic area indicated in the title, first read and record the zero sequence (R and X) Self impedance directly from the table. All values in this table are positive values. If the line under consideration has a ground wire, you go to the next table for the proper geographic area with the reading zero sequence (ground wire) impedance, locate the size of the ground wire and read and record the zero sequence Ground Wire impedance (R and X) for the size of the ground wire under consideration. The total zero sequence impedance for this line is obtained by subtracting the value of the zero sequence (Ground wire) impedance from the value of the zero sequence (self) impedance.

RO (total) = ro (self) - Ro (ground wire)
XO (total) = Xo (self) - xo (ground wire)

If, however, the line under consideration has no ground wire, the zero sequence (self) (RO & XO) is considered to be the total zero sequence Impedance.

Below are examples of how to use these tables:

5.3.2.1 Example No. 1.

Line - 5KV 30 3/C underground
Nominal voltage - 4.16KV
conductors - 500 KCM copper
Length - 4000 ft.
Insul. - PILC

From Table 7.3
Pos. Seq. Imp. (Z) = 0.0247 + jO.0231 ohms/1000' phase

$$\text{Total } Z1 = \frac{4000\text{ft}}{1000\text{ft}} \times (0.0247 + j\ 0.0231 = .0988 + j\ .0924 \text{ ohms phase}$$

To convert to % on 100 MVA Base, multiply by conversion factor obtained from Table 1. K for 4.16KV = 578.7

%Z1 = 578.7 X (.0988 + j .0924) = 57.1755 + j 53.4719

From Impedance Table 7.3
Zero Seq. Imp. (ZO) = 0.3403 + j 0.2260 ohms/1000'/phase

$$\text{Total } ZO = \frac{4000\text{ft}}{1000\text{ft}} \times (0.3403 + j\ 0.2260) = 1.3612 + j\ 0.9040 \text{ ohms/phase}$$

To convert to % on 100 MVA Base, multiply by conversion factor obtained from Table 1. K for 4.16KV = 578.7
% ZO = 578.7 x (1.3612 + j 0.9040) = 787.726 + j 523.144

5.3.2.2 Example No. 2

Line - 5KV 30 3-1/c underground
Nominal voltage - 4.16KV
Conductors - 500 KCM copper
Length - 4000 ft.
Cable spacing - 2 inches
Insulation - PILC

Impedance From Table 7.9
Pes$_o$ Seq. Imp. (Z) = 0.0243 + j 0.0436 ohms/1000'/phase

Total $Z_1 = \frac{4000'}{1000'} \times (0.0243 + j\ 0.0436) = 0.0972 + j\ 0.1744$ ohms/phase

To convert to % on a 100 MVA Base, multiply by conversion factor obtained from Table 1. K for 4.16KV = 578.7
$\%Z_1 = 578.7 \times (0.0972 + j\ 0.1744) = 56.2496 + j\ 100.9253$

From Impedance Table 7.9
Zero Seq. Imp. (Z_o) = 0.3155 + j 0.1705

Total $2_0 = \frac{4000}{1000}$ (0.3155 + j 0.1705 = 1.2620 + j 0.6820 ohms/phase

To convert to % on a 100 MVA Base, multiply by conversion factor obtained from Table 1. K for 4.16KV = 578.7
$\% Z_o. = 578.7\ (1.2620 + j\ 0.6820) = 730.3194 + j\ 394.6734$

5.3.2.3 Example No. 3.

Line - 34.5KV 30 overhead with ground wire
Conductors - 4/0 copper
Length - 4000 ft.
Ground wire - 1/4" diameter nominal
Location - Coastal area

Ground wire:
1/4 " = 250 roils
circular roils = $d^2 = (250)^2$ = 62, 500 circular roils
#2 AWG = 66, 360 circular roils
So, #2 AWG is the wire actually used as the ground wire in this example.

Read Positive sequence Impedance from first table of copper lines for #4/0 copper (Table 9.1):
Pos. Seq. Imp. (Z_1) = 0.0573 + j 0.1297 ohms/1000'/phase

Total $Z_1 = \frac{4000'}{1000'}$ (0.0573 + j 0.1297) = 0.2292 + j 0.5188 ohms/phase

To convert to % on a 100 MVA Base, multiply by the conversion factor obtained from Table 1. K for 34.5KV = 8.40

$\%Z_1$ = 8.40 x (0.2292 + j 0.5188 = 1.9253 + j 4.3579

To find zero Seq. Imp. go to the first zero sequence impedance table for coastal area locations:

Z. (self) = 0.1068 + j 0.5530

From the 2nd zero sequence impedance table for coastal area locations:

Z_0 (Ground wire) = -0.0738 + j 0.1607

= Zo(self) - Zo (Ground wire) = (0.1068 + j 0.5530) - (-0.0738 + j 0.1607) = 0.1806 + j 0.3923 ohms/1000'/phase

Total Zo = $\frac{4000'}{}$ (0.1806 + j 0.3923) = 0.7224 + j 1.5692 ohms/phase

To convert to % on a 100 MVA Base, multiply by the conversion factor obtained from Table 1. K for 34.5KV = 8.40

% Z o = 8.40 x (0.7224 + j 1.5692) = 6.0682 + j 13.1813

5.3.2.4 Example No. 4.

Line - 34.5KV 30 overhead without ground wire
Conductors - 4/0 copper
Length - 4000'
Location - Coastal area

Read positive Seq. Imp. from first table for 30 copper line (Table 9.1):

Pos. Seq. Imp (Z_1) = 0.0573 + j 0.1297 ohms/1000'/phase

Total Z_1 = $\frac{4000'}{1000'}$ (0.0573 + j 0.1297) = 0.2297 + j 0.5188 ohms/phase

To convert to % on a 100 MVA Base, multiply by the conversion factor obtained from Table 1. K for 34.5KV = 8.40

$\%Z_1$ = 8.40 (0.2292 + j 0.5188) = 1.9253 + j 4.3597

To find zero Seq. Imp. go to the first zero sequence impedance table for coastal area locations:

Z. (self) = 0.1068 + j 0.5530 ohms/1000'/phase

With no ground wire:

Total Z. = $\frac{4000'}{1000'}$ (0.1068 + j 0.5530) = 0.4272 + j 2.2120 ohms/phase

To convert to % on a 100 MVA Base, multiply by the conversion factor obtained from Table 1. K for 34.5KV = 8.40

$\% Z_0$ = 8.40 (0.4272 + j 2.2120) = 3.5885 + j 18.5808

TABLE 7
IMPEDANCE TABLES FOR UNDERGROUND CABLE

TABLE 7.1

TYPE 5KV 3/C RUBBER AND XLP

AUG OR MCM	POSITIVE SEQUENCE (OHMS/l000')		ZERO SEQUENCE (OHMS/l000')	
	R	X	R	x
6	0.4526	0.0449	0.7851	0.4246
4	3.2846	0.0417	0.6309	0.4050
2	0.1790	0.0388	0.5244	0.3537
1/0	0.1149	0.0362	0.4440	0.2898
2/i)	0.0911	0.0351	0.4142	0.2694
3/0	0.0723	0.0340	0.3873	0.2558
4/0	3.0573	0.0330	0.3628	0.2294
250	0.0487	0.0327	0.3214	0.1818
300	0.0407	0.0320	0.3016	0.1666
350	0.0349	0.0313	0.2937	0.1634
400	0.0306	0.0309	0.2844	0.1572
500	0.0247	0.0301	0.2679	0.1454

TABLE 7.2

15 KV 3/C CU RUBBER AND XLP

0.2846	0.0513	0.5436	0.2122
0.1790	0.0476	0.4365	0.1965

TABLE 7.2 (Continued)

AWG OR MCM	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
	R	X	R	X
1/0	0.1149	0.0438	0.3662	0.1812
2/0	0.0911	0.0422	0.3383	0.1721
3/0	0.0723	0.0407	0.3158	0.1647
4/0	0.0573	0.0392	0.2928	0.1537
250	0.0487	0.0381	0.2772	0.1461
300	0.0407	0.0371	0.2659	0.1414
350	0.0349	0.0362	0.2306	0.1232
400	0.0306	0.0355	0.2259	0.1155
500	0.0247	0.0344	0.2122	0.1084

TABLE 7.3

5KV 3/C CU PILC

6	0.4526	0,0394	0.7886	0.4913
4	0.2846	0.0366	0.6373	0.4608
2	0.1790	0.0348	0.5381	0.4294
1/0	0.1149	0,0315	0.4787	0.4206
2/0	0.0911	0.0270	0.4574	0.4198
3/0	0.0723	0.0265	0.4365	0.3804
250	0.0573	0.0256	0.4191	0.3637
300	0.0407	0.0247	0.3887	0.2922
350	0.0349	0.0242	0.3731	0.2748
400	0.0306	0.0238	0.3609	0.2554
500	0.0247	0.0231	0.3403	0.2260
750	0.0168	0.0222	0.2945	0.1692
1000	0.0130	0.0217	0.2692	0.1444

TABLE 7.4

15KV 3/C CU PILC

4	0.2846	0.0441	0.6118	0.3284
2	0.1790	0.0410	0.5046	0.2975
1/0	0.1149	0.0370	0.4408	0.2831
2/0	0.0911	0.0355	0.4201	0.2813

TABLE 7.4 (Continued)

AWG OR MCM	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/l000')	
	R	X	R	X
3/0	0.0723	0.0342	0.3871	0.2496
4/0	3.0573	0.0322	0.3645	0.2326
300	0.0407	0.0316	0.3261	0.1962
350	0.0349	0.0284	0.3296	0.2035
400	0.0306	0.0278	0.3203	0.1952
500	0.0247	0.0267	0.2965	0.1709
750	0.0168	0.0254	0.2537	0.1325
1000	0.0130	0.0245	0.2294	0.1139

TABLE 7.5

23KV 3/C CU PILC

4	0.2846	0.0518	0.5861	0.2724
2	0.1790	0.0470	0.4878	0.2659
1/0	0.1149	0.0426	0.4257	0.2573
2/0	0.0911	0.0382	0.4080	0.2589
3/o	0.0723	0.0366	0.3676	0.2514
4/0	0.0573	0.0352	0.3494	0.2077
250	0.0487	0.0343	0.3334	0.1952
300	0.0407	0.0333	0.3109	0.1751
350	0.0349	0.0324	0.3006	0.1685
400	0.0306	0.0317	0.2884	0.1587
500	0.0247	0.0304	0.2660	0.1650
750	0.0168	0.0284	0.2221	0.1077
1000	0.0130	0.0275	0.2067	0.0985

TABLE 7.6

35KV 3/C CU PILC

AWG OR NCM	POSITIVE SEQUENCE (OHMS/1000 ') R	X	ZERO SEQUENCE (OHMS/1000') R	X
2	0.1790	0.0527	0.4195	0.1767
1/0	0.1149	0.0477	0.3598	0.1717
2/o	0.0911	0.0456	0.3367	0.1677
3/0	0.0723	0.0438	0.3030	0.1497
4/0	0.0573	0.0423	0.2853	0.1444
250	0.0487	0.0390	0.2799	0.1432
300	0.0407	0.0377	0.2666	0.1367
350	0.0349	0.0367	0.2489	0.1252
400	0.0306	0.0359	0.2450	0.1243
500	0.0247	0.0350	0.2241	0.1103
759	0.0168	0.0320	0.1931	0.0930
1000	0.0130	0.0308	0.1745	0.0829

TABLE 7.7

5KV 3/C CU VC

6	3.4526	0.0384	0.7682	3.5824
4	0.2846	0.0359	0.6255	0.5382
2	0.1790	0.0347	0.5377	0.4305
1/0	0.1149	0.0309	0.4712	0.3800
2/0	0.0911	0.0302	0.4461	0.3624
3/0	2.0723	0.0294	0.4068	0.2834
4/0	0.0573	0.0286	0.3844	0.2634
250	9.0487	0.0290	0.3613	0.2351
300	0.0407	0.0285	0.3479	0.2249
350	0.0349	0.0280	0.3094	0.1768

TABLE 7.7 (Continued)

AWG OR MCM	POSITIVE SEQUENCE (OHMS/l000')		ZERO SEQUENCE (OHMS/1000')	
	R	X	R	X
400	0.030-6	0.0277	0.3018	0.1723
500	0.0247	0.0271	0.2828	0.1568
750	0.0168	0.0262	0.2530	0.1338

TABLE 7.8

15KV 3/C CU VC

6	9.4526	0.0490	0.7712	0.3694
4	0.2846	0.0455	0.5974	0.2949
2	0.1790	0.0433	0.4903	0.2738
1/0	0.1149	0.0384	0.4210	0.2489
2/0	0.0911	0.0372	0.3865	0.2280
3/0	0.0723	0.0359	0.3389	0.1848
4/o	0.0573	0.0347	0.3189	0.1759
250	0.0487	0.0339	0.3042	0.1672
300	0.0427	0.0331	0.3015	0.1587
350	0.0349	0.0324	0.2825	0.1562
400	0.0306	0.0319	0.2688	0.1458
500	0.0247	0.0309	0.2599	0.1392
750	0.0168	0.0295	0.2007	0.0996

TABLE 7.9

5KV 3-1/C PILC CU

AWG OR MCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
6	1	0.4110	0.0610	0.7856	0.4199
6	2	0.4124	0.0769	0.7691	0.4166
6	3	0.4135	0.0861	0.7593	0.4142
6	u	0.4144	0.0926	0.7522	0.4124
6	5	0.4152	0.0976	0.7467	0.4109
6	6	0.4159	0.1018	0.7421	0.4095
6	7	0.4165	0.1052	0.7383	0.4084
6	8	0.4170	0.1082	0.7349	0.4073
6	9	0.4175	0.1109	0.7319	0.4064
6	10	0.4180	0.1132	0.7293	0.4055
4	1	0.2600	0.0558	0.6340	0.3933
4	2	0.2614	0.0716	0.6182	0.3911
4	3	0.2626	0.0809	0.6088	0.3894
4	4	0.2635	0.0873	0.6020	0.3881
4	5	0.2643	0.0924	0.5967	0.3869
4	6	0.2650	0.0965	0.5923	0.3859
4	7	0.2656	0.0999	0.5886	0.3850
4	8	0.2662	0.1029	0.5854	0.3842
4	9	0.2667	0.1055	0.5825	0.3834
4	10	0.2672	0.1079	0.5799	0.3827
2	1	0.1628	0.0515	0.5342	0.3629
2	2	0.1643	0.0673	0.5195	0.3619

TABLE 7.9 (Continued)

