

A COMPUTER-AIDED FAULT ANALYSIS OF THE
VPI ELECTRIC SERVICE POWER DISTRIBUTION SYSTEM

by

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Table of Contents

	<u>Page</u>
Acknowledgements.	ii
List of Figures	iv
List of Tables.	iv
I. INTRODUCTION AND GENERAL DISCUSSION OF THE TOPIC.	1
II. DESCRIPTION OF THE VPI SYSTEM	2
III. DESCRIPTION OF PROGRAM.	12
3.1 Types of Circuits Programmed	12
3.2 Solution Procedure	13
3.3 User's Guide	15
3.4 Data Deck.	22
IV. CONCLUSIONS	30
REFERENCES.	32
APPENDIX A.	33
A. List of Symbols Used in the Program	33
B. Equations Used.	36
APPENDIX B.	41
APPENDIX C.	56
VITA:	205
ABSTRACT	

LIST OF FIGURES

<u>Figure No.</u>	<u>Title</u>	<u>Page</u>
1	One-Line Diagram of the VPI & SU Substation. .	3
2	VPI Substation Positive and Negative Sequence Distribution Factors (Percent Impedances on 10 MVA Base)	5
3	VPI Substation Zero Sequence Distribution Factors (Percent Impedances on 10 MVA Base) "Infinite Bus"	6
4a	8-Ft. Crossarm	8
4b	5-Ft. 7-In. Crossarm	8
4c	10-Ft. Crossarm.	9
4d	Bundled Support.	9
4e	Steel Conductor Supports	10
5	Distribution System Fault Study Program Flow Chart.	16
6	Illustration of Point Selection Procedure. . .	21

LIST OF TABLES

<u>Table No.</u>	<u>Title</u>	<u>Page</u>
1	Positive and Zero Sequence Substation Impedances	7
2	Maximum Three Phase Fault Currents and 5 Cycle Breaker Ratings for the 4KV and 12 KV Buses. .	31

I. INTRODUCTION AND GENERAL DISCUSSION OF THE TOPIC

The magnitudes of fault currents that can exist on a distribution circuit are important quantities to the distribution engineer. One purpose of a fault study of a distribution system is to determine if circuit breakers can successfully interrupt the fault current without sustaining equipment damage. Another purpose is to coordinate fuses and relay settings so that a fault causes a power outage for the minimum number of customers.

Other studies can be performed using information calculated during the fault study. By knowing the average power at points along the circuit, the impedances found in the fault study can be used to find the voltage profile of a particular circuit.

Therefore, it can be seen that a fault study is an important tool to the distribution engineer. Not only does it give him fault current values, the impedance formulation section of the study can be used as a building block for other important distribution related studies.

In this thesis, the results of an effort to develop a fault analysis program for distribution systems are presented. Although the resulting digital computer program is of a general-purpose nature, it is particularly suited to the needs of the VPI Electric Service.

A complete report follows which includes a description of the topic, general information about the VPI system, details of the computer program, a complete fault analysis and a discussion of the results. A detailed user's guide is also included to aid the reader in using the program to perform his own fault studies.

II. DESCRIPTION OF THE VPI SYSTEM

The VPI Electric Service distribution system supplies power to the VPI & SU campus and portions of the town of Blacksburg. The maximum demand on the system was recorded on January 17, 1977, and was approximately 29 MW. Under normal operating conditions, the two generators in the power plant can supply approximately 25% of the demand, while the remainder is purchased from Appalachian Power Company.

A schematic diagram of the substation is shown in Fig. 1. The 4 KV bus with the Westinghouse generator tied to it is known as the indoor bus because it is located inside the power plant. Breaker PP serves the power plant, and Breakers 1-5, on the indoor bus, connect campus buildings to the bus via underground cables. There are thirteen circuits fed by these five breakers and each building has at least two circuits fed by different breakers. Having multiple circuits in each building reduces the time the building is without power if something goes wrong, i.e. circuit breaker failure or a break in the circuit, because the building can be switched to a healthy circuit.

Circuits 1A, 1B, 2A and 2B on the 12 KV bus are also underground circuits feeding campus buildings. Circuits 1A and 1B serve a certain group of buildings, with 1A and 1B both present in each of these buildings. The position of the 1A and 1B breakers on opposite sides of the automatic tie breaker (ATB) would allow loss of one-half of the 12 KV bus without prolonged loss of power to the buildings served by 1A and 1B. The same is true for buildings served by circuits 2A and 2B.

Circuits 1, 2, 4, 5 and 6 on the 4 KV bus are overhead circuits

Fig. 1 One-Line Diagram of the VPI & SU Substation

serving the town of Blacksburg, as well as circuits 7, 8, 11 and 12 on the 12 KV bus. Switching is also available on these circuits to restore power to a circuit with a defective breaker from another circuit so that minimum power outage can be maintained. The general configuration of the overhead circuits, under normal operation is a radial one.

The source impedances (generator and substation) were calculated for the positive and zero sequences from Figures 2 and 3. The positive and zero sequence impedances for the 4 KV and 12 KV buses are given in Table 1. These impedances were found when all three VPI 5 MVA transformers were operating simultaneously. This particular arrangement was found to give the minimum source impedances which result in maximum fault currents at the substation. The maximum fault currents at the buses were desired to properly determine the MVA capacity of the circuit breakers so that interruption of fault currents is insured.

The overhead circuits in the VPI system are of five basic geometrical configurations (Figures 4a, 4b, 4c, 4d and 4e). Figure 4a, an eight-foot crossarm, is the standard being used for the construction of new lines. Figures 4b and 4c are remains from the older portion of the VPI system with 4c being used to carry two circuits on the same crossarm. Figure 4d is a bundled configuration which is used only twice in the system; Figure 4e is used in only four locations.

The geometrical configuration of overhead circuits is important in fault studies due to the mutual impedances that exist between conductors that are in close proximity. Mutuals also exist between underground cables; the concentric neutral cables which exist in the town distribu-