AWG OR MCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/l000')	
		R	X	R	X
2	3	0.1655	0.0766	0.5106	0.3610
2	4	0.1665	0.0830	0.5043	0.3602
2	5	0.1673	0.0881	0.4992	0.3594
2	6	0.1680	0.0922	0.4951	0.3588
2	7	0.1687	0.0956	0.4916	0.3582
2	8	0.1693	0.0986	0.4885	0.3576
2	9	0.1698	0.1012	0.4858	0.3572
2	10	0.1703	0.1036	0.4833	0.3566
1/0	1	0.1029	0.0501	0.4717	0.3417
1/0	2	0.1044	0.0625	0.4577	0.3413
1/0	3	0.1056	0.0717	0.4492	0.3409
1/0	4	0.1066	0.0782	0.4431	0.3404
1/0	5	0.1075	0.0832	0.4383	0.3399
1/0	6	0.1083	0.0873	0.4343	0.3394
1/0	7	0.1090	0.0907	0.4309	0.3391
1/0	8	0.1096	0.0937	0.4280	0.3387
1/0	9	0.1102	0.0963	0.4254	0.3383
1/0	10	0.1106	0.0986	0.4230	0.3379
2/0	1	0.0819	0.0441	0.4479	0.3258
2/0	2	0.0834	0.0600	0.4345	0.3260
2/0	3	0.0846	0.0692	0.4263	0.3259
2/0	4	0.0856	0.0756	0.4205	0.3256
2/0	5	0.0866	0.0807	0.2265	0.3253
2/0	6	0.0873	0.0848	0.4120	0.3251
2/0	7	0.0880	0.0882	0.4087	0.3248
2/0	8	0.0887	0.0912	0.4059	0.3245
2/0	9	0.0892	0.0937	0.4034	0.3242
2/0	10	0.0898	0.0961	0.4011	0.3240

TABLE 7.9 (Continued)

AWG OR MCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000') R	POSITIVE SEQUENCE (OHMS/1000') X	ZERO SEQUENCE (OHMS/1000') R	ZERO SEQUENCE (OHMS/1000') X
3/0	1	0.0650	0.0413	0.4197	0.2812
3/0	2	0.0666	0.0572	0.4082	0.2827
3/0	3	0.0678	0.0663	0.4012	0.2834
3/0	4	0.0691	0.0728	0.3962	0.2838
3/0	5	0.0701	0.0777	0.3921	0.2841
3/o	6	0.0710	0.0818	0.3887	0.2842
3/0	7	0.0717	0.0852	0.3859	0.2843
3/0	8	0.0724	0.0882	0.3834	0.2844
3/0	9	0.0731	0.0908	0.3812	0.2844
3/0	10	0.0737	0.0930	0.3791	0.2844
4/0	1	0.0517	0.0387	0.4003	0.2629
4/0	2	0.0534	0.0545	0.3896	0.2648
4/0	3	0.0548	0.0637	0.3831	0.2657
4/0	4	0.0559	0.0701	0.3783	0.2663
4/0	5	0.0569	0.0751	0.3745	0.2668
4/0	6	0.0578	0.0791	0.3714	0.2670
4/0	7	0.0586	0.0826	0.3687	0.2673
4/0	8	0.0594	0.0855	0.3663	0.2674
4/0	9	0.0600	0.0880	0.3642	0.2676
4/0	10	0.0606	0.0904	0.3623	0.2676
250	1	0.0441	0.0366	0.3874	0.2488
250	2	0.0458	0.0524	0.3774	0.2510
250	3	0.0472	0.0616	0.3712	0.2521
250	4	0.0484	0.0680	0.3667	0.2529
250	5	0.0494	0.0730	0.3631	0.2534
250	6	0.0503	0.0770	0.3601	0.2537
250	7	0.0511	0.0804	0.3576	0.2541
250	8	0.0519	0.0833	0.3553	0.2543
250	9	0.0526	0.0859	0.3533	0.2545
250	10	0.0532	0.0882	0.3515	0.2547

TABLE 7.9 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000') R	X	ZERO SEQUENCE (OHMS/1000') R	X
300	1	0.0368	0.0345	0.3727	0.2317
300	2	0.0385	0.0503	0.3629	0.2341
300	3	0.0399	0.0595	0.3577	0.2355
300	4	0.0412	0.0659	0.3536	0.2364
300	5	0.0423	0.0709	0.3540	0.2370
300	6	0.0432	0.0749	0.3475	0.2375
300	7	0.0441	0.0783	0.3451	0.2379
300	8	0.0448	0.0812	0.3430	0.2382
300	9	0.0455	0.0837	0.3412	0.2385
300	10	0.0462	0.0860	o* 3394	0.2387
350	2	3.0335	0.0479	0.3433	0.2021
350	3	0.0351	0.0570	0.3378	0.2037
350	4	0.0364	0.0634	0.3350	0.2048
350	5	0.0375	0.0683	0.3322	0.2057
350	6	0.0386	0.0534	0.3298	0.2063
350	7	0.0395	0.0756	0.3278	0.2069
350	8	0.0403	0.0785	0.3261	0.20,73
350	9	0.0411	0.0811	0.3245	0.2077
350	10	0.0418	0.0833	0.3230	0.2080
400	2	0.0297	0.0464	0.3330	0.1906
400	3	0.0312	0.0555	0.3286	0.1923
400	4	0.0326	0.0619	0.3253	0.1934
400	5	0.0338	0.0669	0.3227	0.1943
400	6	0.0348	0.0708	0.3205	0.1950
400	7	0.0358	0.0741	0.3186	0.1955
400	8	0.0366	0.0770	0.3169	0.1961
400	9	0.0374	0.0796	0.3155	0.1965
400	10	0.0381	0.0818	0.3141	0.1969

TABLE 7.9 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
500	2	0.0243	0.0436	0.3155	0.1705
500	3	0.0259	0.0527	0.3116	0.1723
500	4	0.0273	0.0591	0.3087	0.1735
500	5	0.0286	0.0640	0.3064	0.1744
500	6	0.0297	0.0680	0.3044	0.1752
500	7	0.0306	0.0713	0.3028	0.1758
500	8	0.0316	0.0741	0.3013	0.1763
500	9	0.0324	0.0766	0.3000	0.1768
500	10	0.0331	0.0789	0.2988	0.1772
750	2	0.0172	0.0391	0.2738	0.1265
750	3	0.0190	0.0482	0.2712	0.1282
750	u	0.0205	0.0545	0.2693	0.1294
750	5	0.0219	0.0593	0.2677	0.1303
750	6	0.0232	0.0632	0.2666	0.1311
750	7	0.0243	0.0665	0.2652	0.1317
750	8	0.0254	0.0693	0.2642	0.1323
750	9	0.0263	0.0717	0.2634	0.1328
750	10	0.0272	0.0738	0.2625	0.1333
1000	2	0.0137	0.0359	0.2418	0.0985
1000	3	0.0156	0.0450	0.2400	0.1000
1000	4	0.0173	0.0511	0.2387	0.1011
1000	5	0.0188	0.0560	0.2375	0.1020
1000	6	0.0202	0.0600	0.2366	0.1027
1000	7	0.0215	0.0629	0.2358	0.1033
1000	8	0.0226	0.0656	0.2351	0.1038
1000	9	0.0237	0.0680	0.2344	0.1042
1000	10	0.0247	0.0701	0.2338	0.1047

TABLE 7.10

15KV 3-1/C CU PILC

AWG OR MCH	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
6	1	0.4108	0.0611	0.7641	0.3027
6	2	0.4125	0.0769	0.7528	0.2987
6	3	0.4138	0.0860	0.7459	0.2994
6	u	0.4150	0.0925	0.7409	0.2999
6	5	0.4159	0.0974	0.7369	0.3001
6	6	0.4168	0.1015	0.7337	0.3003
6	7	0.4176	0.1049	0.7308	0.3005
6	8	0.4183	0.1079	0.7284	0.3005
6	9	0.4190	0.1105	0.7262	0.3006
6	10	0.4196	0.1127	0.7241	0.3006
4	1	0.2598	0.0558	0.6076	0.2780
4	2	0.2615	0.0716	0.5970	0.2800
4	3	0.2629	0.0808	0.5905	0.2810
4	4	0.2641	0.0872	0.5858	0.2816
4	5	0.2651	0.0922	0.5821	0.2820
4	6	0.2659	0.0962	0.5790	0.2823
4	7	0.2668	0.0996	0.5763	0.2826
4	8	0.2675	0.1026	0.5740	0.2827
4	9	0.2682	0.1052	0.5719	0.2829
4	10	0.2688	0.1074	0.5700	0.2830
2	1	0.1626	0.0515	0.5026	0.2567
2	2	0.1643	0.0673	0.4929	0.2591
2	3	0.1657	0.0765	0.4870	0.2603
2	4	0.1669	0.0829	0.4826	0.2611
2	5	0.1680	0.0879	0.4791	0.2616
2	6	0.1689	0.0919	0.4762	0.2621
2	7	0.1698	0.0953	0.4738	0.2624
2	8	0.1705	0.0982	0.4716	0.2627
2	9	0.1712	0.1008	0.4697	0.2629
2	10	0.1719	0.1031	0.4679	0.2631

TABLE 7.10 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/l000')	
		R	X	R	X
1/0	1	0.1027	0.0466	0.4407	0.2478
1/0	2	0.1044	0.0624	0.4312	0.2502
1/0	3	0.1059	0.0716	0.4254	0.2515
1/0	4	0.1071	0.0780	0.4212	0.2523
1/0	5	0.1081	0.0830	0.4196	0.2530
1/0	6	0.1091	0.0870	0.4149	0.2534
1/0	7	0.1099	0.0904	0.4125	0.2538
1/0	8	0.1107	0.0934	0.4104	0.2541
1/0	9	0.1114	0.0959	0.4085	0.2544
1/0	10	0.1120	0.0982	0.4067	0.2545
2/0	1	0.0817	0.0441	0.4149	0.2362
2/0	2	0.0834	0.0599	0.4059	0.2387
2/0	3	0.0848	0.0691	0.4004	0.2402
2/o	4	0.0861	0.0755	0.3963	0.2411
2/0	5	0.0872	0.0805	0.3930	0.2417
2/0	6	0.0881	0.0845	0.3904	0.2423
2/0	7	0.0890	0.0879	0.3880	0.2427
2/0	8	0.0898	0.0908	0.3860	0.2430
2/0	9	0.0905	0.0934	0.3842	0.2434
2/0	10	0.0911	0.0956	0.3825	0.2436
3/0	2	0.0666	0.0571	0.3771	0.2124
3/0	3	0.0682	0.0662	0.3723	0.2141
3/0	4	0.0695	0.0726	0.3687	0.2152
3/0	5	0.0707	0.0776	0.3659	0.2159
3/0	6	0.0717	0.0816	0.3635	0.2166
3/0	7	0.0726	0.0849	0.3615	0.2171
3/0	8	0.0734	0.0878	0.3597	0.2176
3/0	9	0.0742	0.0904	0.3581	0.2180
3/0	10	0.0749	0.0926	0.3566	0.2183

TABLE 7.10 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
4/0	2	0.0533	0.0545	0.3574	0.1997
4/o	3	0.0549	0.0636	0.3529	0.2014
4/0	4	0.0562	0.0700	0.3496	0.2025
4/0	5	0.0574	0.0749	0.3469	0.2034
4/0	6	0.0585	0.0789	0.3448	0.2041
4/0	7	0.0594	0.0823	0.3428	0.2046
4/0	8	0.0603	0.0852	0.3412	0.2052
4/0	9	0.0611	0.0876	0.3397	0.2055
4/0	10	0.0618	0.0899	0.3383	0.2059
250	2	0.0457	0.0523	0.3443	0.1894
250	3	0.0473	0.0615	0.3401	0.1912
250	4	0.0487	0.0679	0.3369	0.1923
250	5	0.0499	0.0728	0.3345	0.1932
250	6	0.0510	0.0767	0.3323	0.1940
250	7	0.0519	0.0801	0.3306	0.1946
250	8	0.0528	0.0830	0.3290	0.1951
250	9	0.0536	0.0855	0.3276	0.1955
250	10	0.0544	0.0877	0.3263	0.1959
300	2	0.0384	0.0503	0.3296	0.1773
300	3	0.0401	0.0594	0.3258	0.1791
300	4	0.0415	0.0677	0.3229	0.1803
300	5	0.0427	0.0707	0.3206	0.1812
300	6	0.0438	0.0747	0.3187	0.1819
300	7	0.0448	0.0780	0.3170	0.1826
300	8	0.0457	0.0809	0.3155	0.1831
300	9	0.0466	0.0834	0.3142	0.1836
300	10	0.0473	0.0856	0.3130	0.1840

TABLE 7.10 (Continued)

AWG OR KCM	SPACING (INCHES]	POSITIVE SEQUENCE (OHMS/1000') R	X	ZERO SEQUENCE (OHMS/1000') R	X
350	2	0.0334	0.0479	0.3081	0.1536
350	3	0.0351	0.0569	0.3049	0.1554
350	4	0.0367	0.0633	0.3025	0.1566
350	5	0.0380	0.0681	0.3006	0.1576
350	6	0.0392	0.0720	0.2990	0.1584
350	7	0.0402	0.0753	0.2976	0.1590
350	8	0.0412	0.0781	0.2963	0.1595
350	9	0.0421	0.0806	0.2952	0.1601
350	10	0.0430	0.0828	0.2942	0.1605
400	2	0.0296	0.0464	0.2979	0.1455
400	3	0.0313	0.0555	0.2949	0.1470
400	4	0.0329	0.0618	0.2926	0.1483
400	5	0.0342	0.0666	0.2909	0.1492
400	6	0.0354	0.0705	0.2894	0.1500
400	7	0.0365	0.0738	0.2881	0.1507
400	8	0.0375	0.0766	0.2869	0.1512
400	9	9.0384	0.0791	0.2859	0.1517
400	10	0.0393	0.0813	0.2850	0.1521
500	2	0.0242	0.0436	0.2819	0.1320
500	3	0.0259	0.0526	0.2792	0.1337
500	4	0.0276	0.0590	0.2772	0.1349
500	5	0.0289	0.0638	0.2756	0.1359
500	6	0.0302	0.0677	0.2743	0.1366
500	7	0.0313	0.0710	0.2732	0.1373
500	8	0.0323	0.0737	0.2722	0.1379
500	9	0.0333	0.0762	0.2712	0.1384
500	10	0.0341	0.0784	0.2704	0.1388

TABLE 7.10 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/l000')		ZERO SEQUENCE (OHMS/1000)	
		R	X	R	X
750	2	0.0170	0.0391	0.2429	0.1001
750	3	0.0190	0.0481	0.2411	0.1016
750	4	0.0207	0.0544	0.2400	0.1026
750	5	0.0223	0.0591	0.2387	0.1034
750	6	0.0237	0.0630	0.2377	0.1041
750	7	0.0249	0.0662	0.2370	0.1047
750	8	0.0261	0.0688	0.2363	0.1052
750	9	0.0271	0.0712	0.2356	0.1057
750	10	0.0281	0.0733	0.2351	0.1061
1000	2	0.0135	0.0359	0.2141	0.0796
1000	3	0.0156	0.0448	0.2128	0.0809
1000	4	0.0174	0.0510	0.2119	0.0818
1000	5	0.0191	0.0557	0.2111	0.0825
1000	6	0.0206	0.0594	0.2105	0.0831
1000	7	0.0220	0.0626	0.2099	0.0837
1000	8	0.0233	0.0652	0.2094	0.0841
1000	9	0.0244	0.0675	0.2089	0.0845
1000	10	0.0255	0.0695	0.2085	0.0848