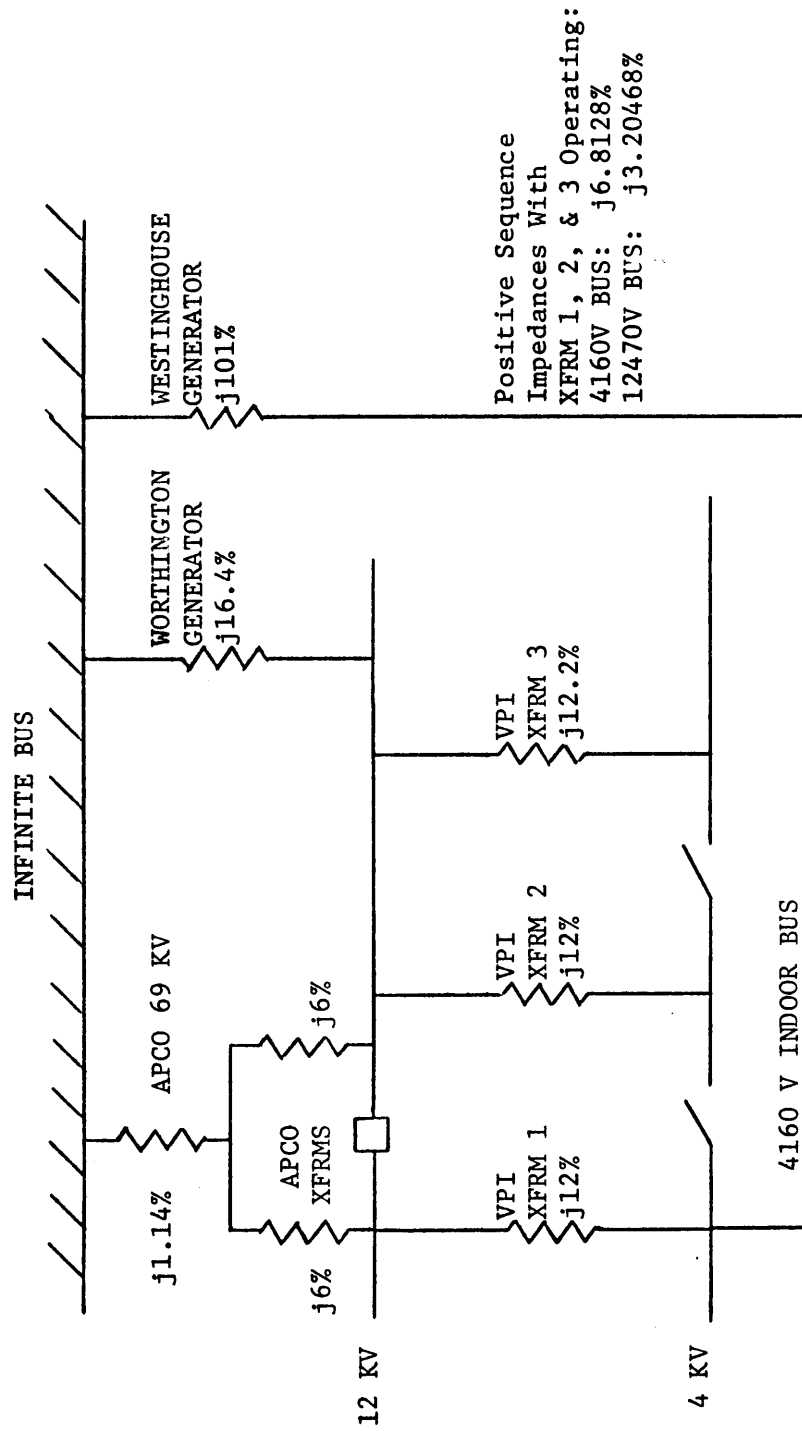


Fig. 2 VPI Substation Positive and Negative Sequence Distribution Factors
 (Percent Impedances on 10 MVA Base)

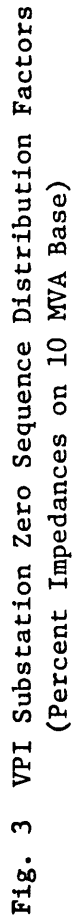


**Fig. 3 VPI Substation Zero Sequence Distribution Factors
(Percent Impedances on 10 MVA Base)**

Table 1. Positive and Zero Sequence
Substation Impedances (10 MVA Base)

	Positive sequence impedance	Zero sequence impedance
4 KV bus	j6.8128%	j2.1000%
12 KV bus	j3.20468%	j2.1747%

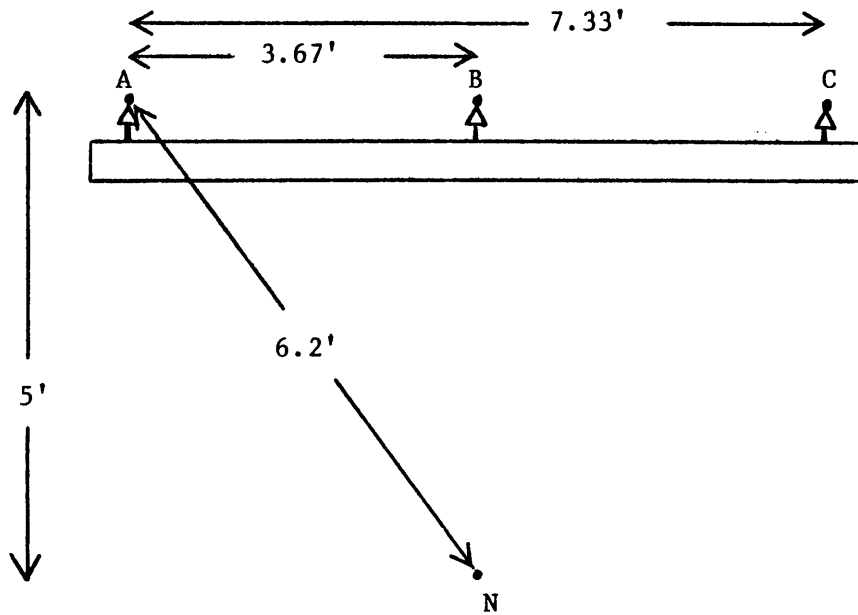


Fig. 4a 8-Ft. Crossarm

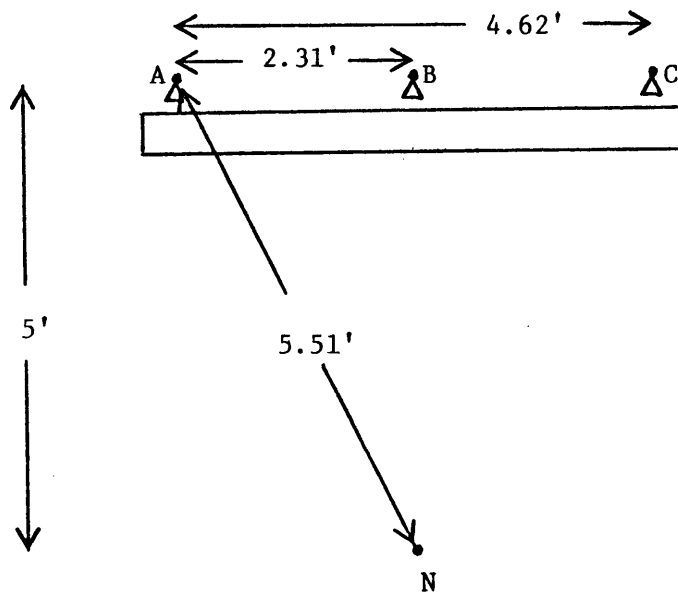


Fig. 4b 5-Ft. 7-In. Crossarm

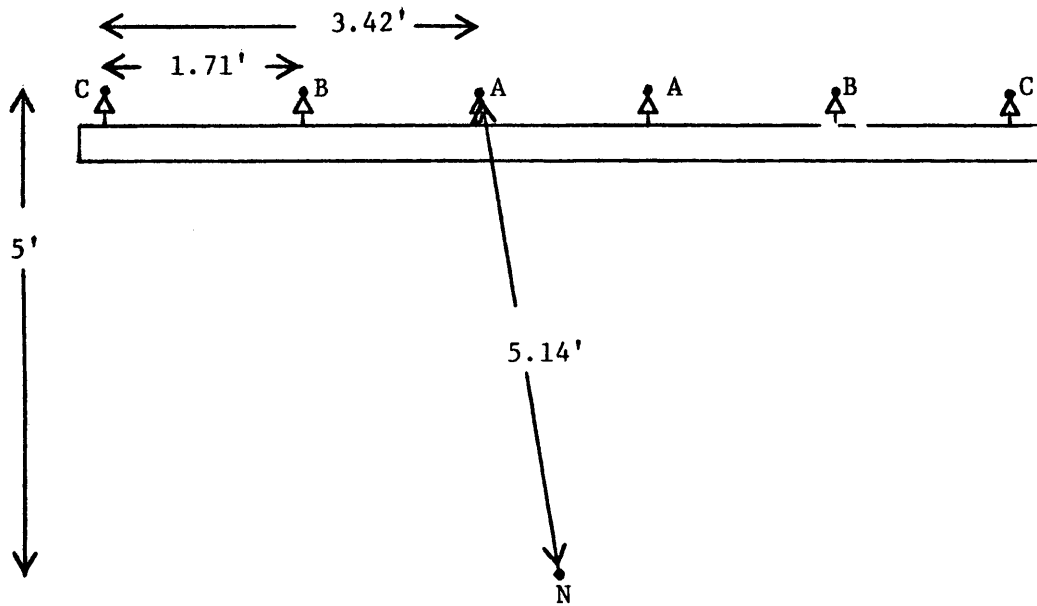


Fig. 4c 10-Ft. Crossarm

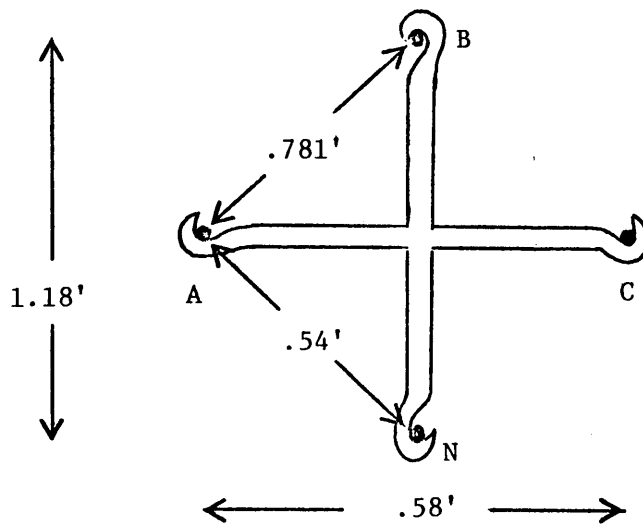


Fig. 4d Bundled Support

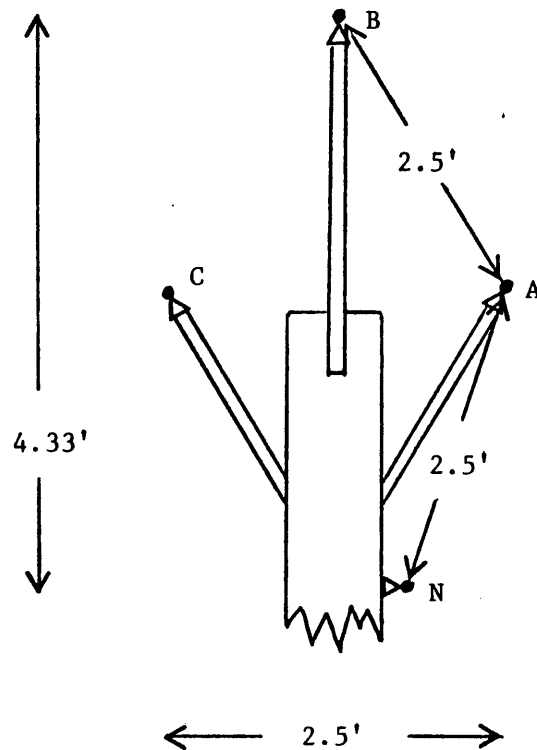


Fig. 4e Steel Conductor Supports

tion have the mutuals calculated, but the shielded cables on campus do not. This is due to the fact that the shields are assumed to contain the fields produced by currents flowing in the conductors; therefore, the mutuals for shielded cables are zero.

This should give a good indication of the general layout of the VPI system and will serve as an introduction to a description of the computer program used to solve for the fault currents.

III. DESCRIPTION OF PROGRAM

The purpose of this program is to calculate the values of fault currents for three phase to ground, line to line, line to line to ground, and line to ground faults on a power distribution system. The program was written in a general manner so that major circuit types in use today can be handled.

3.1 Types of Circuits Programmed

The circuit types included in the program are:

- 1) Three phase Y, 4-wire (three identical phase conductors, one multigrounded neutral conductor).
- 2) Three phase Y, 4-wire (three identical phase conductors, one unigrounded neutral conductor).
- 3) Three phase Y, 3-wire (three identical phase conductors, neutral grounded at substation).
- 4) Three phase delta (3 identical phase conductors).
- 5) Two phase open Y, 3 wire (two identical phase conductors, one multigrounded neutral conductor).
- 6) Two phase open Y, 3 wire (two identical phase conductors, one unigrounded neutral conductor).
- 7) Single phase, 2 wire (two identical phase conductors, neutral grounded at substation).
- 8) Single phase, 2 wire (two identical phase conductors, no ground).
- 9) Single phase, 2 wire (one phase conductor, one multigrounded neutral conductor).

- 10) Single phase, 2 wire (one phase conductor, one unigrounded neutral conductor).
- 11) Three phase underground (three phase conductors, each surrounded by a concentric neutral conductor).
- 12) Single phase underground (one phase conductor surrounded by a concentric neutral conductor).
- 13) Three phase underground (three phase conductors, each surrounded by a shield, and a neutral conductor pulled in the conduits with the phase conductors; neutral and shields multigrounded).

It should be noted here that an approximation was made in circuit type 13. The impedance of the shields are so large compared to the impedance of the neutral conductor that when they are paralleled between grounding points, the impedance of the shields can be neglected. The terms r_s and x_s in the underground shielded equations are simply the resistance and reactance of the neutral conductor (see Appendix A).

3.2 Solution Procedure

The solution procedure of the program is as follows: Before the study begins, the circuit(s) to be studied is divided into segments (see user's guide for details). Once the segments have been chosen, data pertaining to the particular circuit type of the segment is read and values of impedance of the segment (self and mutual) are calculated and the positive and zero sequence impedances of the segment are calculated in ohms per 1000 feet. This process is repeated for each segment in the circuit.

Once these impedances have been calculated, they are multiplied by

the corresponding segment lengths so that the positive and zero sequence impedances are now in terms of ohms. Having these values, a radial line search is performed to connect the proper segments together so that the total positive and zero impedances can be calculated from each point back to the substation. The radial line search works by starting at the ending node of the first line segment that is connected to the substation. A search is performed to find a segment whose starting node is the same as the ending node of the first segment. When one is found, then the total impedance at the end of this second segment is the total impedance of the first segment plus the impedance of the second segment. This process continues until all segments have had total impedances calculated at their ending nodes.

Having these total impedances at each ending node, the three-phase to ground fault current can be calculated at each point by

$$IF3PH = \frac{VN}{ZS1 + ZP1 + ZF} \quad (3.2.1)$$

where VN is the line to ground voltage of the circuit.

ZS1 is the positive sequence impedance of the substation.

ZP1 is the positive sequence impedance from the particular point to the substation.

ZF is the fault impedance, i.e., not a direct short to ground (a tree touching a line).

(Note: Subscripts were not used in the thesis text or in the appendices due to the fact that in computer printout, subscripts do not exist.

Therefore, all variable names refer to the form in which they appear in the program.)

Currents for the remaining three types of faults are calculated using symmetrical components. The formulations are given in Appendix A. The maximum value for each of the four different fault currents at the chosen points occur when $ZF = 0$. The minimum fault current is determined by the value of ZF selected by the user. The program will automatically calculate the maximum and minimum fault currents at each point for each of the four fault conditions.

Similar equations exist for the other types of faults and once the fault currents are calculated at each point, the MVA capacity of the circuit breaker on that line is calculated.

Although a great deal more logic was needed to perform the calculations, this is the general idea of the program. More specific details about preparing data to be used in the program will be presented in the user's guide, which follows a flow chart of the program.

3.3 User's Guide

This program is really quite easy to use. First, the individual circuits to be studied must be selected. The next step is to divide the circuit into line segments by the following method:

- (1) A point must be declared whenever
 - a) Conductor sizes change.
 - b) Spacing changes, either between conductors and neutral or between conductors/neutral and ground.
 - c) The number of phases changes; if the fault currents are desired beyond these points.
- (2) A point must be declared at branches if the fault currents are