TABLE 7.11

23KV 3-1/C CU PILC

4	2	0.2615	0.0716	0.5642	0.2147
4	3	0.2630	0.0807	0.5598	0.2164
4	4	0.2644	0.0871	0.5565	0.2176
4	5	0.2656	0.0920	0.5539	0.2184
4	6	0.2666	0.0960	0.5517	0.2191
4	7	0.2676	0.0993	0.5498	0.2197
4	8	0.2685	0.1022	0.5482	0.2202
4	9	0.2693	0.1047	0.5467	0.2206
4	10	0.2700	0.1069	0.5454	0.2210

TABLE 7.11 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/l000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
2	2	0.1643	0.0673	0.4607	0.2013
2	3	0.1659	0.0764	0.4566	0.2030
2	4	0.1673	0.0828	0.4535	0.2042
2	5	0.1685	0.0877	0.4511	0.2051
2	6	0.1695	0.0916	0.4491	0.2059
2	7	0.1705	0.0950	0.4473	0.2065
2	8	0.1714	0.0979	0.4458	0.2070
2	9	0.1723	0.1004	0.4444	0.2074
2	10	0.1730	0.1026	0.4431	0.2078
1/0	2	0.1044	0.0624	0.4008	0.1965
1/0	3	0.1060	0.0716	0.3967	0.1983
1/0	4	0.1074	0.0779	0.3936	0.1994
1/0	5	0.1086	0.0828	0.3912	0.2004
1/0	6	0.1097	0.0868	0.3892	0.2011
1/0	7	0.1106	0.0902	0.3874	0.2017
1/0	8	0.1116	0.0930	0.3859	0.2022
1/0	9	0.1123	0.0955	0.3845	0.2026
1/0	10	0.1131	0.0977	0.3832	0.2030
300	2	0.0384	0.0503	0.3010	0.1434
300	3	0.0402	0.0594	0.2982	0.1452
300	4	0.0417	0.0657	0.2962	0.1464
300	5	0.0431	0.0705	0.2944	0.1473
300	6	0.0444	0.0744	0.2930	0.1481
300	7	0.0455	0.0777	0.2919	0.1488
300	8	0.0465	0.0805	0.2908	0.1494
300	9	0.0474	0.0830	0.2898	0.1498
300	10	0.0483	0.0851	0.2889	0.1503

TABLE 7.11 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
350	2	0.0333	0.0479	0.2889	0.1343
350	3	0.0351	0.0569	0.2863	0.1360
350	4	0.0366	0.0632	0.2844	0.1372
350	5	0.0380	0.0672	0.2829	0.1381
350	6	0.0393	0.0719	0.2816	0.1389
350	7	0.0404	0.0752	0.2805	0.1395
350	8	0.0415	0.0780	0.2794	0.1401
350	9	0.0424	0.0804	0.2786	0.1406
350	10	0.0433	0.0826	0.2777	0.1410
400	2	0.0294	0.0464	0.2799	0.1283
400	3	0.0312	0.0555	0.2775	0.1299
400	4	0.0328	0.0618	0.2757	0.1311
400	5	9.0342	0.0666	0.2742	0.1320
400	6	0.0355	0.0705	0.2730	0.1328
400	7	0.0366	0.0737	0.2719	0.1334
400	8	0.0377	0.0765	0.2710	0.1340
400	9	0.0387	0.0789	0.2702	0.1345
400	10	0.0395	0.0811	0.2694	0.1349
500	2	0.0241	0.0436	0.2547	0.1079
500	3	0.0261	0.0526	0.2527	0.1094
500	4	0.0278	0.0589	0.2513	0.1105
500	5	0.0293	0.0637	0.2502	0.1114
500	6	0.0307	0.0675	0.2492	0.1123
500	7	0.0319	0.0706	0.2484	0.1127
500	8	0.0330	0.0734	0.2476	0.1132
500	9	0.0341	0.0758	0.2470	0.1137
500	10	0.0351	0.0779	0.2464	0.1141

TABLE 7.11 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
750	2	0.0169	0.0391	0.2201	0.0844
750	3	0.0190	0.0481	0.2188	0.0857
750	4	0.0209	0.0543	0.2179	0.0866
750	5	0.0226	0.0590	0.2170	0.0874
750	6	0.0241	0.0627	0.2164	0.0880
750	7	0.0254	0.0659	0.2158	0.0885
750	8	0.0266	0.0685	0.2153	0.0890
750	9	0.0278	0.0708	0.2148	0.0894
750	10	0.0288	0.0728	0.2144	0.0898
1000	2	0.0134	0.0359	0.1933	0.0673
1000	3	0.0156	0.0448	0.1924	0.0690
1000	4	0.0176	0.0509	0.1917	0.0698
1000	5	0.0194	0.0555	0.1911	0.0704
1000	6	0.0210	0.0592	0.1906	0.0709
1000	7	0.0225	0.0622	0.1902	0.0713
1000	8	0.0239	0.0648	0.1898	0.0717
1000	9	0.0251	0.0669	0.1895	0.0720
1000	10	0.0262	0.0689	0.1892	0.0724

TABLE 7.12

35KV 3-1/C CU PILC

2	2	0. 1641	0.0673	0.4156	0.1501
2	3	0.1659	0.0763	0.4132	0.1517
2	4	0.1679	0.0826	0.4113	0.1530
2	5	0.1689	0.0875	0.4098	0.1538
2	6	0.1701	0.0913	0.4086	0.1546
2	7	0.1713	0.0946	0.4076	0.1552
2	8	0.1723	0.0974	0.4066	0.1558
2	9	0.1733	0.0998	0.4058	0.1563
2	10	0.1742	0.1020	0.4050	0.1567

TABLE 7.12 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
* * * *	******	**********		**********	
		R	X	R	X
1/0	2	0.1042	0.0624	0.3558	0.1451
1/0	3	0.1061	0.0715	0.3533	0.1468
1/0	4	0.1076	0.0778	0.3515	0.1480
1/0	5	0.1091	0.0826	0.3501	0.1489
1/0	6	0.1103	0.0865	0.3488	0.1496
1/0	7	0.1115	0.0897	0.3477	0.1503
1/0	8	0.1125	0.0925	0.3468	0.1509
1/0	9	0.1135	0.0949	0.3459	0.1513
1/0	10	0.1144	0.0971	0.3452	0.1517
2/0	2	0.0833	0.0599	0.3230	0.1313
2/0	3	0.0852	0.0689	0.3208	0.1329
2/0	4	0.0869	0.0752	0.3192	0.1341
2/0	5	0.0884	0.0800	0.3180	0.1349
2/0	6	0.0897	0.0838	0.3169	0.1357
2/0	7	0.0909	0.0870	0.3159	0.1363
2/0	8	0.0920	0.0898	0.3151	0.1368
2/0	9	0.0930	0.0922	0.3144	0.1373
2/0	10	0.0940	0.0943	0.3137	0.1377
3/0	2	0.0664	0.0571	0.3038	0.1267
3/0	3	0.0684	0.0661	0.3017	0.1283
3/0	4	0.0700	0.0724	0.3002	0.1294
3/o	5	0.0716	0.0772	0.2990	0.1303
3/0	6	0.0729	0.0810	0.2979	0.1310
3/0	7	0.0741	0.0842	0.2970	0.1316
3/0	8	0.0752	0.0869	0.2962	0.1322
3/o	9	0.0762	0.0894	0.2955	0.1327
3/0	10	0.0772	0.0915	0.2948	0.1331

TABLE 7.12 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
4/0	2	0.0531	0.0545	0.2882	0.1224
4/0	3	0.0551	0.0635	0.2862	0.1240
4/0	4	0.0567	0.0698	0.2848	0.1251
4/0	5	0.0583	0.0745	0.2836	0.1259
4/0	6	0.0596	0.0784	0.2825	0.1266
4/0	7	0.0608	0.0816	0.2816	0.1273
4/0	8	0.0619	0.0843	0.2809	0.1278
4/0	9	0.0630	0.0867	0.2801	0.1283
4/0	10	0.0639	0.0888	0.2795	0.1287
250	2	0.0455	0.0523	0.2760	0.1167
250	3	0.0474	0.0613	0.2741	0.1183
250	4	0.0491	0.0676	0.2727	0.1194
250	5	0.0507	0.0724	0.2716	0.1202
250	6	0.0520	0.0762	0.2706	0.1209
250	7	0.0533	0.0794	0.2698	0.1215
250	8	0.0544	0.0821	0.2691	0.1220
250	9	0.0555	0.0845	0.2684	0.1225
250	10	0.0564	0=0866	0.2678	0.1229
300	2	0.0383	0.0503	0.2641	0.1113
300	3	0.0402	0.0593	0.2623	0.1127
300	4	0.0419	0.0655	0.2609	0.1138
300	5	0.0435	0.0703	0.2599	0.1147
300	6	0.0448	0.0741	0.2590	0.1154
300	7	0.0461	0.0773	0.2582	0.1159
300	8	0.0473	0.0800	0.2575	0.1165
300	9	0.0483	0.0824	0.2569	0.1169
300	10	0.0493	0.0845	0.2563	0.1173

TABLE 7.12 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
350	2	0.0331	0.0479	0.2529	0.1045
350	3	0.0351	0.0569	0.2512	0.1060
350	4	0.0368	0.0631	0.2500	0.1070
350	5	0.0384	0.0678	0.2490	0.1078
350	6	0.0398	0.0716	0.2481	0.1085
350	7	0.0411	0.0748	0.2474	0.1091
350	8	0.0423	0.0775	0.2467	0.1095
350	9	0.0433	0.0798	0.2462	0.1100
350	10	0.0443	0.0819	0.2456	0.1104
400	2	0.0293	0.0464	0.2364	0.0940
400	3	0.0312	0.0554	0.2351	0.0953
400	4	0.0332	0.0616	0.2340	0.0962
400	5	0.0349	0.0662	0.2331	0.0970
400	6	0.0364	0.0700	0.2324	0.0977
400	7	0.0377	0.0731	0.2318	0.0982
400	8	0.0390	0.0758	0.2313	0.0987
400	9	0.0401	0.0781	0.2308	0.0991
400	10	0.0411	0.0801	0.2303	0.0994
500	2	0.0239	0.0436	0.2231	0.0867
500	3	0.0259	0.0526	0.2219	0.0879
500	4	0.0279	0.0587	0.2210	0.0888
500	5	0.0295	0.0634	0.2207	0.0895
500	6	0.0311	0.0672	0.2196	0.0902
500	7	0.0324	0.0703	0.2190	0.0906
500	8	0.0337	0.0729	0.2185	0.0911
500	9	0.0348	0.0752	0.2181	0.0915
500	10	0.0359	0.0772	0.2177	0.0918

TABLE 7.12 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000') R	POSITIVE SEQUENCE (OHMS/1000') X	ZERO SEQUENCE (OHMS/1000') R	ZERO SEQUENCE (OHMS/1000') X
750	2	0.0167	0.0391	0.1923	0.0694
750	3	0.0189	0.0480	0.1915	0.0704
750	4	0.0209	0.0542	0.1909	0.0712
750	5	0.0227	0.0588	0.1903	0.0717
750	6	0.0244	0.0624	0.1898	0.0723
750	7	0.0259	0.0655	0.1894	0.0726
750	8	0.0273	0.0680	0.1891	0.0730
750	9	0.0285	0.0702	0.1888	0.0734
750	10	0.0297	0.0721	0.1885	0.0737
1000	3	0.0155	0.0448	0.1689	0.0583
1000	4	0.0176	0.0508	0.1684	0.0589
1000	5	0.0195	0.0553	0.1680	0.0594
1000	6	0.0213	0.0589	0.1677	0.0598
1000	7	0.0229	0.0618	0.1674	0.0601
1000	8	0.0244	0.0642	0.1671	0.0605
1000	9	0.0257	0.0663	0.1667	0.0608
1000	10	0.0269	0.0682	0.1667	0.0610

TABLE 7.13

5KV 3-1/C CU VC

6	1	0.4108	0.0611	0.7733	0.5042
6	2	0.4119	0.0769	0.7548	0.4958
6	3	0.4128	0.0862	0.7438	0.4905
6	4	0.4135	0.0927	0.7361	0.4865
6	5	0.4141	0.0978	0.7300	0.4832
6	6	0.4146	0.1019	0.7251	0.4805
6	7	0.4151	0.1055	0.7209	0.4781
6	8	0.4155	0.1085	0.7173	0.4761
6	9	0.4159	0.1112	0.7141	0.4742
6	10	0.4162	0.1135	0.7112	0.4725

TABLE 7.13 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
4	1	0.2598	0.0558	0.6283	0.4678
4	2	0.2609	0.0717	0.6103	0.4615
4	3	0.2619	0.0809	0.5997	0.4573
4	4	0.2626	0.0875	0.5921	0.4542
4	5	0.2633	0.0926	0.5862	0.4516
4	6	0.2638	0.0967	0.5814	0.4495
4	7	0.2643	0.1001	0.5773	0.4476
4	8	0.2648	0.1032	0.5737	0.4459
4	9	0.2652	0.1059	0.5706	0.4444
4	10	0.2656	0.1082	0.5678	0.4430
2	1	0.1626	0.0515	0.5341	0.4337
2	2	0.1638	0.0674	0.5169	0.4293
2	3	0.1647	0.0766	0.5067	0.4262
2	4	0.1655	0.0832	0.4994	0.4230
2	5	0.1662	0.0882	0.4937	0.4219
2	6	0.1668	0.0923	0.4891	0.4202
2	7	0.1673	0.0959	0.4851	0.4188
2	8	0.1678	0.0988	0.4816	0.4175
2	9	0.1683	0.1015	0.4786	0.4163
2	10	0.1687	0.1039	0.4759	0.4152
1/0	1	0.1027	0.0466	0.4744	0.3924
1/0	2	0.1039	0.0625	0.4585	0.3899
1/0	3	0.1049	0.0718	0.4490	0.3881
1/0	4	0.1057	0.0783	0.4421	0.3866
1/0	5	0.1065	0.0834	0.4367	0.3853
1/0	6	0.1071	0.0874	0.4323	0.3842
1/0	7	0.1077	0.0909	0.4286	0.3833
1/0	8	0.1082	0.0939	0.4253	0.3824
1/0	9	0.1087	0.0965	0.4224	0.3816
1/0	10	0.1091	0.0989	0.4198	0.3808