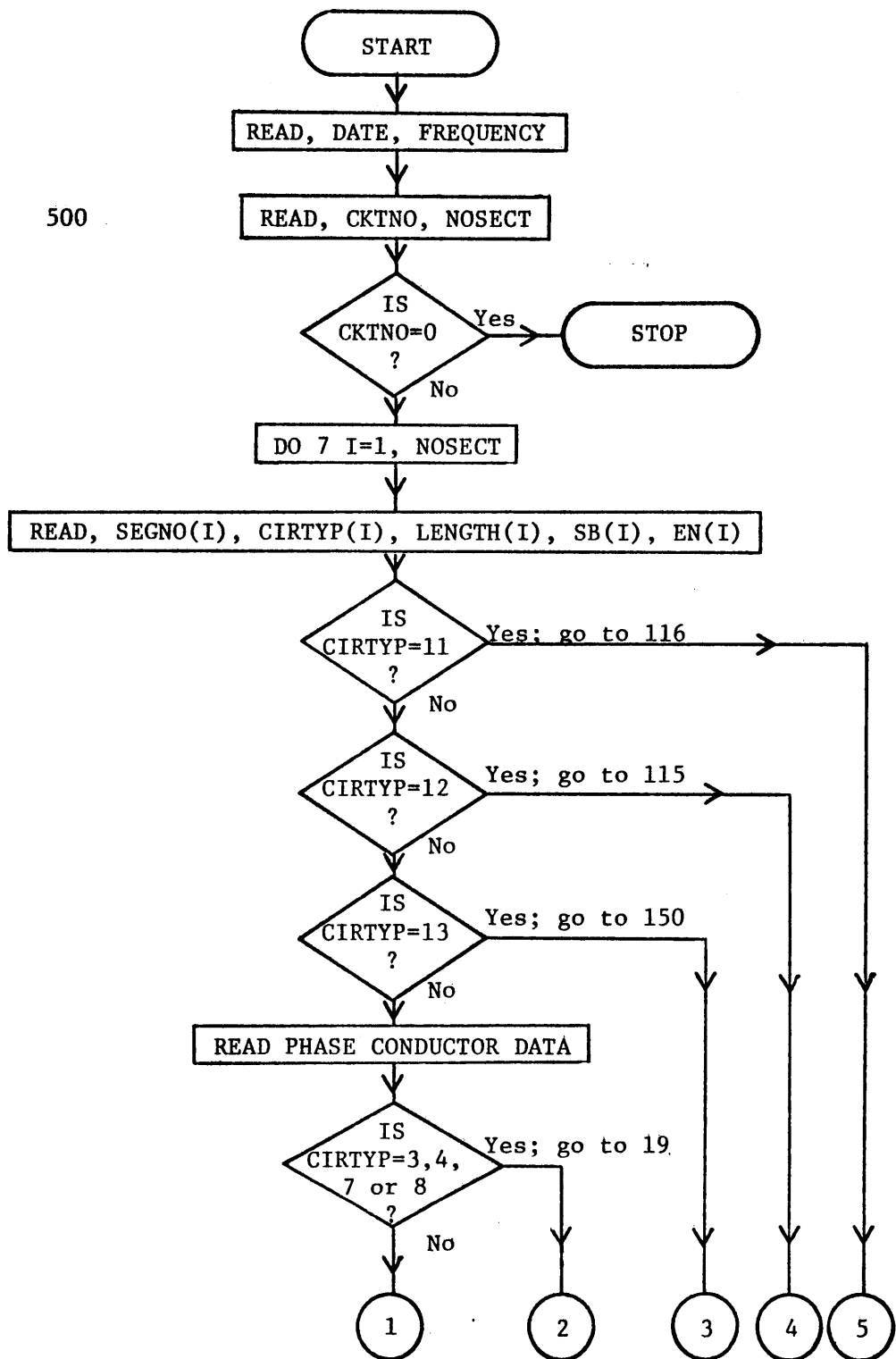
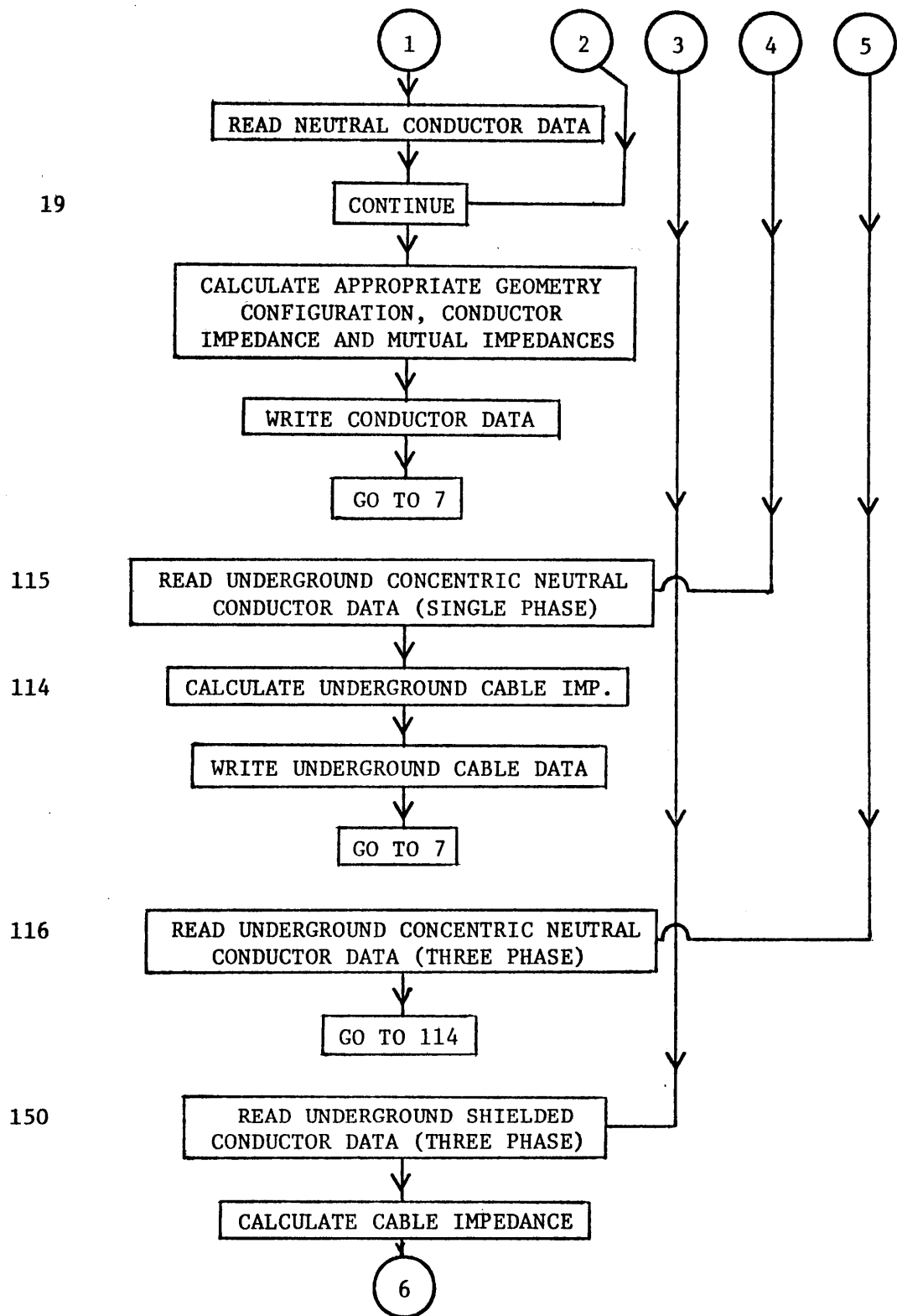
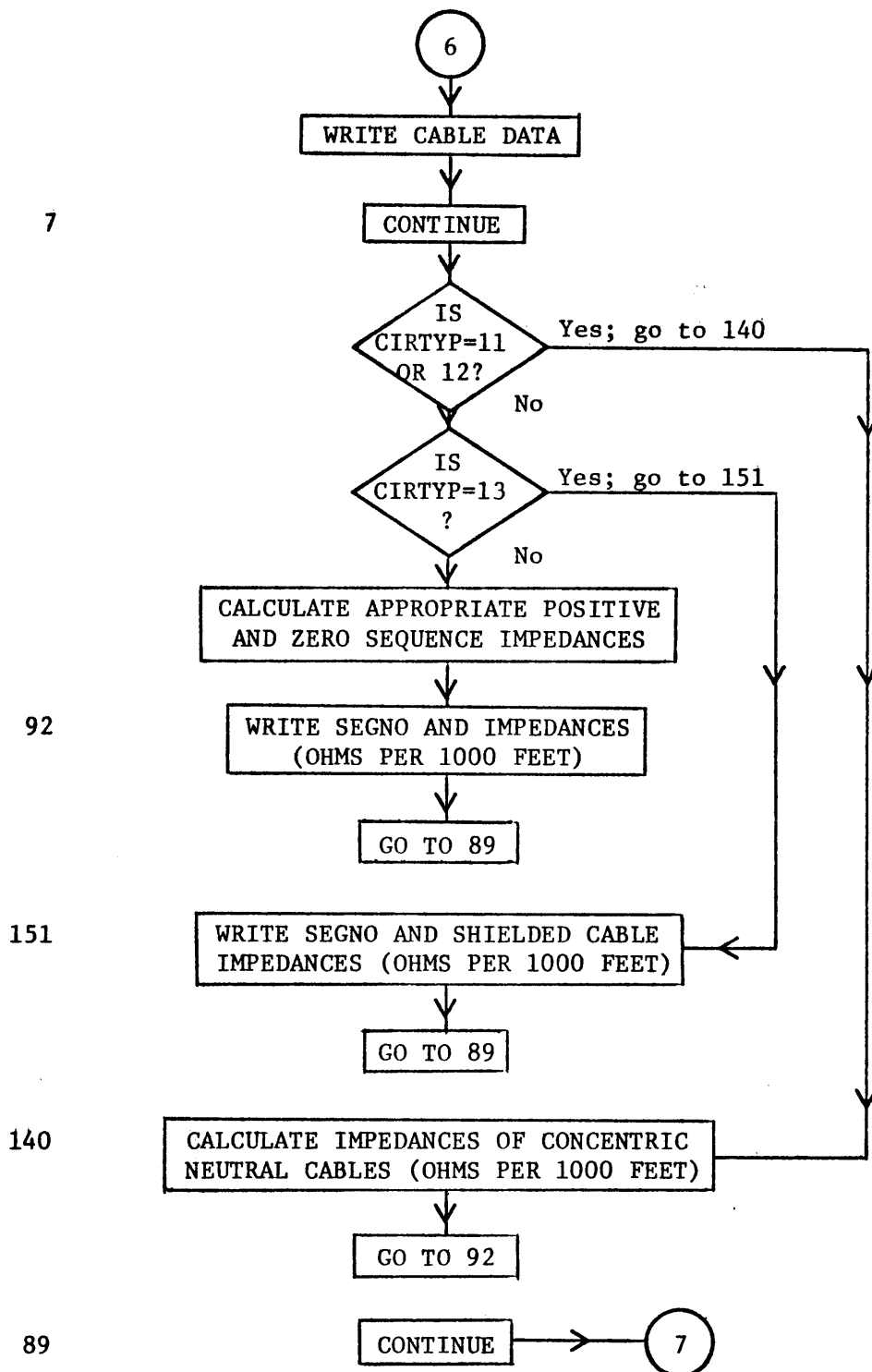
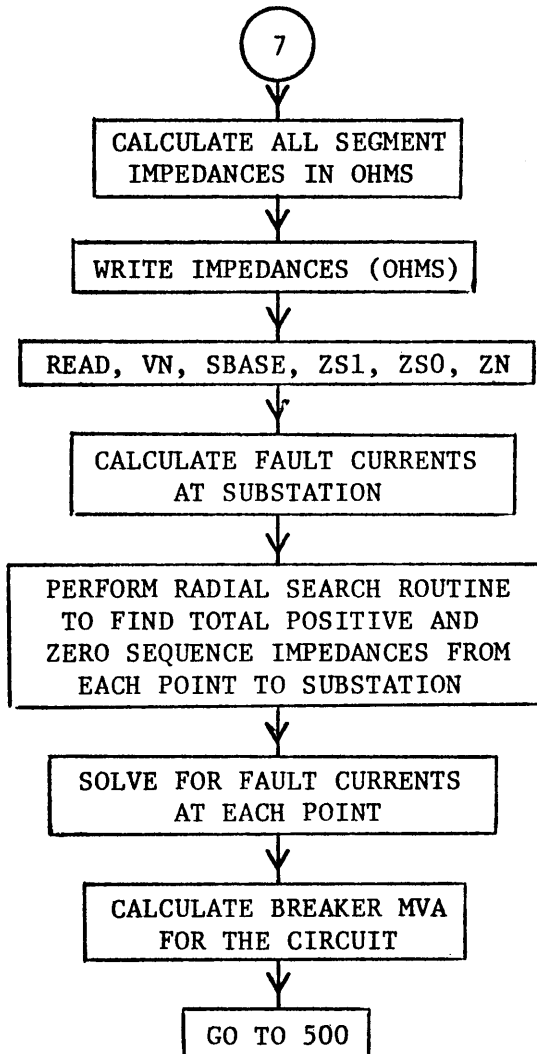


Fig. 5 Distribution System Fault Study Program Flow Chart





(Fig. 5 cont.)



(Fig. 5 finished)

desired at more than one of the branches.

(3) A point may be declared anywhere the fault currents are desired.

(4) Point zero is always the substation.

For example, in Fig. 6, if the currents are desired at point A, then point B must also be declared a point for two reasons: (1) the number of phases has changed; (2) the conductor size and geometry has changed. If the currents at A are not desired, then point B does not have to be declared a point in order to find the currents farther down the line because geometries, wire sizes and phases are the same from point 0 to point C (the spacing is assumed to be the same from 0 to C).

If the currents at D are wanted, point C must be declared for the same reasons as above. If the currents at D are not required, C need not be declared. However, if the currents at point H are desired and currents at D, E, F and G are not required, point C does not have to be declared because no changes have taken place from point 0 to H. The remaining segments in Fig. 6 can be reasoned out in the same manner.

Once the points have been selected, according to the above rules, they must be numbered. However, they need not be numbered in any particular order; but in this study, for convenience, the points have been numbered consecutively in the overhead circuits. Furthermore, the segments should be numbered consecutively, beginning at the substation and numbering sequentially toward the end of the line, so that the last segment number in the circuit is equal to the total number of segments in the circuit.

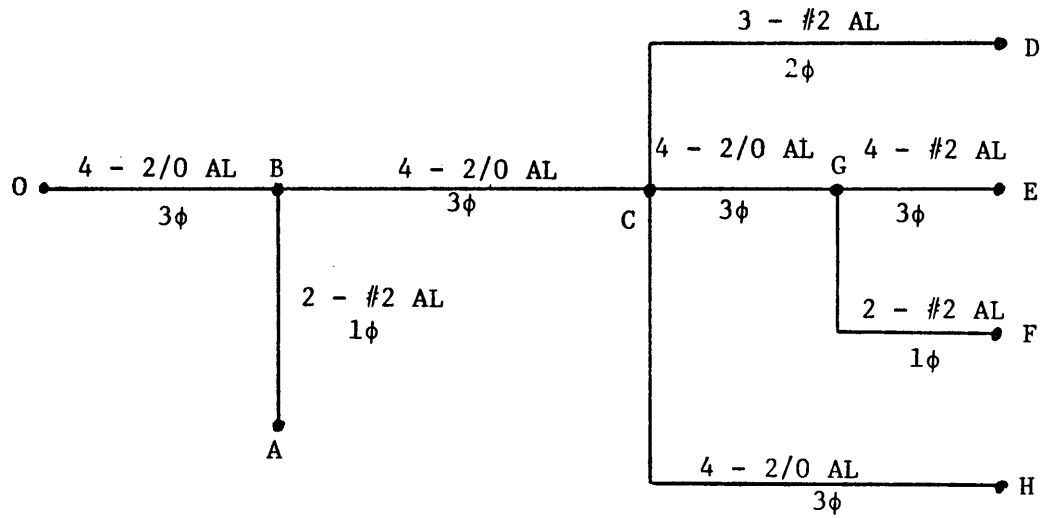


Fig. 6 Illustration of Point Selection Procedure

3.4 The Data Deck

To begin the data deck, the first card required contains the following data: the month (DATE1), the day (DATE2), the year (DATE3) and the system frequency (f). The data card for June 5, 1977, with a system frequency of 60 HZ would be

6 5 77 60 (A)

It should be noted here that all data is read in an unformatted manner so that data elements do not have to appear in a certain location on the data card. Individual values need to be separated by a space or a comma in order for them to be read.

The next data card begins the data set required for each circuit studied. This card contains the circuit number (CKTNO) and the number of line segments that the line has been divided into (NOSECT). For a circuit number 5 with 18 segments the data card would be

5 18 (B)

The next card required contains the segment number (SEGNO), circuit type (CIRTYP), length of the segment (LENGTH), starting node of the segment (SB), and the ending node of the segment (EN). The CIRTYP refers to the list of conductor configurations presented in section 3.1. For example, let segment number 15 be a three phase multigrounded configuration (CIRTYP = 1), 300 feet long, starting at point 6 and ending at point 7. The data card describing this data would be

15 1 300 6 7 (c)

Next, the properties of conductors in the segment are read. First, a list must be defined for conductor sizes and conductor materials.

NSIZE(1) = 750 MCM	MATRL(1) = AL
NSIZE(2) = 350 MCM	MATRL(2) = CU
NSIZE(3) = 336 MCM	MATRL(3) = AL-UG
NSIZE(4) = 4/0	MATRL(4) = CU-UG
NSIZE(5) = 2/0	MATRL(5) = C-CN
NSIZE(6) = 1/0	MATRL(6) = CSN
NSIZE(7) = #1	MATRL(7) = C & CSN
NSIZE(8) = #2	
NSIZE(9) = #4	
NSIZE(10) = #6	
NSIZE(11) = #10	
NSIZE(12) = #12	
NSIZE(13) = 3/0	

The conductor sizes are self-explanatory. The conductor material abbreviations are defined in this manner:

AL - Aluminum

CU - Copper

AL-UG - Aluminum underground

CU-UG - Copper underground

C-CN - Copper, concentric neutral

CSN - Copper shielded neutral

C & CSN - Copper conductor and a copper shielded neutral

The next data card read is for the phase conductors. The information

contained is: conductor type (CNDTYP), material (MAT), resistance (R), geometric mean radius (GMR), diameter (D), height of phase A above the ground (HA), B above the ground (HB), C above the ground (HC), distance from A to B (HHAB), distance from A to C (HHAC), and RHO (RHO), the resistivity of the earth. For a 336 MCM aluminum phase conductor, R = .306 ohms/mi, GMR = .0255 ft., D = .741 in., HA = 30 ft., HB = 30 ft., HC = 30 ft., HHAB = 3.67 ft., HHAC = 7.33 ft., RHO = 100 meter-ohms, the data card would be

```
3  1  .306  .0255  .741  30  30  30  3.67  7.33  100  (D)
```

where the 3 and the 1 come from the list of the NSIZES and MATRLs.