TABLE 7.13 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
2/0	2	0.0829	0.0600	0.4369	0.3701
2/0	3	0.0839	0.0693	0.4277	0.3688
2/0	4	0.0848	0.0758	0.4211	0.3677
2/0	5	0.0855	0.0809	0.4159	0.3668
2/0	6	0.0862	0.0849	0.4116	0.3659
2/0	7	0.0867	0.0884	0.4080	0.3651
2/0	8	0.0873	0.0914	0.4048	0.3644
2/0	9	0.0878	0.0941	0.4153	0.3638
2/0	10	0.0883	0.0964	0.3995	0.3633
3/0	2	0.0664	0.0572	0.4043	0.2754
3/0	3	0.0677	0.0663	0.3976	0.2762
3/0	4	0.0688	0.0728	0.3927	0.2767
3/0	5	0.0698	0.0778	0.3887	0.2770
3/0	6	0.0706	0.0819	0.3855	0.2773
3/0	7	0.0714	0.0853	0.3827	0.2774
3/0	8	0.0721	0.0882	0.3803	0.2775
3/o	9	0.0727	0.0908	0.3782	0.2776
3/0	10	0.0733	0.0931	0.3762	0.2777
4/0	2	0.0530	0.0545	0.3839	0.2543
4/0	3	0.0544	0.0637	0.3777	0.2555
4/0	4	0.0555	0.0702	0.3732	0.2562
4/0	5	0.0566	0.0752	0.3696	0.2567
4/0	6	0.0574	0.0792	0.3666	0.2571
4/0	7	0.0582	0.0826	0.3641	0.2574
4/0	8	0.0590	0.0855	0.3619	0.2576
4/0	9	0.0596	0.0881	0.3598	0.2578
4/0	10	0.0602	0.0904	0.3580	0.2580

TABLE 7.13 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000)		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
250	2	0.0454	0.0524	0.3661	0.2304
250	3	0.0468	0.0616	0.3606	0.2318
250	4	0.0480	0.0680	0.3566	0.2327
250	5	0.0491	0.0730	0.3534	0.2334
250	6	0.0500	0.0770	0.3507	0.2340
250	7	0.0508	0.0804	0.3484	0.2344
250	8	0.0516	0.0833	0.3464	0.2348
250	9	0.0523	0.0859	0.3446	0.2351
250	10	0.0529	0.0882	0.3430	0.2353
300	2	0.0382	0.0504	0.3512	0.2142
300	3	0.0396	0.0595	0.3462	0.2157
300	4	0.0408	0.0659	0.3425	0.2168
300	5	0.0419	0.0709	0.3395	0.2175
300	6	0.0429	0.0749	0.3371	0.2182
300	7	0.0437	0.0783	0.3350	0.2187
300	8	9.0445	0.0812	0.3331	0.2191
300	9	0.0452	0.0837	0.3315	0.2194
300	10	0.0459	0.0860	0.3300	0.2198
350	2	0.0330	0.0479	0.3400	0.2017
350	3	0.0344	0.0570	0.3353	0.2034
350	4	0.0357	0.0635	0.3318	0.2044
350	5	0.0368	0.0684	0.3291	0.2053
350	6	0.0377	0.0724	0.3268	0.2059
350	7	0.0387	0.0758	0.3248	0.2065
350	8	0.0394	0.0787	0.3230	0.2065
350	9	0.0402	0.0812	0.3215	0.2073
350	10	0.0409	0.0835	0.3201	0.2077

TABLE 7.13 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000') R	POSITIVE SEQUENCE (OHMS/1000') X	ZERO SEQUENCE (OHMS/1000') R	ZERO SEQUENCE (OHMS/1000') X
400	2	0.0291	0.0465	0.3274	0.1871
400	3	0.0306	0.0556	0.3232	0.1888
400	4	0.0319	0.0620	0.3201	0.1900
400	5	0.0330	0.0669	0.3176	0.1909
400	6	0.0340	0.0710	0.3155	0.1916
400	7	0.0349	0.0743	0.3136	0.1922
400	8	0.0358	0.0772	0.3120	0.1927
400	9	0.0366	0.0798	0.3125	0.1931
400	10	0.0373	0.0820	0.3114	0.1935
500	2	0.0241	0.0436	0.2777	0.1284
500	3	0.0259	0.0527	0.2752	0.1302
500	4	0.0275	0.0590	0.2733	0.1313
500	5	0.0289	0.0638	0.2718	0.1323
500	6	0.0301	0.0677	0.2705	0.1330
500	7	0.0312	0.0709	0.2694	0.1337
500	8	0.0323	0.0737	0.2685	0.1342
500	9	0.0333	0.0762	0.2676	0.1347
500	10	0.0341	0.0784	0.2668	0.1351
750	2	0.0169	0.0391	0.2475	0.1050
750	3	0.0187	0.0482	0.2456	0.1065
750	4	0.0204	0.0545	0.2442	0.1076
750	5	0.0219	0.0593	0.2430	0.1085
750	6	0.0232	0.0631	0.2420	0.1092
750	7	0.0244	0.0663	0.2412	0.1098
750	8	0.0255	0.0691	0.2405	0.1103
750	9	0.0265	0.0715	0.2398	0.1108
750	10	0.0275	0.0736	0.2392	0.1112

TABLE 7.13 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000') R	X	ZERO SEQUENCE (OHMS/1000') R	X
1000	2	0.0133	0.0359	0.2282	0.0909
1000	3	0.0151	0.0449	0.2267	0.0923
1000	4	0.0168	0.0512	0.2255	0.0934
1000	5	0.0184	0.0560	0.2246	0.0941
1000	6	0.0198	0.0598	0.2238	0.0948
1000	7	0.0210	0.0630	0.2231	0.0954
1000	8	0.0222	0.0657	0.2225	0.0959
1000	9	0.0232	0.0680	0.2219	0.0963
1000	10	0.0242	0.0701	0.2214	0.0967

TABLE 7.14

15KV 3-1/C CU VC

6	1	0.4106	0.0611	0.7816	0.3942
6	2	0.4118	0.0769	0.7661	0.3923
6	3	0.4129	0.0862	0.7569	0.3909
6	4	0.4137	0.0548	0.7502	0.3897
6	5	0.4144	0.0409	0.7449	0.3887
6	6	0.4151	0.1019	0.7406	0.3877
6	7	0.4157	0.1053	0.7369	0.3869
6	8	0.4162	0.1083	0.7337	0.3862
6	9	0.4167	0.1109	0.7309	0.3855
6	10	0.4172	0.1133	0.7284	0.3848
4	1	0.2598	0.0558	0.6117	0.2919
4	2	0.2613	0.0716	0.6005	0.2935
4	3	0.2626	0.0808	0.5937	0.2943
4	4	0.2637	0.0873	0.5887	0.2948
4	5	0.2647	0.0923	0.5847	0.2950
4	6	0.2655	0.0963	0.5815	0.2952
4	7	0.2662	0.0997	0.5787	0.2954
4	8	0.2669	0.1038	0.5762	0.2955
4	9	0.2676	0.1053	0.5740	0.2955
4	10	0.2682	0.1076	0.5720	0.2955

TABLE 7.14 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
2	1	0.1625	0.0515	0.5063	0.2679
2	2	0.1641	0.0673	0.4961	0.2701
2	3	0.1654	0.0765	0.4898	0.2712
2	4	0.1666	0.0830	0.4852	0.2719
2	5	0.1675	0.0880	0.4816	0.2723
2	6	0.1684	0.0920	0.4786	0.2727
2	7	0.1692	0.0954	0.4760	0.2730
2	8	0.1699	0.0984	0.4737	0.2732
2	9	0.1706	0.1009	0.4717	0.2734
2	10	0.1712	0.1032	0.4697	0.2735
1/0	2	0.1041	0.0625	0.4258	0.2424
1/0	3	0.1055	0.0716	0.4203	0.2438
1/0	4	0.1067	0.0781	0.4162	0.2447
1/0	5	0.1077	0.0830	0.4130	0.2454
1/0	6	0.1087	0.0871	0.4103	0.2459
1/0	7	0.1095	0.0905	0.4080	0.2463
1/0	8	0.1103	0.0934	0.4059	0.2467
1/0	9	0.1110	0.0959	0.4041	0.2469
1/0	10	0.1116	0.0983	0.4025	0.2472
2/0	2	0.0825	0.0600	0.3984	0.2279
2/0	3	0.0845	0.0691	0.3932	0.2294
2/0	4	0.0857	0.0756	0.3894	0.2304
2/0	5	0.0867	0.0805	0.3864	0.2312
2/0	6	0.0877	0.0845	0.3839	0.2318
2/0	7	0.0886	0.0880	0.3817	0.2323
2/0	8	0.0894	0.0909	0.3798	0.2326
2/o	9	0.0901	0.0934	0.3781	0.2330
2/0	10	0.0907	0.0957	0.3766	0.2333

TABLE 7.14 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
3/0	2	0.0662	0.0572	0.3750	0.2140
3/0	3	0.0676	0.0474	0.3702	0.2156
3/0	4	0.0688	0.0727	0.3667	0.2167
3/0	5	0.0699	0.0777	0.3639	0.2175
3/0	6	0.0709	0.0817	0.3615	0.2181
3/o	7	0.0718	0.0851	0.3595	0.2187
3/0	8	0.0726	0.0880	0.3577	0.2191
3/o	9	0.0733	0.0905	0.3562	0.2195
3/0	10	0.0740	0.0928	0.3547	0.2199
4/0	2	0.0528	0.0545	0.3518	0.1962
4/0	3	0.0543	0.0637	0.3475	0.1979
4/0	4	0.0555	0.0701	0.3444	0.1991
4/0	5	0.0567	0.0751	0.3419	0.1999
4/0	6	0.0577	0.0791	0.3397	0.2006
4/0	7	0.0586	0.0824	0.3379	0.2012
4/0	8	0.0594	0.0853	0.3363	0.2017
4/0	9	0.0602	0.0878	0.3348	0.2022
4/0	10	0.0609	0.0901	0.3336	0.2026
250	2	0.0451	0.0524	0.3338	0.1799
250	3	0.0466	0.0616	0.3300	0.1817
250	4	0.0480	0.0680	0.3272	0.1829
250	5	0.0491	0.0729	0.3249	0.1838
250	6	0.0501	0.0769	0.3230	0.1846
250	7	0.0511	0.0802	0.3214	0.1852
250	8	0.0520	0.0831	0.3199	0.1858
250	9	0.0528	0.0856	0.3187	0.1862
250	10	0.0535	0.0879	0.3175	0.1866

TABLE 7.14 (Continued)

AWG OR KC M	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000') R	POSITIVE SEQUENCE (OHMS/1000') X	ZERO SEQUENCE (OHMS/1000') R	ZERO SEQUENCE (OHMS/1000') X
300	2	0.0383	0.0503	0.2909	0.1342
300	3	0.0401	0.0594	0.2884	0.1359
300	4	0.0417	0.0657	0.2866	0.1371
300	5	0.0431	0.0705	0.2851	0.1380
300	6	0.0433	0.0744	0.2838	0.1388
300	7	0.0455	0.0777	0.2827	0.1394
300	8	0.0465	0.0804	0.2817	0.1400
300	9	0.0474	0.0829	0.2809	0.1405
300	10	0.0484	0.0850	0.2801	0.1409
350	2	0.0331	0.0479	0.2794	0.1263
350	3	0.0349	0.0569	0.2771	0.1279
350	4	0.0365	0.0632	0.2753	0.1291
350	5	0.0380	0.0672	0.2740	0.1300
350	6	0.0392	0.0719	0.2728	0.1308
350	7	0.0404	0.0751	0.2718	0.1314
350	8	0.0414	0.0779	0.2709	0.1319
350	9	0.0424	0.0804	0.2701	0.1324
350	10	0.0433	0.0825	0.2694	0.1329
400	2	0.0293	0.0464	0.2690	0.1194
400	3	0.0311	0.0555	0.2669	0.1209
400	4	0.0327	0.0618	0.2653	0.1221
400	5	0.0342	0.0666	0.2640	0.1230
400	6	0.0355	0.0705	0.2629	0.1237
400	7	0.0366	0.0737	0.2620	0.1243
400	8	0.0377	0.0764	0.2612	0.1249
400	9	0.0387	0.0788	0.2604	0.1254
400	10	0.0397	0.0809	0.2597	0.1258

TABLE 7.14 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
500	2	0.0238	0.0437	0.2533	0.1086
500	3	0.0257	0.0527	0.2515	0.1102
500	4	0.0273	0.0590	0.2501	0.1112
500	5	0.0288	0.0637	0.2489	0.1121
500	6	0.0302	0.0676	0.2480	0.1128
500	7	0.0314	0.0708	0.2471	0.1134
500	8	0.0325	0.0735	0.2464	0.1139
500	9	0.0335	0.0759	0.2458	0.1144
500	10	0.0345	0.0780	0.2452	0.1148
750	2	0.0166	0.0392	0.2265	0.0909
750	3	0.0185	0.0482	0.2251	0.0923
750	4	0.0202	0.0544	0.2240	0.0933
750	5	0.0217	0.0592	0.2231	0.0941
750	6	0.0232	0.0630	0.2224	0.0947
750	7	0.0244	0.0662	0.2217	0.0952
750	8	0.0256	0.0689	0.2212	0.0957
750	9	0.0267	0.0712	0.2206	0.0961
750	10	0.0277	0.0733	0.2201	0.0965
1000	2	0.0132	0.0359	0.1845	0.0644
1000	3	0.0154	0.0448	0.1837	0.0654
1000	4	0.0174	0.0509	0.1831	0.0661
1000	5	0.0192	0.0555	0.1826	0.0667
1000	6	0.0209	0.0592	0.1822	0.0672
1000	7	0.0224	0.0622	0.1818	0.0676
1000	8	0.0238	0.0647	0.1815	0.0679
1000	9	0.0251	0.0669	0.1812	0.0682
1000	10	0.0262	0.0694	0.1809	0.0685

TABLE 7.15

5KV 3-1/C CU RUBBER OR XLPE

AGW OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000') R	POSITIVE SEQUENCE (OHMS/1000') X	ZERO SEQUENCE (OHMS/1000') R	ZERO SEQUENCE (OHMS/1000') X
6	1	0.4108	0.0611	0.7776	0.4831
6	2	0.4119	0.0769	0.7594	0.4762
6	3	0.4128	0.0862	0.7487	0.4716
6	4	0.4135	0.0927	0.7411	0.4683
6	5	0.4141	0.0978	0.7351	0.4655
6	6	0.4147	0.1019	0.7302	0.4631
6	7	0.4152	0.1054	0.7261	0.4611
6	8	0.4156	0.1084	0.7225	0.4612
6	9	0.4161	0.1111	0.7194	0.4577
6	10	0.4164	0.1135	0.7166	0.4562
4	1	0.2598	0.0558	0.6309	0.4428
4	2	0.2609	0.0717	0.6137	0.4380
4	3	0.2619	0.0809	0.6034	0.4348
4	4	0.2626	0.0874	0.5960	0.4323
4	5	0.2634	0.0925	0.5903	0.4303
4	6	0.2639	0.0966	0.5856	0.4286
4	7	0.2644	0.1001	0.5816	0.4270
4	8	0.2649	0.1031	0.5781	0.4256
4	9	0.2654	0.1058	0.5751	0.4244
4	10	0.2658	0.1081	0.5723	0.4233
2	1	0.1626	0.0515	0.5346	0.4065
2	2	0.1637	0.0674	0.5184	0.4035
2	3	0.1648	0.0766	0.5086	0.4014
2	4	0.1655	0.0831	0.5016	0.3997
2	5	0.1663	0.0882	0.4962	0.3983
2	6	0.1669	0.0923	0.4917	0.3970
2	7	0.1675	0.0958	0.4879	0.3959
2	8	0.1680	0.0988	0.4845	0.3949
2	9	0.1684	0.1015	0.4816	0.3940
2	10	0.1689	0.1038	0.4790	0.3932