If the same conductor had been used except two phase, the data card would be

```
3  1  .306  .0255  .741  30  30  0  7.33  0  100
```

since there is no phase C, HC = 0 and HHAC = 0.

Similarly, if the same conductor had been used, except single phase, the data card would be

```
3  1  .306  .0255  .741  30  0  0  0  0  100
```

since now HB, HC, HHAB, HHAC = 0.

If the CIRTYP equals 3, 4, 7 or 8, this is all the data that is required for that segment since no neutral wire is present. However, for CIRTYP's 1, 2, 5, 6, 9 and 10, a data card for a neutral conductor is required. For a neutral conductor, the data card contains the following information: conductor type of the neutral conductor (CNDTYN),

neutral conductor material (MATN), resistance of the neutral (RN), GMR of the neutral (GMRN), diameter of the neutral (DN), height of the neutral (HN), distance from phase A to the neutral (HHAN). A neutral conductor of 4/0 copper, RN = .303 ohms/mi, GMRN = .01579 ft., DN = .522 in., HN = 25 ft. and HHAN = 5.67 ft. would have the data card

4 2 .303 .01579 .522 25 5.67 (E)

This completes the data for a segment of CIRTYP 1, 2, 5, 6, 9 and 10.

If the CIRTYP = 11, 12 or 13, then the data for an underground cable must be read. For a CIRTYP 11 (three phase UG), the following information is read: conductor type (CNDTYP), conductor material (MAT), resistance (R), geometric mean radius (GMR), diameter (D), distance from center of A to center of B (DAB), from B to C (DBC) and from C to A (DCA), and RHO. Therefore, if the conductor is a 350 MCM AL-UG cable, R = .295 ohms/mi., GMR = .01983 ft., D = .611 in., DAB = .1133 ft., DBC = .1133 ft., DCA = .1133 ft. and RHO = 100 meter-ohms, the data card would be

2 3 .295 .01983 .611 .1133 .1133 .1133 100.0 (F)

If CIRTYP = 12 (single phase UG), the data is very similar: CNDTYP, MAT, T, GMR, D, the diameter of the entire cable, including concentric neutral (S), and RHO. A single phase underground concentric neutral cable with the following data--2/0 AL, R = .771 ohms/mi., GMR = .01317 ft., D = .406 in., S = .0883 ft., RHO = 100 meter-ohms--would have the following data card:

5 3 .771 .01317 .406 .0883 100 (G)

The data card for the concentric neutral of both CIRTYP 11 and 12 is the same. The data contained is conductor size of one strand of the concentric neutral (CNDTYN), conductor material (MATN), resistance of one strand of the concentric neutral (RN), GMRN of one strand of the concentric neutral, diameter of the concentric neutral and number of strands in the concentric neutral (NN). For a concentric neutral of #12 copper, RN = 8.849 ohms/mi., GMRN = .00262 ft., DEE = 1.06 in., NN = 13 strands, the data card would be

12	5	8.849	.00262	1.06	13	(H)
----	---	-------	--------	------	----	-----

For a CIRTYP 13 (three phase shielded underground), the following information is required: conductor type (CNDTYP), conductor material (MAT), resistance (R), geometric mean radius (GMR), diameter (D) and RHO (RHO). Therefore, for a 350 MCM shielded aluminum conductor, R = .295 ohms/mi., GMR = .01983 ft., D = .611 ft., RHO = 100 meter-ohms, the data card would be

2	3	.295	.01983	.611	100	(I)
---	---	------	--------	------	-----	-----

The data read for the neutral conductor pulled in the conduit with the three phase conductors contains the following information: conductor size (CNDTYN), conductor material (MATN), resistance (RN), geometric mean radius (GMRN), and diameter (DN). Therefore, the neutral conductor accompanying a shielded underground cable, having neutral conductor data 4/0 copper, RN = .303 ohms/mi., GMRN = .01519 ft., DN = .522 in., would have a data card as follows:

2	7	.303	.01579	.522	(J)
---	---	------	--------	------	-----

The MATN = 7 comes from the fact that the neutral is copper pulled in with shielded cable having a copper shield (C & CSN).

So, in conclusion, one card of type (A) is needed to start the data deck. Then, for each line studied, one card of type (B) is next.

For each line segment, the following cards are needed:

Type (C) card

If CIRTYP = 1 - 10

Type (D) card

If CIRTYP = 1, 2, 5, 6, 9, 10

Type (E) card

or

If CIRTYP = 11

Type (F) card

Type (H) card

or

If CIRTYP = 12

Type (G) card

Type (H) card

or

If CIRTYP = 13

Type (I) card

Type (J) card

After an entire group of line segments has been read, one more card must be read. The information contained is: line to neutral voltage of the circuit (VN), MVA base (SBASE), positive sequence source impedance (ZS1), zero sequence source impedance (ZS0) and the fault impedance (ZN). For a VN = 2400 volts, SBASE = 10 MVA, ZS1 = j.11773, ZS0 = j.03629, ZN = 10 ohms, the data card is

```
2400    10    (0.0, 0.11773)    (0.0, 0.03629)    10
```

After all lines have been studied, a final data card is read. This card contains the data

```
0        0
```

This card is simply a control card which signals the program that all lines have been studied and the program stops.

A simple example deck to illustrate the data deck follows:

```
6  5  77  60
```

```
11  2
```

```
1  1  980  0  1
```

```
3  1  .306  .0255  .741  30  30  30  3.67  7.33  100
```

```
3  1  .306  .0255  .741  26.33  5.17
```

```
2  12  100  1  2
```

```
6  3  .973  .01175  .362  .085  100
```

```
12  5  8.849  .00262  1.02  10
```

```
2400  10  (0.0, 0.11773)  (0.0, 0.03629)  10
```

```
0      0
```

This is a complete data deck for circuit number 11 containing two line

segments, the first a three phase overhead line, the second a single phase underground cable with concentric neutral. The data does not appear in well defined columns due to the fact that unformatted read is used. However, data cards read in an unformatted manner are much easier to type and the above example deck is in the form of an actual data deck.

It should be noted here that for overhead circuits on crossarm types pictured in Figs. 4a, 4b and 4c, the conductor heights were assumed to be 30 feet, with the neutral height 25 feet. For Fig. 4d, the neutral height is 30 feet with the other heights calculated by the dimensions given in the figure. In Fig. 4e, phase B is 30 feet high with the other conductor heights also calculated from the dimensions given in the figure. All three phase underground circuits were assumed to be spaced so that the three conductors formed an equilateral triangle.

It should be noted at this point that conductor data (resistances, GMRs, etc.) were obtained from Reference 7 and from cable manufacturers' catalogs.

This concludes the user's guide for this program. Results of fault current calculations for the entire VPI Electric Service distribution system follow.

IV. CONCLUSIONS

The program was tested by running the first eight segments of the system which had been previously studied by Wylie, Auer and Ender [2] and the results of the two studies differed by a maximum of .003%. This would lead one to believe that the program written for this thesis is accurate.

Some important results of the study are contained in Table 2. Since the Wiley and Wilson study was performed in 1972, one of the old generators has been replaced, causing a new value of source impedance. Also, Wiley and Wilson performed their study with only one of the VPI 5 MVA transformers operating, which is not the condition for maximum fault current. As a result, the values of the fault currents at the substation are considerably different from those obtained in the Wiley & Wilson study. However, the fault currents occurring on a circuit do conform to the same pattern in both studies.

It is felt that the contribution of this thesis is in two areas. First, an up-to-date system description has been provided for the VPI Electric Service distribution network. Secondly, a digital computer program has been developed to perform general-purpose fault studies. The program can be used for several additional distribution system studies. Specifically, system voltage profiles can be performed readily. By adding the storage of fuse characteristics to the program, a fuse-relay coordination study is possible. Additionally, this program should be useful in future system planning.