TABLE 7.15 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
1/0	1	0.1027	0.0466	0.4576	0.2905
1/0	2	0.1043	0.0625	0.4460	0.2920
1/0	3	0.1055	0.0716	0.4389	0.2926
1/0	4	0.1066	0.0781	0.4337	0.2930
1/0	5	0.1076	0.0831	0.4297	0.2932
1/0	6	0.1084	0.0872	0.4263	0.2933
1/0	7	0.1092	0.0906	0.4234	0.2934
1/0	8	0.1098	0.0936	0.4209	0.2934
1/0	9	0.1105	0.0962	0.4186	0.2934
1/0	10	0.1111	0.0985	0.4166	0.2934
2/0	1	0.0817	0.0442	0.4302	0.2715
2/0	2	0.0832	0.0600	0.4194	0.2734
2/0	3	0.0845	0.0691	0.4128	0.2743
2/0	4	0.0857	0.0756	0.4080	0.2748
2/0	5	3.0866	0.0806	0.4042	0.2752
2/0	6	0.0875	0.0847	0.4010	0.2755
2/0	7	0.0883	0.0881	0.3983	0.2757
2/0	8	0.0890	0.0910	0.3959	0.2759
2/0	9	0.0896	0.0936	0.3938	0.2760
2/0	10	0.0902	0.0959	0.3919	0.2761
3/0	2	0.0663	0.0572	0.3963	0.2549
3/0	3	0.0676	0.0663	0.3902	0.2561
3/0	4	0.0688	0.0728	0.3857	0.2569
3/0	5	0.0698	0.0778	0.3822	0.2574
3/0	6	0.0707	0.0818	0.3792	0.2578
3/0	7	0.0715	0.0852	0.3767	0.2581
3/0	8	0.0723	0.0881	0.3745	0.2584
3/0	9	0.0729	0.0907	0.3725	0.2586
3/0	10	0.0735	0.0930	0.3707	0.2587

TABLE 7.15 (Continued)

AWG OR KC M	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000') R	POSITIVE SEQUENCE (OHMS/1000') X	ZERO SEQUENCE (OHMS/1000') R	ZERO SEQUENCE (OHMS/1000') X
4/0	2	0.0530	0.0545	0.3752	0.2354
4/0	3	0.0544	0.0637	0.3696	0.2368
4/0	4	0.0556	0.0701	0.3655	0.2377
4/0	5	0.0566	0.0751	0.3623	0.2384
4/0	6	0.0576	0.0791	0.3596	0.2389
4/0	7	0.0584	0.0826	0.3573	0.2393
4/0	8	0.0591	0.0855	0.3552	0.2397
4/0	9	0.0598	0.0880	0.3534	0.2399
4/0	10	0.0605	0.0903	0.3517	0.2402
250	2	0.0454	0.0524	0.3560	0.2122
250	3	0.0468	0.0616	0.3511	0.2138
250	4	0.0480	0.0680	0.3475	0.2149
250	5	0.0491	0.0730	0.3447	0.2157
250	6	0.0501	0.0769	0.3423	0.2163
250	7	0.0509	0.0804	0.3402	0.2169
250	8	0.0517	0.0833	0.3384	0.2173
250	9	0.0524	0.0858	0.3368	0.2177
250	10	0.0531	0.0881	0.3353	0.2180
300	2	0.0381	0.0504	0.3425	0.2001
300	3	0.0395	0.0595	0.3379	0.2018
300	4	0.0408	0.0659	0.3346	0.2029
300	5	0.0419	0.0709	0.3319	0.2037
300	6	0.0429	0.0749	0.3297	0.2044
300	7	0.0438	0.0783	0.3277	0.2050
300	8	0.0446	0.0812	0.3260	0.2055
300	9	0.0454	0.0837	0.3245	0.2059
300	10	0.0461	0.0859	0.3231	0.2062

TABLE 7.15 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000') R	POSITIVE SEQUENCE (OHMS/1000') X	ZERO SEQUENCE (OHMS/1000') R	ZERO SEQUENCE (OHMS/1000') X
350	2	0.0333	0.0479	0.2969	0.1421
350	3	0.0351	0.0569	0.2940	0.1438
350	4	0.0366	0.0633	0.2919	0.1441
350	5	0.0380	0.0681	0.2902	0.1460
350	6	0.0392	0.0720	0.2888	0.1468
350	7	0.0403	0.0752	0.2876	0.1474
350	8	0.0413	0.0780	0.2865	0.1480
350	9	0.0422	0.0805	0.2855	0.1485
350	10	0.0431	0.0827	0.2846	0.1490
400	2	0.0294	0.0464	0.2861	0.1340
400	3	0.0312	0.0555	0.2835	0.1357
400	4	0.0328	0.0618	0.2816	0.1369
400	5	0.0342	0.0666	0.2800	0.1379
400	6	0.0354	0.0705	0.2787	0.1386
400	7	0.0366	0.0738	0.2775	0.1393
400	8	0.0376	0.0766	0.2765	0.1398
400	9	0.0385	0.0790	0.2756	0.1403
400	10	0.0394	0.0812	0.2748	0.1408
500	2	0.0240	0.0436	0.2707	0.1211
500	3	0.0258	0.0527	0.2670	0.1227
500	4	0.0274	0.0590	0.2652	0.1239
500	5	0.0289	0.0638	0.2639	0.1248
500	6	0.0301	0.0676	0.2627	0.1255
500	7	0.0313	0.0709	0.2617	0.1262
500	8	0.0324	0.0737	0.2609	0.1267
500	9	0.0334	0.0761	0.2601	0.1272
500	10	0.0343	0.0782	0.2593	0.1276

TABLE 7.15 (Continued)

AWG OR KCH	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000') R	POSITIVE SEQUENCE (OHMS/1000') X	ZERO SEQUENCE (OHMS/1000') R	ZERO SEQUENCE (OHMS/1000') X
750	2	0.0167	0.0391	0.2403	0.1000
750	3	0.0186	0.0482	0.2386	0.1015
750	4	0.0203	0.0545	0.2373	0.1025
750	5	0.0218	0.0592	0.2362	0.1034
750	6	0.0231	0.0631	0.2353	0.1041
750	7	0.0244	0.0663	0.2345	0.1046
750	8	0.0255	0.0690	0.2339	0.1051
750	9	0.0266	0.0714	0.2333	0.1056
753	10	0.0275	0.0735	0.2327	0.1060
1000	2	0.0134	0.0359	0.1933	0.0679
1000	3	0.0156	0.0448	0.1924	0.0690
1000	4	0.0176	0.0509	0.1917	0.0698
1000	5	0.0194	0.0555	0.1911	0.0704
1000	6	0.0210	0.0592	0.1906	0.0709
1000	7	0.0225	0.0622	0.1902	0.0713
1000	8	0.0239	0.0648	0.1898	0.0717
1000	9	0.0251	0.0669	0.1895	0.0720
1000	10	0.0262	0.0689	0.1892	0.0724

TABLE 7.16

15KV 3-1/C CU RUBBER OR XLPE

4	1	0.2595	0.0558	0.5783	0.2266
4	2	0.2611	0.0716	0.5705	0.2294
4	3	0.2625	0.0808	0.5657	0.2310
4	4	0.2637	0.0872	0.5622	0.2321
4	5	0.2648	0.0922	0.5593	0.2330
4	6	0.2658	0.0962	0.5569	0.2336
4	7	0.2666	0.0995	0.5549	0.2341
4	8	0.2674	0.1024	0.5531	0.2346
4	9	0.2682	0.1050	0.5515	0.2349
4	10	0.2689	0.1073	0.5501	0.2353

TABLE 7.16 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000') R	X	ZERO SEQUENCE (OHMS/1000') R	X
2	1	0.1623	0.0516	0.4681	0.2040
2	2	0.1638	0.0673	0.4614	0.2069
2	3	0.1653	0.0765	0.4572	0.2087
2	4	0.1666	0.0829	0.4541	0.2098
2	5	0.1677	0.0879	0.4516	0.2107
2	6	0.1687	0.0919	0.4495	0.2115
2	7	0.1696	0.0952	0.4477	0.2120
2	8	0.17'05	0.0981	0.4461	0.2126
2	9	0.1712	0.1006	0.4447	0.2130
2	10	0.1719	0.1029	0.4434	0.2134
1/0	2	0.1039	0.0625	0.3910	0.1880
1/0	3	0.1054	0.0716	0.3872	0.1897
1/0	4	0.0859	0.0780	0.3844	0.1909
1/0	5	0.1079	0.0830	0.3822	0.1919
1/0	6	0.1089	0.0869	0.3804	0.1927
1/0	7	0.1098	0.0903	0.3787	0.1933
1/0	8	0.1107	0.0931	0.3773	0.1938
1/0	9	0.1115	0.0957	0.3761	0.1943
1/0	10	0.1123	0.0975	0.3749	0.1947
2/0	2	0.0832	0.0599	0.3347	0.1429
2/0	3	0.0850	0.0690	0.3323	0.1445
2/0	4	0.0866	0.0753	0.3305	0.1458
2/0	5	0.0880	0.0801	0.3290	0.1467
2/0	6	0.0892	0.0840	0.3277	0.1474
2/0	7	0.0904	0.0873	0.3266	0.1481
2/0	8	0.0914	0.0901	0.3257	0.1486
2/0	9	0.0924	0.0925	0.3248	0.1491
2/0	10	0.0933	0.0946	0.3241	0.1496

TABLE 7.16 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')`	
		R	X	R	X
3/0	2	0.0662	0.0571	0.3115	0.1346
3/0	3	0.0680	0.0662	0.3092	0.1362
3/0	4	0.0697	0.0725	0.3075	0.1374
3/0	5	0.0711	0.6773	0.3061	0.1383
3/0	6	0.0724	0.0812	0.3049	0.1390
3/0	7	0.0736	0.0844	0.3040	0.1397
3/0	8	0.0746	0.0872	0.3031	0.1402
3/0	9	0.0756	0.0896	0.3023	0.1407
3/0	10	0.0765	0.0917	0.3016	0.1411
4/0	2	0.0529	0.0545	0.2904	0.1256
4/0	3	0.0548	0.0636	0.2884	0.1272
4/0	4	0.0564	0.0698	0.2868	0.1283
4/0	5	0.0579	0.0747	0.2855	0.1292
4/0	6	0.0591	0.0785	0.2845	0.1301
4/0	7	0.0604	0.0817	0.2836	0.1305
4/0	8	0.0614	0.0845	0.2828	0.1311
4/0	9	0.0624	0.0869	0.2820	0.1316
4/0	10	0.0634	0.0890	0.2814	0.1320
250	2	0.0453	0.0524	0.2771	0.1191
250	3	0.0471	0.0614	0.2751	0.1206
250	4	0.0488	0.0677	0.2737	0.1217
250	5	0.0502	0.0725	0.2725	0.1226
250	6	0.0516	0.0763	0.2716	0.1233
250	7	0.0528	0.0795	0.2707	0.1239
250	8	0.0539	0.0823	0.2699	0.1244
250	9	0.0549	0.0847	0.2693	0.1249
250	10	0.0559	0.0868	0.2687	0.1253
300	2	0.0380	0.0503	0.2627	0.1119
300	3	0.0398	0.0594	0.2610	0.1134
300	4	0.0416	0.0656	0.2597	0.1144
300	5	0.0430	0.0704	0.2586	0.1152
300	6	0.0444	0.0742	0.2576	0.1159
300	7	0.0456	0.0774	0.2569	0.1165

TABLE 7.16 (Continued)

AWG OR KCM	SPACING (INCHES)	POSITIVE SEQUENCE (OHMS/1000')		ZERO SEQUENCE (OHMS/1000')	
		R	X	R	X
300	8	0.0468	0.0802	0.2562	0.1170
300	9	0.0478	0.0826	0.2556	0.1175
300	10	0.0488	0.0847	0.2550	0.1179
350	2	0.0328	0.0479	0.2527	0.1061
350	3	0.0347	0.0569	0.2511	0.1076
350	4	0.0364	0.0632	0.2498	0.1086
350	5	0.0379	0.0680	0.2488	0.1094
350	6	0.0393	0.0718	0.2480	0.1101
350	7	0.0405	0.0750	0.2473	0.1107
350	8	0.0416	0.0777	0.2466	0.1112
350	9	0.0427	0.0801	0.2460	0.1116
350	10	0.0437	0.0822	0.2455	0.1120
400	2	0.0290	0.0465	0.2440	0.1015
400	3	0.0308	0.0555	0.2424	0.1029
400	4	0.0325	0.0617	0.2412	0.1039
400	5	0.0341	0.0665	0.2403	0.1030
400	6	0.0355	0.0703	0.2395	0.1053
400	7	0.0367	0.0735	0.2388	0.1059
400	8	0.0379	0.0762	0.2382	0.1064
400	9	0.0390	0.0786	0.2377	0.1068
400	10	0.0399	0.0806	0.2371	0.1072
500	2	0.0235	0.0437	0.2270	0.0916
500	3	0.0254	0.0527	0.2257	0.0930
500	4	0.0271	0.0590	0.2247	0.0939
500	5	0.0287	0.0637	0.2239	0.0946
500	6	0.0301	0.0675	0.2232	0.0952
500	7	0.0314	0.0706	0.2226	0.0958
500	8	0.0326	0.0733	0.2221	0.0962
500	9	0.0337	0.0756	0.2216	0.0966
500	10	0.0348	0.0777	0.2212	0.0970

TABLE 9
IMPEDANCE TABLES FOR OVERHEAD LINES

TABLE 9.1

THREE PHASE COPPER OVERHEAD LINE
****

AWG OR KCM *****	POSITIVE SEQUENCE (OHMS/1000') ********** R	X 2.4KV & 4.16KV	13.2KV	34.5KV
6	0.4526	0.1420	0.1458	0.1553
4	0.2846	0.1363	0.1444	0.1501
2	0.1790	0.1297	0.1376	0.1444
1	0.1434	0.1273	0.1349	0.1406
1/0	0.1149	0.1255	0.1321	0.1380
2/0	0.0911	0.1216	0.1297	0.1354
3/o	0.0723	0.1193	0.1269	0.1326
4/0	0.0573	0.1165	0.1240	0.1297
250	0.0487	0.1131	0.1212	0.1269
300	0.0407	0.1112	0.1188	0.1255
500	0.0247	0.1061	0.1129	0.1188

THREE PHASE COPPER OVERHEAD LINE
****

COASTAL AREA
****

(ZERO SEQUENCE IMP. =SELF IMP.-GROUND WIRE IMP.)

AWG OR KCM *****	ZERO SEQUENCE (SELF) (OHMS/1000') ********** R	X 2.4KV & 4.16KV	13.2KV	34.5KV
6	0.4670	0.6051	0.5890	0.5776
4	0.3144	0.6004	0.5842	0.5729

TABLE 9.1 (Continued)

AWG OR KCM	ZERO SEQUENCE (SELF) (OHMS/1000') R	X 2.4KV & 4.16KV	13.2KV	34.5KV
2	0.3181	0.5933	0.5776	0.5662
1	0.1865	0.5904	0.5753	0.5634
1/0	0.1592	0.5966	0.5719	0.5606
2/0	0.1375	0.5852	0.5696	0.5582
3/0	0.1204	0.5828	0.5672	0.5559
4/0	0.1068	0.5795	0.5639	0.5530
250	0.0987	0.5762	0.5611	0.5492
300	0.0915	0.5748	0.5587	0.5473
500	0.0768	0.5681	0.5530	0.5412

THREE PHASE COPPER OVERHEAD LINE

COASTAL AREA

(ZERO SEQUENCE IMP.=SELF IMP.-GROUND WIRE IMP.)

(INDICATED WIRE SIZES ARE FOR GROUND WIRE ONLY)

AWG OR KCM	ZERO SEQUENCE (GROUND WIRE) (OHMS/1000') R 2.4KV & 4.16KV	13.2KV	34.5KV	X 2.4KV & 4.16KV	13.2KV	34.5KV
6	-0.0913	-0.0814	-0.0738	+0.1018	+0.0928	+0.0866
4	-0.0913	-0.0814	-0.0738	+0.1529	+0.1398	+0.1304
2	-0.0913	-0.0814	-0.0738	+0.1894	+0.1720	+0.1607
1	-0.0568	-0.0492	-040435	+0.2178	+0.1976	+0.1834
1/0	-0.0430	-0.0359	-0.0303	+0.2329	+0.2107	+0.1955
2/0	-0.0284	-0.0227	-0.0189	+0.2424	+0.2197	+0. 2042
3/0	-0.0166	-0.0109	-0.0076	+0.2505	+0.2099	+0.2099
4/0	-0.0071	-0.0019	0.0000	+0.2576	+0.2329	+0.2159
250	+0.0019	+0.0052	+0.0076	+0.2657	+0.2367	+0.2197
300	+0.0076	+0.0109	+0.0123	+0.2651	+0.2405	+4.2232

TABLE 9.1 (Continued)

THREE PHASE COPPER OVERHEAD LINE

INLAND AREA

(ZERO SEQUENCE IMP.=SELF IMP.-GROUND WIRE IMP.)

AWG OR KCM	ZERO SEQUENCE (SELF) (OHMS/1000') R	X 2.4KV & 4.16KV	13.2KV	34.5KV
6	0.4670	0.7376	0.7216	0.7102
4	0.3144	0.7329	0.7168	0.7055
2	0.3181	0.7258	0.7102	0.6988
1	0.1865	0.7230	0.7078	0.6960
1/0	0.1592	0.7291	0.7045	0.6931
2/0	0.1375	0.7178	0.7022	0.6908
3/0	0.1204	0.7154	0.6998	0.6884
4/0	0.1068	0.7121	0.6965	0.6856
250	0.0987	0.7088	0.6936	0.6818
300	0.0915	0.7073	0.6912	0.6799
500	0.0768	0.7007	0.6856	0.6737

THREE PHASE COPPER OVERHEAD LINE

INLAND AREA

(ZERO SEQUENCE IMP.=SELF IMP.-GROUND WIRE IMP.)

(INDICATED WIRE SIZES ARE FOR GROUND WIRE ONLY)

AWG OR KCM	ZERO SEQUENCE (GROUND WIRE) (OHMS/1000') R 2.4KV & 4.16KV	13.2KV	34.5KV	X 2.4KV & 4.16KV	13.2KV	34.5KV
6	-0.1434	-0.1306	-0.1226	+0.1648	+0.1136	+0.1436
4	-0.1341	-0.1221	-0.1136	+0.2405	+0.2220	+0.2097

TABLE 9.1 (continued)

AWG OR KCH	ZERO SEQUENCE (GROUND WIRE) (OHMS/1000') R 2.4KV & 4.16KV	13. 2KV	34.5KV	X 2.4KV & 4. 16KV	13. 2KV	34.5KV
2	-0.1023	-0.0928	-0.0857	+0.3040	+0.2803	+0. 2637
1	-0.0823	-0.0738	-0.0681	+0 .3257	+0. 2997	+0.2822
1/o	-0.0630	-0.0559	-0.0508	+0.3409	+0.3141	+0.2954
2/o	-0.0440	-0.0379	-0.0341	+0.3559	+0.3267	+0.3068
3/0	-0.0284	-0.0234	-0.0205	+0. 3650	+0.3357	+0.3153
4/o	-0.0151	-0.0113	-0.0085	+0.3726	+0.3423	+0. 3215
250	-0.0061	-0.0035	-0.0017	+0.3778	+0.3475	+0.3257
300	+0.0019	+0.0047	+0.0061	+0.3806	+0.3504	+0.3314

TABLE 9.2

THREE PHASE ACSR OVERHEAD LINE

AWG OR KCH	POSITIVE SEQUENCE (OHMS/1000') R	X 2.4KV & 4.16KV	13.2KV	34.5KV
6	0.7462	0.1430	0.1505	0.1562
4	0.4769	0.1368	0.1444	0.1504
2	0.3083	0.1331	0.1409	0.1467
1	0.2471	0.1311	0.1387	0.1444
1/0	0.1992	0.1287	0.1363	0.1420
2/0	0.1615	0.1259	0.1335	0.1394
3/0	0.1306	0.1231	0.1311	0.1368
4/0	0.1077	0.1202	0.1278	0.1340
266.8	0.0718	0.1089	0.1166	0.1226
336.4	0.0569	0.1060	0.1141	0.1198
477	0.0401	0.1023	0.1100	0.1160

TABLE 9.2 (Continued)

THREE PHASE ACSR OVERHEAD LINE

COASTAL AREA

(ZERO SEQUENCE IMP.=SELF IMP.-GROUND WIRE IMP.)

AWG OR KCM	ZERO SEQUENCE (SELF) (OHMS/1000') R	X 2.4KV & 4.16KV	13.2KV	34.5KV
6	0.7284	0.6060	0.5909	0.5791
4	0. 4784	0.6004	0.5847	0.5748
2	0.3212	0.5966	0.5809	0.5696
1	0.2662	0.5942	0.5791	0.5672
1/0	0.2223	0.5923	0.5767	0.5648
2/0	0.1879	0.5894	0.5738	0.5625
3/0	0.1602	0.5866	0.5710	0.5596
4/0	0.1384	0.5838	0.5681	0.5568
266.8	0.1204	0.5724	0.5568	0.5454
336.4	0.1068	0.5696	0.5540	0.5426
477	0.0912	0.5658	0.5501	0.5388

THREE PHASE ACSR OVERHEAD LINE

COASTAL AREA

(ZERO SEQUENCE IMP .=SELF IMP.-GROUND WIRE IMP.)

(INDICATED WIRE SIZES ARE FOR GROUND WIRE ONLY)

AWG OR KCM	ZERO SEQUENCE (GROUND WIRE) (OHMS/1000') R 2.4KV & 4.16KV	13.2KV	34.5KV	X 2.4KV & 4.16KV	13.2KV	34.5KV
6	-0.0776	-0.0691	-0.0615	+0.0573	+0.0530	+0.0492
4	-0.0946	-0.0833	-0.0757	+0.0994	+0.0909	+0.0847

TABLE 9.2 (Continued)

AWG OR KCM	ZERO SEQUENCE (GROUND WIRE) (OHMS/1000') R 2.4KV & 4.16KV	R 13.2KV	R 34.5KV	X 2.4KV & 4.16KV	X 13.2KV	X 34.5KV
2	-0.0946	-0.0833	-0.0757	+0.1529	+0.1529	+0.1302
1	-0.0852	-0.0752	-0.0681	+0.1780	+0.1780	+0.1513
1/0	-0.0738	-0.0644	-0.0577	+0.2007	+0.2007	+0.1695
2/0	-0.0592	-0.0511	-0.0454	+0.2197	+0.2192	+0.1856
3/0	-0.0454	-0.0379	-0.0322	+0.2339	+0.2344	+0.1969
4/0	-0.0308	-0.0246	-0.0189	+0.2452	+0.2452	+0.2064
266.8	-0.0203	-0.0151	-0.0113	+0.2594	+0.2594	+0.2178
336.4	-0.0094	-0.0047	-0.0019	+0.2670	+0.2670	+0.2244
477	+0.0056	+0.0080	+0.0099	+0.2755	+0.2755	+0.2301

THREE PHASE ACSR OVERHEAD LINE

INLAND AREA

(ZERO SEQUENCE IMP.=SELF IMP.-GROUND WIRE IMP.)

AWG OR KCM	ZERO SEQUENCE (SELF) (OHMS/1000') R	X 2.4KV & 4.16KV	13.2KV	34.5KV
6	0.7284	0.7386	0.7234	0.7117
4	0.4784	0.7329	0.7173	0.7073
2	0.3212	0.7291	0.7135	0.7022
1	0.2662	0.7268	0.7116	0.6998
1/0	0.2223	0.7249	0.7092	0.6974
2/0	0.1879	0.7220	0.7064	0.6951
3/0	0.1602	0.7192	0.7036	0.6922
4/0	0.1384	0.7163	0.7007	0.6894
266.8	0.1204	0.7050	0.6894	0.6780
336.4	0.1068	0.7022	0.6865	0.6751
477	0.0912	0.6984	0.6827	0.6714

TABLE 9.2 (Continued)

THREE PHASE ACSR OVERHEAD LINE

INLAND AREA

(ZERO SEQUENCE IMP. =SELF IMP.-GROUND WIRE IMP.)

(INDICATED WIRE SIZES ARE FOR GROUND WIRE ONLY)

AWG OR KCM	ZERO SEQUENCE (GROUND HIRE) (OHMS/1000′) R 2.4KV & 4.16KV	13.2KV	34.5KV	X 2.4KV & 4. 16KV	13.2KV	34.5KV
6	-0.1231	-0.1130	-0.1055	+0.0946	+0.0871	+0.0833
4	-0.1467	-0.1326	-0.1245	+0.1591	+0.1477	+0.1397
2	-0.1382	-0.1259	-0.1174	+0.2358	+0.2187	+0.2064
1	-0.1231	-0.1130	-0.1055	+0.2698	+0.2500	+0.2358
1/0	-0.1046	-0.0947	-0.0871	+0.2983	+0.2765	+0.2609
2/0	-0.0842	-0.0757	-0.0686	+0.3219	+0.2978	+0.2812
3/o	-0.0648	-0.0573	-0.0520	+0.3394	+0.3144	+0.2954
4/0	-0.0469	-0.0402	-0.0356	+0.3537	+0.3291	+0.3087
266.8	-0.0322	-0.0269	-0.0232	+0.3726	+0.3442	+0.3238
336.4	-0.0180	-0.0132	-0.0104	+0.3797	+0.3523	+0.3314
477	-0.0009	+0.0023	+0.0052	+0.3835	+0.3598	+0.3390

TABLE 9.3

THREE PHASE ALUMINUM OVERHEAD LINE

AWG OR KCM	POSITIVE SEQUENCE (OHMS/1000′) R	X 2.4KV & 4.16KV	13.2KV	34.5KV
4	0.4659	0.1330	0.1403	0.1467
2	0.2930	0.1280	0.1352	0.1416

TABLE 9.3 (Continued)

AWG OR KCH	POSITIVE SEQUENCE (OHMS/1000') R	X 2.4KV & 4.16KV	13.2KV	34.5KV
1/0	0.1842	0.1226	0.1299	0.1359
4/o	0.0920	0.1165	0.1236	0.1301
336.4	0.0579	0.1100	0.1169	0.1236
477	0.0411	0.1055	0.1130	0.1193
636	0.0310	0.1023	0.1108	0.1155
795	0.0248	0.0999	0.1070	0.1131

THREE PHASE ALUMINUM OVERHEAD LINE

COASTAL AREA

(ZERO SEQUENCE IMP.=SELF IMP.-GROUND WIRE IMP.)

AWG OR KCM	ZERO SEQUENCE (SELF) (OHMS/1000') R	X . 2.4KV & 4.16KV	13.2KV	34.5KV
4	0.5040	0.5964	0.5819	0.5696
2	0.3363	0.5909	0.5767	0.5640
1/0	0.2312	0.5862	0.5719	0.5591
4/0	0.1466	0.5795	0.5651	0.5525
336.4	0.1123	0.5738	0.5591	0.5464
477	0.0952	0.5691	0.5549	0.5421
636	0.0852	0.5653	0.5509	0.5383
795	0.0791	0.5630	0.5487	0.5359

TABLE 9.3 (Continued)

THREE PHASE ALUMINUM OVERHEAD LINE

COASTAL AREA

(ZERO SEQUENCE IMP.=SELF IMP.-GROUND WIRE IMP.)

(INDICATED HIRE SIZES ARE FOR GROUND WIRE ONLY)

AWG OR KCM	ZERO SEQUENCE (GROUND WIRE) (OHMS/1000') R 2.4KV & 4.16KV	13.2KV	34.5KV	X 2.4KV & 4.16KV	13.2KV	34.5KV
4	-0.0786	-0.0696	-0.0634	+0.0947	+0.0866	+0.0809
2	-0.0786	-0.0696	-0.0634	+0.1454	+0.1321	+0.1226
1/0	-0.0559	-0.0483	-0.0430	+0. 1875	+0.1699	+0. 1572
4/0	-0.0180	-0.0132	-0.0104	+0.2163	+0.1955	+0.1814
336.4	+0.0019	+0.0040	+0.0056	+0.2273	+0.2059	+0.1908
477	+0.0123	+0.0137	+0.0147	+0.2320	+0.2097	+0.1951
636	+0.0142	+0.0156	+0.0161	+0.2348	+0.2126	+0.1969
795	+0.0232	+0.0237	+0.0237	+0.2391	+0.2159	+0.2002

THREE PHASE ALUMINUM OVERHEAD LINE

INLAND AREA

(ZERO SEQUENCE IMP.=SELF IMP.-GROUND WIRE IMP.)

AWG OR KCM	ZERO SEQUENCE (SELF) (OHMS/1000') R	X 2.4KV & 4. 16KV	13. 2KV	34.5KV
4	0.5040	0.7290	0.7144	0.7008
2	0.3363	0.7234	0.7092	0.6966

TABLE 9.3 (Continued)

AWG OR KCM	ZERO SEQUENCE (SELF) (OHMS/1000') R	X 2.4KV & 4.16KV	13.2KV	34. 5KV
1/0	0.2312	0.7187	0.7045	0.6917
4/0	0.1466	0.7121	0.6977	0.6851
336.4	0.1123	0.7064	0.6917	0.6790
477	0.0952	0.7008	0.6875	0.6747
636	0.0852	0.6979	0.6835	0.6709
795	0.0791	0.6955	0.7002	0.6685

THREE PHASE ALUMINUM OVERHEAD LINE

INLAND AREA

(ZERO SEQUENCE IMP .=SELF IMP.-GROUND WIRE IMP.)