Table 2. Maximum Three Phase Fault Currents
and 5 Cycle Breaker Ratings for the 4 KV and 12 KV Buses

	4 KV Bus	12 KV Bus
Maximum three phase current (amps)	20385.62	14448.26
Breaker MVA (5 cycle)	161.45	343.29

REFERENCES

1. Clarke, Edith, Circuit Analysis of AC Power Systems, Vol. I & II, John Wiley & Sons, New York, N.Y., 1943 and 1950.
2. Wylie, R. A., G. G. Auer and R. C. Ender, "Digital Calculation of Sequence Impedances and Fault Currents for Radial Primary Distribution Circuits", AIEE Transactions, PT. III, Power Apparatus and Systems, Vol. 79, February 1961, pp. 1264-1277.
3. Electrical Transmission and Distribution Reference Book, Westinghouse Electric Corporation, Pittsburgh, PA., 4th Ed., 1964.
4. Webb, R. L. and O. W. Manz, Jr., "Impedance Measurements on Underground Cables", AIEE Transactions, Pt. III, Power Apparatus and Systems, April, 1936, p. 359.
5. Wiseman, R. J., E. H. Salter and G. B. Shanklin, "Resistance and Reactance of 3-conductor Cables", AIEE Transactions, Pt. III, Power Apparatus and Systems, Vol. 53, December 1934, pp. 1581-1589.
6. Lewis, W. A. and P. D. Tuttle, "The Resistance and Reactance of Aluminum Conductors, Steel Reinforced", AIEE Transactions, Pt. III, Power Apparatus and Systems, Vol. 77, pp. 1189-1215.
7. Silent Sentinels, Westinghouse Protective Relays, Westinghouse Electric Corporation, Newark, N.J., 1949.
8. Distribution System Protection Manual, McGraw-Edison Co., Power Systems Div., Canonsburg, PA., Bulletin No. 71022, pp. 17-48.
9. Calabrese, G. O., Symmetrical Components, Ronald Press Co., New York, N.Y., 1950.

APPENDIX A

A. List of Symbols Used in the Program

The following variable names were used in the computer program:

DATE 1	- Two-digit number representing the month of today's date (i.e. January = 1)
DATE 2	- Two-digit number representing the day of today's date (i.e. 27th = 27)
DATE 3	- Two-digit number representing the year of today's date (i.e. 1977 = 77)
f	- System frequency (HZ)
CKTNO	- Circuit number under study
NOSECT	- Number of segments in the circuit under study
SEGNO	- Segment number
SB	- Starting node of a particular segment
EN	- Ending node of a particular segment
LENGTH	- Length of a segment (ft)
LENTHO	- Length of a segment (thousands of feet)
ZHOLD1	- Positive sequence impedance being held at a point
ZHOLDO	- Zero sequence impedance being held at a point
NUMB	- Dummy variable
CIRTP	- Circuit type
CNDTYP	- Phase conductor type
MAT	- Phase conductor material
R	- Phase conductor resistance (ohms/mi)
GMR	- Phase conductor geometric mean radius (ft)

D	- Phase conductor diameter (in)
HA	- Height of phase above the ground (ft)
HB	- Height of phase B above the ground (ft)
HC	- Height of phase C above the ground (ft)
HHAB	- Distance from phase A to phase B (ft)
HHAC	- Distance from phase A to phase C (ft)
RHO	- Resistivity of the earth (meter-ohms)
CNDTYN	- Conductor type of neutral
MATN	- Material of neutral conductor
RN	- Resistance of neutral conductor (ohms/mi)
GMRN	- Geometric mean radius of neutral conductor (ft)
DN	- Diameter of neutral conductor (in)
HN	- Height of neutral conductor above the ground (ft)
HHAN	- Distance from neutral conductor to phase A (ft)
H	- Average height of a group of conductors (ft)
HH,HHN	- Average horizontal spacing of a group of conductors (ft)
SS,SSN	- Average spacing between a conductor and the image of another (ft)
S,SN	- Geometric mean spacing between a group of conductors
THETA	- The angle formed between lines drawn from a conductor to its own image and the image of another conductor (degrees)
THETAR	- Theta in radians
X	- Reactance of conductor (ohms/mi)
RR	- Real component of self impedance with earth return external to the conductor (ohms/mi)

RM	- Real component of the mutual impedance (ohms/mi)
XX	- Imaginary component of self impedance (ohms/mi)
XM	- Imaginary component of mutual impedance (ohms/mi)
ZZ	- Complex self impedance (ohms/1000 ft)
ZM	- Complex mutual impedance (ohms/1000 ft)
S	- Outside diameter of a single phase, concentric neutral cable (feet)
DEE	- Diameter of concentric neutral (in.)
NN	- Number of strands in the concentric neutral
Z11	- Positive sequence self impedance (ohms/1000 ft)
Z001	- Zero sequence self impedance without neutral wire but with presence of earth taken into account (ohms/1000 ft)
Z002	- Zero sequence self impedance of a circuit with a unigrounded neutral (ohms/1000 ft)
Z003	- Zero sequence self impedance for a circuit with a multi-grounded neutral
Z11T	- Z11 in ohms
Z001T	- Z001 in ohms
Z002T	- Z002 in ohms
Z003T	- Z003 in ohms
VN	- Line to neutral voltage (volts)
SBASE	- MVA base (MVA)
ZS1	- Positive sequence source impedance (ohms)
ZS0	- Zero sequence source impedance (ohms)
ZN	- Real part of fault impedance (ohms)

V	- Line to line voltage (volts)
ZBASE	- Impedance base (ohms)
ZF	- Complex fault impedance (ohms)
ZS2	- Negative sequence source impedance (ohms)
IF3PHO	- Three phase fault current at substation (amps)
IFLLO	- Line to line fault current at substation (amps)
IFLLGO	- Line to line to ground fault current at substation (amps)
IFLGO	- Line to ground fault current at substation (amps)
ZT1	- Positive sequence impedance at point I (ohms)
ZT0	- Zero sequence impedance at point I (ohms)
IF3PH	- Three phase fault current (amps)
IFLL	- Line to line fault current (amps)
IFLLG	- Line to line to ground fault current (amps)
IFLG	- Line to ground fault current (amps)
SCC	- Short circuit capacity of breaker (MVA)
RAT2	- Rating of a 2-cycle breaker (MVA)
RAT4	- Rating of a 4-cycle breaker (MVA)
RAT5	- Rating of a 5-cycle breaker (MVA)

B. Equations Used

Overhead lines (reference 2)

<u>Circuit type</u>	<u>Phase conductors</u> $\frac{1}{3}$	<u>Neutral conductor</u> $\frac{1}{3}$
1,2	$S = (SAB * SAC * SBC)^{\frac{1}{3}}$	$SN = (SAN * SBN * SCN)^{\frac{1}{3}}$
	$SS = \frac{1}{3}(SSAB + SSAC + SSBC)$	$SSN = \frac{1}{3}(SSAN + SSBN + SSCN)$
	$H = \frac{1}{3}(HA + HB + HC)$	$HN = HN$
	$HH = \frac{1}{3}(HHAB + HHBC + HHAC)$	$HHN = \frac{1}{3}(HHAN + HHBN + HHCN)$

<u>Circuit type</u>	<u>Phase conductors</u>	<u>Neutral conductor</u>
3,4	same as 1,2	no neutral conductor
5,6	S = SAB	$SN = (SAN \cdot SBN)^{\frac{1}{2}}$
	SS = SSAB	$SSN = \frac{1}{2}(SSAN + SSBN)$
	$H = \frac{1}{2}(HA + HB)$	HN = HN
	HH = HHAB	$HHN = \frac{1}{2}(HHAN + HHBN)$
7,8	same as 5,6	no neutral conductor
9,10	H = HA	SN = SAN
		SSN = SSAN
		HN = HN
		HHN = HHAN

$$HHBC = |HHAC - HHAB|$$

$$HHBN = |HHAN - HHAB|$$

$$HHCN = |HHAN - HHAC|$$

$$S_{xy} = [HHx_y^2 + (Hx - Hy)^2]^{\frac{1}{2}}$$

$$SS_{xy} = [HHxy^2 + (Hx + Hy)^2]^{\frac{1}{2}}$$

where xy = ab, ac, bc, an, bn or cn.