(INDICATED WIRE SIZES ARE FOR GROUND WIRE ONLY)

AWG OR KCM	ZERO SEQUENCE (GROUND WIRE) (OHMS/1000') R 2.4KV & 4.16KV	13.2KV	34.5KV	X 2.4KV & 4.16KV	13.2KV	34. 5KV
4	-0.1420	-0.1297	-0.1212	+0.1496	+0.1401	+0.1326
2	-0.1363	-'0.1255	-0.1179	+0.2310	+0.2159	+0.2026
1/0	-0.1065	-0.0966	-0.0894	+0.3020	+0.2798	+0.2642
4/0	-0.0473	-0.0412	-0.0364	+0.3579	+0.3309	+0.3106
336.4	-0.0170	-0.0132	-0.0104	+0.3769	+0.3499	+0.3291
477	+0.0009	+0.0033	+0.0042	+0.3844	+0.3560	+0.3352
636	+0.0033	+0.0052	+0.0061	+0.3901	+0.3612	+0.3399
795	+0.0180	+0.0189	+0.0198	+0.3948	+0.3655	+0.3447

CHAPTER 6. LOAD SURVEY

6.1 ACCURACY REQUIREMENTS. The validity of a power system analysis is also dependent upon the accuracy of the loads used for system modeling. Extreme care must be exercised when the representative loads for each selected load center are developed. Load data, which is not representative of actual system loads, will cause unrealistic system conditions to be modeled and will result in erroneous conclusions for the study. Most information required for developing representative system loads is available in existing activity records. Enhancement and verification of the system loading can be accomplished by taking spot readings at permanently installed metering points or with portable metering. Also, the activity electrician foreman's knowledge of the daily operation of the electrical power system is a valuable asset when engineering personnel are developing the representative system loads.

6.2 DEFINITIONS. The following definitions are provided to facilitate understanding of the information which is developed in a load survey.

1. Maximum Demand - The maximum system load or capacity actually utilized. It is the integrated maximum kilowatt demand, usually over a 15 or 30-minute interval rather than the instantaneous peak demand. This information is available on previous utility bills.
2. Connected Load - The total of all loads connected to the system. In distribution systems, this is the sum of all transformers which provide power directly to loads without any intermediate transformation. (Usually output of 600 volts or less.) In buildings, the connected load is the total of all installed equipment, lighting, motors, etc. loads within the building.
3. Demand Factor - The ratio of the maximum demands to the total connected load.
4. Diversity Factor - The ratio of the sum of the individual maximum demands of the various parts of the system to the maximum demand of the whole system measured at the point of supply.
5. Load Factor - The ratio of the average load over a designated period of time to the peak load occurring in that period.
6. Coincidence Factor - The reciprocal of the diversity factor.
7. Coincident Demand - The maximum demand of a part of a system (for example, feeder, building) multiplied by the coincidence factor established for the activity.
8. Impact Load - Large loads which are imposed on the system on a non-scheduled basis (for example, fire pumps, peak

berthing loads, wind tunnels).

9. Load Diagram - Simplified one-line diagram showing location of load centers and magnitude of loads.

10. Load Center - A substation, building or location on a feeder where loads are consolidated for analyses purposes. Load centers should be greater than 250 KW wherever practical.

6.3 DOCUMENTATION OF LOAD DATA.

6.3.1 Load Calculation. Most activity personnel think of system loads as amps and kilowatts because circuits are metered using ammeters and kilowatt meters. However, computerized modeling used for system analysis requires system loads to be shown as kilowatts and kilovars. In any A.C. electrical circuit, the following geometric relationship (Figure 14) exists for any given load condition.

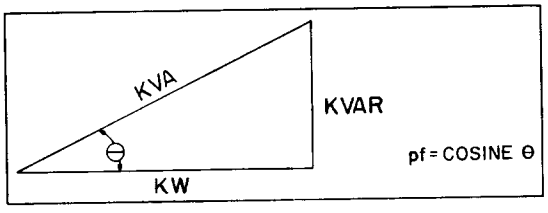


FIGURE 14
KW, KVAR, KVA, Pf Angle Relationship

KVA is the product of the circuit voltage and the amperes flowing in the circuit or:

$$KVA = \frac{C}{1000} \times \text{voltage} \times \text{amperes}$$

C is a constant

C = 1.00 single phase circuit
c = 1.73 three phase circuit

Power Factor (Pf) is the ratio: $\frac{KW}{KVA}$

Pf is also the cosine θ.

Example:

A three-phase 13,200 volt circuit has a load of 280 amperes and the kilowattmeter on the circuit reads 5440 KW.

$$KVA = \frac{1.73}{1000} \times 13{,}200 \times 280 = 6400 \text{ KVA}$$

$$Pf = \frac{KW}{KVA} = \frac{5400}{6400} = 0.85 = 85\%$$

From Table 10:

$$KVAR = KW \times \text{conversion factor}$$
$$= 5440 \times 0.620$$
$$= 3370 \text{ KVAR}$$

From Table 11:

KVAR = KVA x conversion Factor
= 6400 X 0.527
= 3370 KVAR

Therefore the circuit load is:

5440 KW
3370 KVAR

TABLE 10
Power Factor KW Conversion Tables

Pf%	KW	Conversion Factors	
		KVAR	KVA
100	1.00	0.000	1.000
99	1.00	0.142	1.010
98	1.00	0.203	1.020
97	1.00	0.249	1.031
96	1.00	0.291	1.041
95	1.00	0.329	1.053
94	1.00	0.363	1.064
93	1.00	0.395	1.075
92	1.00	0.426	1.087
91	1.00	0.456	1.099
90	1.00	0.484	1.111
89	1.00	0.512	1.123
88	1.00	0.539	1.136
87	1.00	0.567	1.150
86	1.00	0.594	1.163
85	1.00	0.620	1.177
84	1.00	0.645	1.190
83	1.00	0.672	1.205
82	1.00	0.698	1.220
81	1.00	0.724	1.235
80	1.00	0.750	1.250
75	1.00	0.881	1.333
70	1.00	1.019	1.428
65	1.00	1.169	1.538
60	1.00	1.333	1.666

TABLE 11
Power Factor KVA Conversion Tables

Pf%	KVA	Conversion Factors	
		KW	KVAR
100	1.00	1.00	0.000
99	1.00	0.99	0.141
98	1.00	0.98	0.199
97	1.00	0.97	0.243

TABLE 11 (Continued)
Power Factor KVA Conversion Tables

Pf%	KVA	Conversion Factors KW	KVAR
96	1.00	0.96	0.280
95	1.00	0.95	0.312
94	1.00	0.94	0.341
93	1.00	0.93	0.367
92	1.00	0.92	0.392
91	1.00	0.91	0.415
90	1.00	0.90	0.436
89	1.00	0.89	0.456
88	1.00	0.88	0.475
87	1.00	0.87	0.493
86	1.00	0.86	0.510
85	1.00	0.85	0.527
84	1.00	0.84	0.543
83	1.00	0.83	0.558
82	1.00	0.82	0.572
81	1.00	0.81	0.586
80	1.00	0.80	0.600
75	1.00	0.75	0.661
70	1.00	0.70	0.714
65	1.00	0.65	0.760
60	1.00	0.60	0.800

6.3.2 Historical Demand Data. Figures 14 and 15 are examples of typical daily and yearly peak demand curves. These curves can be extremely helpful in analyzing load trends at an activity.

6.3.3 Distribution of Load. The starting point for developing the distribution of the activity load is the highest recorded activity demand within the past 12 months. This peak load is then adjusted to represent the estimated activity peak demand for the current calendar year. This new adjusted peak demand then becomes the base load which is apportioned among load centers throughout the activity. Load centers are buildings, substations or points along a feeder where load can conveniently be represented. To ease the task of system modeling, load centers selected should represent loads of 250 KW or more whenever practical. For feeders which have many small loads distributed evenly along their length, such as housing feeders, the entire feeder load can be lumped at the electrical midpoint of the feeder. Loads to be represented at each load center can be determined by field measurement, engineering estimates or a combination of both. Field measurements taken with existing metering or portable metering can provide a good indication of load distribution. However, these readings should not be considered as absolute, but as guides, when developing loads to be represented at each load center. Measurements cannot always be made when the system reaches its annual peak demand (one hour a year) because of time limitations and the inability to predict when the activity peak demand will actually occur. Therefore, measurements must always be adjusted to

represent peak loads even though they were taken at non-peak load conditions. These adjustments are made using the coincidence factor established for the load center by measurements taken over a period of time or by applying coincidence factors listed in NAVFAC MO-303, "Utilities Target Manual." The targets required by NAVCOMPT Manual, Chapter 7 and developed in accordance with MO-303, can also provide guidance for distributing loads upon each feeder. During the development of the representative loading for the activity, it is extremely important that the knowledge of engineering and operating personnel be combined to provide the most accurate composite picture of station load distribution as is possible.

6.3.3.1 Example:

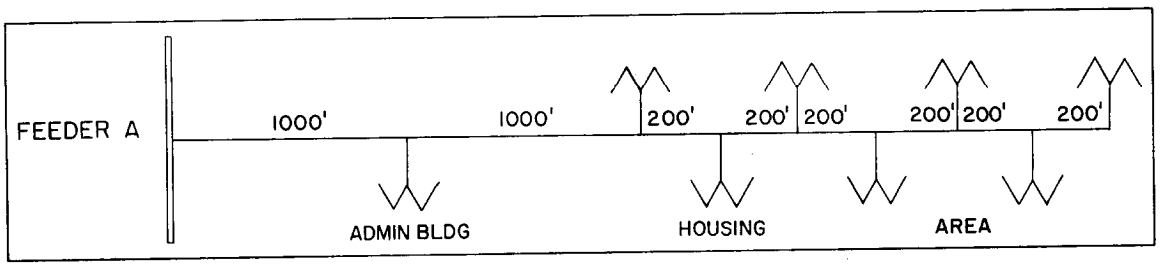


FIGURE 15
Typical Feeder with Distributed Loads

Feeder A supplies the admin building and base housing. Measurements have shown, that when the station daily peak occurs in the summer, the admin building represents 40% of the load on the feeder A. The remaining load is all housing. The measured coincidence factor for feeder A is 10% of the station demand and the anticipated station peak demand will occur this summer and will be 10,000 KW. It is also known that the power factor of this. feeder is 80%. Coincident demand Fdr A = 10,000 x 0.10 = 1000 KW

Admin bldg = 40% x 1000 = 400 KW
Housing = 60% X 1000 = 600 KW

See Figure 16 for a typical load diagram.

6.3.4 Impact Loading. Impact load examines the effect non-scheduled peak demands have upon electrical power distribution systems. These impact loads can be caused by increased ship berthing loads, fire pump operation, wind tunnels or specialized testing equipment, etc. For purposes of an electric power system analysis, impact loads are considered to contribute to an activities peak demand, but will not raise the peak demand. Impact load data must be included when these loads occur at an activity.

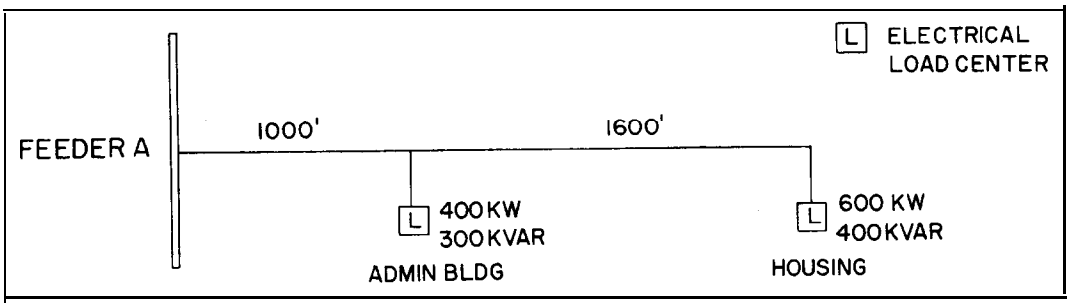


FIGURE 16
Typical Feeder with Loads Consolidated

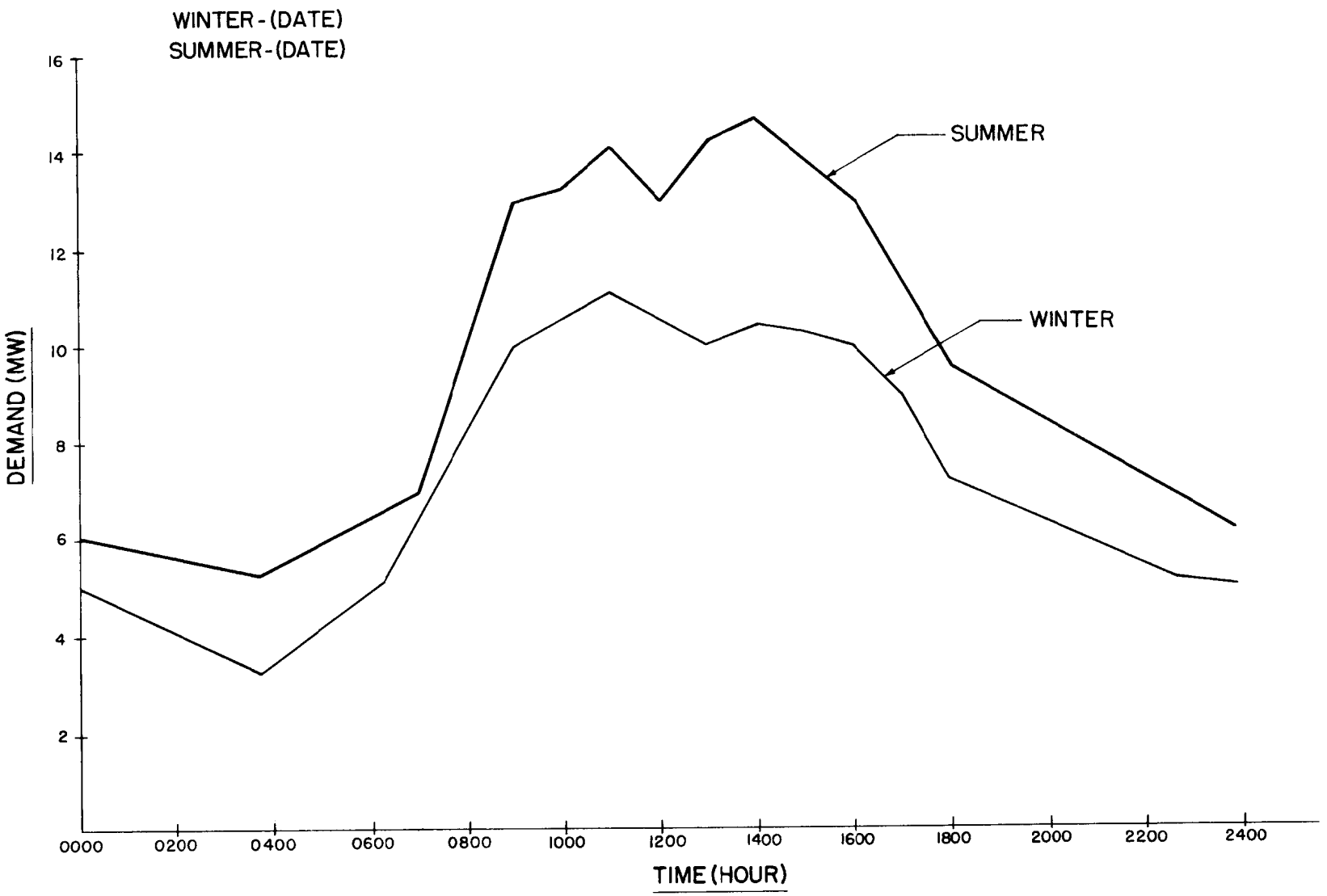
Development of the magnitude of impact loads are taken from previously recorded demands of these loads. (See Figures 17 and 18.) If documented information on the "impact load" is not available, a subjective evaluation will have to be made considering any known load parameters, such as published load requirements for ships in cold iron status or from the name plate rating of the equipment.

6.3.5 Future Load Data. Activity load for five years in the future is used to evaluate whether the existing system will be capable of supplying developing loads and to optimize the benefits of any system expansion or reinforcement. Future loads are developed by assuming an annual growth rate of 2%, or 10% growth for five years. To this new base load is added the coincident demand of all special construction and MILCON projects which will be completed during the next five years. (As a general rule, it requires two years to complete a project from the year in which it was funded). New construction loads should be either placed on an existing load center or when required, a new load center should be established to support the load.

Sample Future Load Development

	Fdr A	Fdr B
Current Load	250	500 KW
Normal 5-yr. growth	25 KW	50 KW
MILCON	40 KW (P-000)	180 KW (P-001)
Total	315 KW	730 KW

Load data is represented on a simplified one-line diagram. A typical load diagram is shown in Figure 19.



[1] FOR TOTAL ACTIVITY ⇒ ALSO PROVIDE SIMILAR DATA FOR FEEDERS IF AVAILABLE.

FIGURE 17
Hourly Demand[1] Summer/Winter

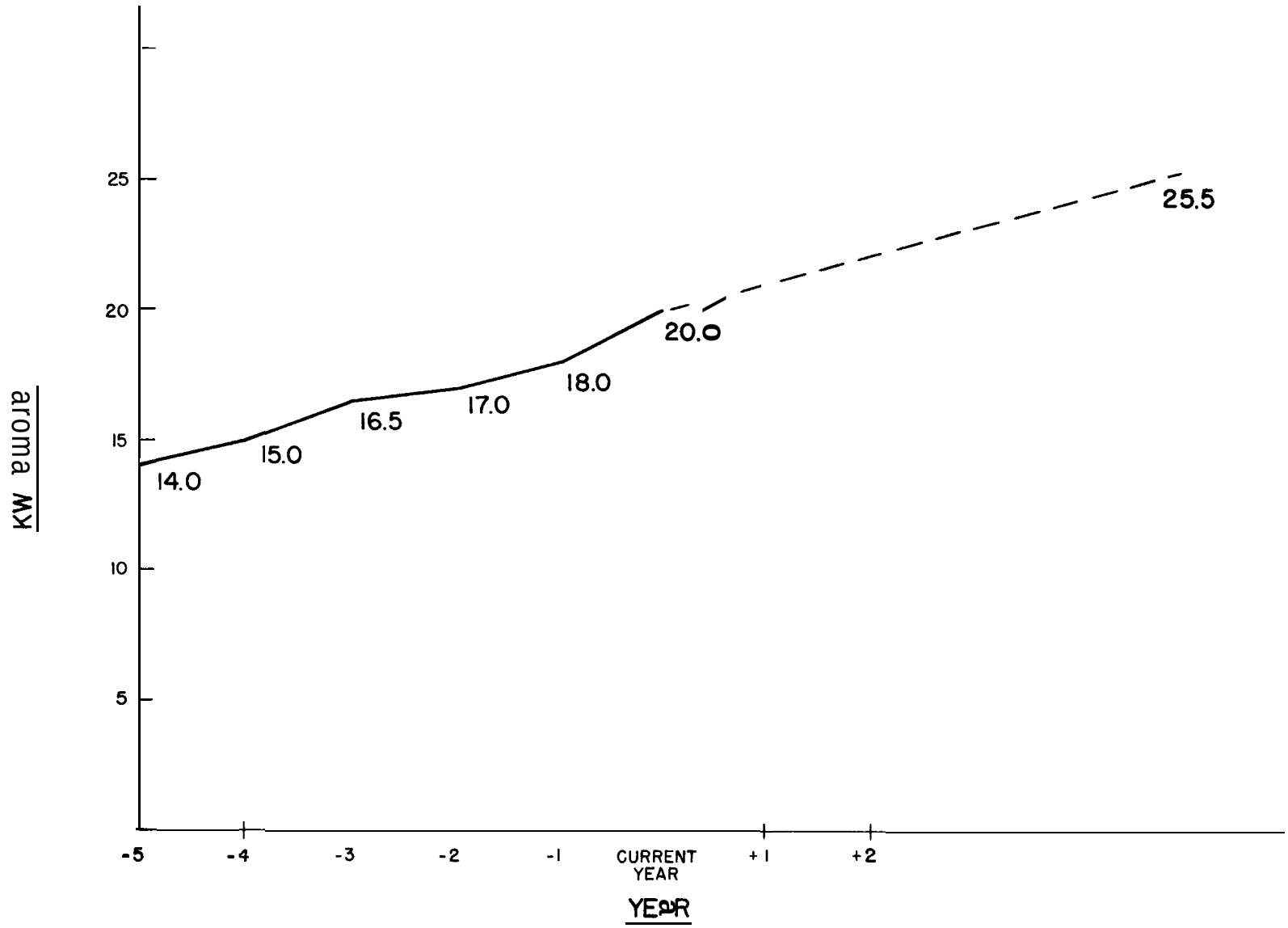


FIGURE 18
Annual Peak Demand

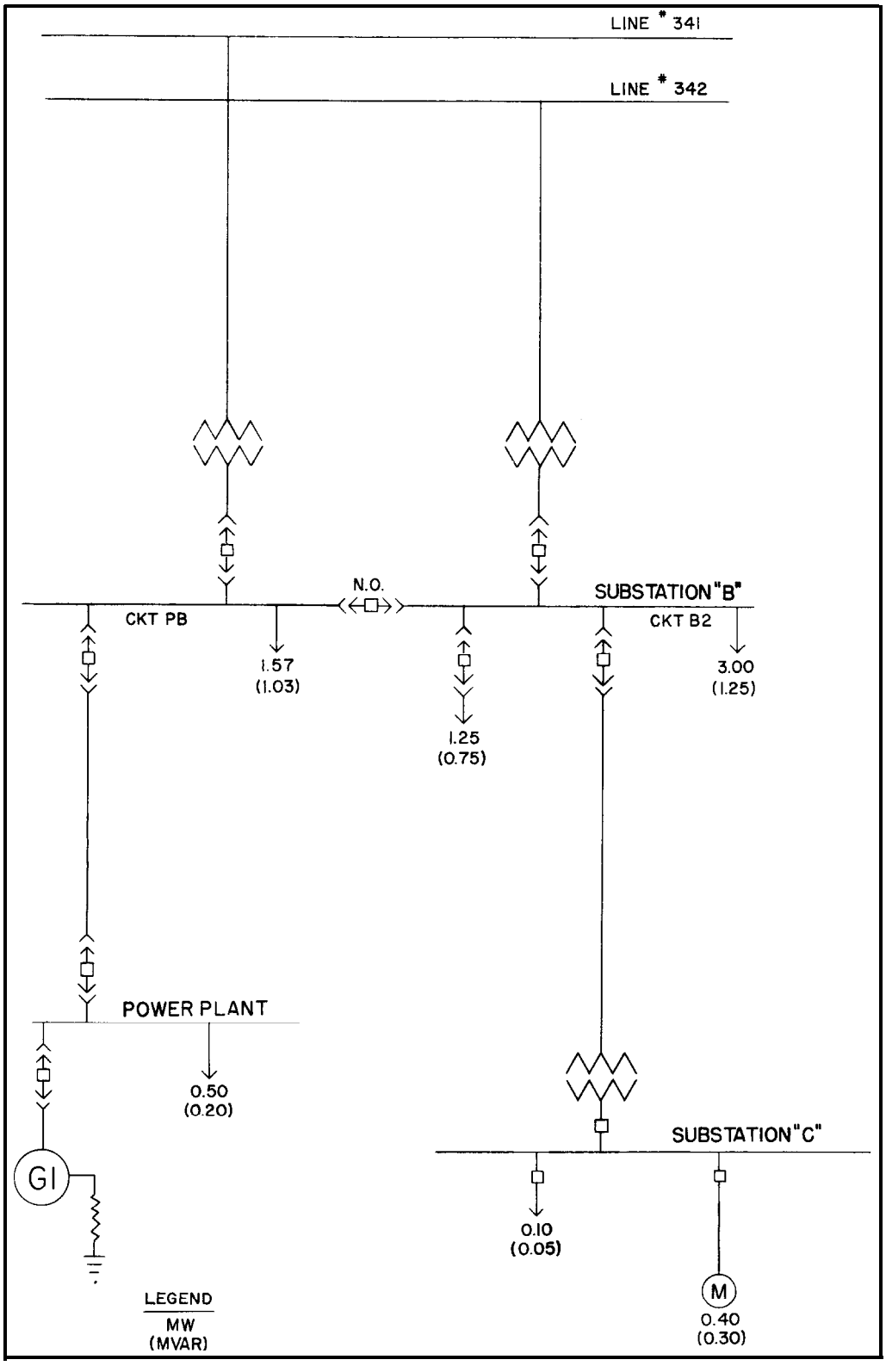


FIGURE 19
Partial Load Diagram

INDEX

Paragraph

Capacitors
  equipment inventory 2.3.9
  line diagram checklist item . . . . . 3.2(9)
Circuit breakers
  equipment inventory l 2.3.9
  line diagram checklist item . . . . . 3.2(5)
Circuit load, calculation 6.3.1
Circuit routing plan 2.3.2
Coincidence factors
  definition . . . . . 6.2(6)
  in load distribution 6.3.3
Coincident demand . . . . . 6.2(7)
Computer capability 1.3
Connected load . . . . . 6.2(2)
Conversion factors 4.2

Data accuracy 1.5, 2.2, 6.1
Data, future load 6.3.5
Demand factor . . . . . 6.2(3)
Diversity factor . . . . . 6.2(4)

Equipment inventory 2.3.9
  See also circuit breakers; reactors,
  capacitors, and voltage regulators;
  motors and generators; relay coordination
  study; switches and fuses; transformers

Fault levels
  in utility (source) impedance . . . . . 2.3.6(1)
  phase to ground . . . . . 3.2(1)
  three phase . . . . . 3.2(1)
Feeders, See Load centers
Fuses
  equipment inventory 2.3.9
  line diagram checklist item . . . . . 3.2(6)

Generators
  equipment inventory l 2.3.9
  line diagram checklist item . . . . . 3.2(7)

Impact load . . . . . 6.2(8)
Impedance diagram
  base conversion 4.2

Paragraph

definition 1.4.2
requirement 2.3.4, 4.1
utility (source) impedance . . . . . 2.3.6(3)

Kilovars
use in system analysis 6.3.1
Kilowatts
use in system analysis 6.3.1
KVA
base for impedances 4.2
use with reactors, capacitors, and voltage regulators. . 3.2(9)

Line Impedance
background
factors affecting 5.1
use with impedance table data 5.2
using overhead lines 5.3.2
using underground cables 5.3.1
calculations
examples 5.3.2.1, 5.3.2.2, 5.3.2.3, 5.3.2.4
involving overhead lines 5.3.2
involving underground cables 5.3.1
Load
accuracy 6.1
centers
definition . . . . . 6.2(10)
distribution of load 6.3.3
factor . . . . . 6.2(5)
survey
accuracy requirements 6.1
application to future loads 6.3.5
calculation 6.3.1
component definitions 6.2
data documentation 6.3
definition 1.4.4
development 2.3.5
distribution 6.3.3
historical demand data 6.3.2
impact load 6.3.4

Maximum demand, load survey . . . . . 6.2(1)
Motors
equipment inventory 2.3.9
line diagram checklist item . . . . . 3.2(7)

One-Line Diagram
checklist 3.2
definition 1.4.1
development 3.1
future projects annotation 3.3
requirement 2.3.3

Paragraph

small system survey 2.4
Overhead lines
in line impedance calculations 5.3.2
in one-line diagram . . . . . 3.2(4)
standard equivalent delta spacing 5.2

Peak demand
curves 6.3.2
in distribution of load 6.3.3
nonscheduled 6.3.4
Phases, system survey 2.2
Plot plan
circuit routing plan 2.3.2
definition 2.3.1
Positive sequence impedance
in impedance diagram 2.3.4
in impedance tables 5.2
in overhead lines 5.3.2
in utility (source) impedance . . . . . 2.3.6(2), 2.3.6(3)
location in impedance tables 5.3.2
Power factor 6.3.1

Reactance, resistance
conversion to percent 4.2
Reactors
equipment inventory 2.3.9
line diagram checklist item . . . . . 3.2(9)
Relay coordination study
equipment inventory 2.3.9
requirements . . . . . 3.2(9)

Small system survey 2.4
Switches
equipment inventory 2.3.9
line diagram checklist item . . . . . 3.2(6)
Symbols, nonstandard 3.1
System analysis, benefits of 1.6
System data assembly 1.4
System operating problems synopsis 2.3.8
System survey
phases 2.2
purpose 2.1
requirements 2.3

Transformers
equipment inventory 2.3.9
in relay coordination study . . . . . 3.2(9) (a)
line diagram checklist item . . . . . 3.2(2)

Underground cables
in line impedance calculations 5.3.1

Paragraph

in one-line diagram . . . . . 3.2(3)
Utility (source) impedance
future changes . . . . . 2.3.6(3)
positive and zero sequence impedance . . . . . 2.3.6(2)
three-phase and phase to ground fault current . . . . 2.3.6(1)

Voltage regulation, utility 2.3.7
Voltage regulators
equipment inventory 2.3.9
line diagram checklist item . . . . . 3.2(9)

Zero sequence impedance
in impedance diagram 2.3.4
in impedance tables 5.2
in overhead lines 5.3.2
in utility (source) impedance . . . . . 2.3.6(2), 2.3.6(3)
location in impedance tables 5.3.2