$$X = .2794(f/60) \log_{10} \frac{D}{24(GMR)}$$

$$THETA = \sin^{-1}(HH/SS)$$

$$KN = NN^{(1/(NN-1))}$$

$$RR = OMEGA(2.528 \times 10^{-4} - 2.599 \times 10^{-7} H(f/RHO)^{\frac{1}{2}} + 2.717 \times 10^{-10} H^2(f/RHO) \times (3.36 + \log_{10} \frac{1}{H} (RHO/f)^{\frac{1}{2}} + 5.084 \times 10^{-14} H^3 (f/RHO)^{\frac{3}{2}})$$

$$\begin{aligned}
 RM = & \text{OMEGA}(2.528 \times 10^{-4} - 1.299 \times 10^{-7} (f/\text{RHO})^{\frac{1}{2}} \text{SS} \cos \text{THETAR} + \\
 & 6.785 \times 10^{-11} (f/\text{RHO}) \text{SS}^2 \cos 2 \text{THETAR} (3.661 + \log_{10}(\frac{1}{S}) (\text{RHO}/f)) \\
 & + 2.951 \times 10^{-11} (f/\text{RHO}) \text{S}^2 \text{THETAR} (\sin 2 \text{THETAR}) + 6.355 \times 10^{-15} \\
 & \times (f/\text{RHO})^{\frac{3}{2}} \cos 3 \text{THETAR})
 \end{aligned}$$

$$\begin{aligned}
 XX = & \text{omega}(3.4944 \times 10^{-3} + 7.4113 \times 10^{-4} \log_{10}(\frac{1}{D}) (\text{RHO}/f)^{\frac{1}{2}} + \\
 & 2.599 \times 10^{-7} \text{H} (f/\text{RHO})^{\frac{1}{2}} - 9.271 \times 10^{-11} \text{H}^2 (f/\text{RHO}) + 5.084 \times \\
 & 10^{-14} \text{H}^3 (f/\text{RHO})^{\frac{3}{2}})
 \end{aligned}$$

$$\begin{aligned}
 XM = & \text{omega}(2.4715 \times 10^{-3} + 7.4113 \times 10^{-4} \log_{10}(\frac{1}{S}) (\text{RHO}/f)^{\frac{1}{2}} + 1.299 \times \\
 & 10^{-7} (f/\text{RHO})^{\frac{1}{2}} \text{S} \cos \text{THETAR} - 2.318 \times 10^{-11} (f/\text{RHO}) \text{S}^2 \cos 2 \\
 & \text{THETAR})
 \end{aligned}$$

Each of the above four equations is used for the phase conductors and for the neutral conductor.

$$ZZ = (R + RR) + j(X + XX)$$

$$ZM = RM + jXM$$

$$Z11 = ZZ - ZM$$

$$Z001 = ZZ + 2ZM$$

$$Z002 = Z001 + 3ZZN - 6ZAN$$

$$Z003 = Z001 - 3ZAN^2/ZZN$$

$$IF3PH = \left| \frac{VN}{Z1 + ZS + ZF} \right|$$

$$IFLL = \left| \frac{(3)^{\frac{1}{2}} VN}{Z11 + Z22 + ZS + ZF} \right|$$

$$IFLG = \left| \frac{3VN}{Z003 + Z11 + Z22 + ZS + 3ZF} \right|$$

$$I_{FLLG} = \left| (3)^{\frac{1}{2}VN} \frac{Z_{003}+3ZF-aZ_{22}}{Z_{11}Z_{22}+ZS+(Z_{11}+Z_{22})(Z_{003}+3ZF)} \right|$$

$$a = 1/\underline{120}$$

UNDERGROUND CABLE EQUATIONS (Reference 8)

$$ZZ_{AA} = (R+4.788 \times 10^{-5} * 2 * \pi * f) + j 2 * \pi * f (4.681 \times 10^{-4} + 6.096 \times 10^{-5} \log_e (1/GMR) (RHO/f)^{\frac{1}{2}}) \quad (A1)$$

$$Z_{MAB} = (4.788 \times 10^{-5} * 2 * \pi * f) + j 2 * \pi * f (4.681 \times 10^{-4} + 6.096 \times 10^{-5} \log_e (1/S) (RHO/f)^{\frac{1}{2}}) \quad (A2)$$

$$ZZ_{NN} = ((RN/3NN)+4.788 \times 10^{-5} * 2 * \pi * f) + j 2 * \pi * f (4.681 \times 10^{-4} + 6.096 \times 10^{-5} \log_e (RHO/f)^{\frac{1}{2}} + 6.096 \times 10^{-5} \log_e (1/(S^2)^{\frac{1}{3}}) + 6.096 \times 10^{-5} \log_e (1/(S^2)^{\frac{1}{3}}) + 6.096 \times 10^{-5} \log_e (1/(S^2)^{\frac{1}{3}})) \quad (A3)$$

$$Z_{MAN} = (4.788 \times 10^{-5} * 2 * \pi * f) + j 2 * \pi * f (4.681 \times 10^{-4} + 6.096 \times 10^{-5} \log_e (1/((DEE/2)S^2)^{\frac{1}{3}}) (RHO/f)^{\frac{1}{2}}) \quad (A4)$$

$$ZZ_{NN} = (RN/NN+4.788 \times 10^{-5} * 2 * \pi * f) + j \frac{2 * \pi * f}{NN} (4.681 \times 10^{-4} + 6.096 \times 10^{-5} \log_e (1/GMRN) (RHO/f)^{\frac{1}{2}}) + (NN-1) 4.681 \times 10^{-4} + (NN-1) 6.096 \times 10^{-5} \log_e ((2/KN * DEE) * (RHO/f)^{\frac{1}{2}}) \quad (A5)$$

$$ZM_{AN} = (4.788 \times 10^{-5} * 2 * \pi * f) + j * 2 * \pi * f \frac{1}{(4.681 \times 10^{-4} + 6.096 \times 10^{-5} \log_e (2/DEE) (RHO/f)^2)} \quad (A6)$$

$$ZZ_{NN} = RN/NN + j2 * \pi * f * 6.096 \times 10^{-5} ((NN-1)/NN \log_e (2/(KN * DEE)) + (1/N) \log_e (1/GMRN) - \log_e (1/S)) \quad (A7)$$

$$ZM_{AN} = j2 * \pi * f * 6.096 \times 10^{-5} (\log_e (2/DEE) - \log_e (1/S)) \quad (A8)$$

$$Z11_{3-phase} = ZZAA - ZMAB - ZMAN^2 / ZZNN \quad (A9)$$

$$Z003_{3-phase} = ZZAA + 2ZMAB - (3 ZMAN^2 / ZZNN) \quad (A10)$$

$$Z11_{1-phase} = ZZAA - ZMAB \quad (A11)$$

$$Z003_{1-phase} = ZZAA + 2 ZMAB - (3 ZMAN^2 / ZZNN) \\ \text{(from reference 7)}$$

$$Z11_{3-phase} = R + jX \quad (A12)$$

$$Z003_{3-phase} = R + RN + j(X - XN) \quad (A13)$$

For circuit type 11 use equations A1, A2, A3, A4, A7, A8, A9, A10.

For circuit type 12 use equations A1, A2, A5, A6, A11, A12.

For circuit type 13 use equations A13, A14.

APPENDIX B
PROGRAM LISTING

```

//WATFIV      HOGSHEAD,PAGES=200
C
C      DISTRIBUTION SYSTEM FAULT STUDY PROGRAM
C
      DIMENSION CAPH(2),CAPS(2),LITH(2),LITS(2),GGNR(2),DD(2),RE(2),
      LTHETA(2),THETA(2),RX(3),RX(3),XN(2),XX(3),X(2),ZZ(70,3),ZM(70,3),
      IZ11(70),Z001(70),Z002(70),Z003(70),SEGNO(70),CIRTP(70),SB(70),
      IEN(70),LENGTH(70),LENTHO(70),ZHOLD1(70),ZHOLD0(70),NUMB(70),
      IZ002T(70),Z001T(70),Z11T(70),Z003T(70),ZT1(70),ZT2(70),
      IIF3PH(70),IFLL(70),IFLG(70),IF3PHO(2),IFLLO(2),IFLLO(2),IFLLO(2),
      I,IFLGO(2)
      REAL OMEGA,LITH,LITS,KN,LENGTH,LENTHO,IF3PH,IFLL,IFLLG,IFLG,IF3PHO
      I,IFLLO,IFLGO,IFLGO
      COMPLEX CMPLX,ZZ,Z4,Z11,Z001,Z002,Z003,ZHOLD1,ZHOLD0,Z002T,Z001T,
      IZ11T,Z003T,ZS1,ZS0,ZT1,ZT2,ZF,AA,ZS2
      INTEGER DATE1,DATE2,DATE3,CKTNO,CIRTP,SEGNO,CIRDTYP,CNDTYP,SB,EN
      CHARACTER NSIZE*(13),750CN',350*CP',326*CN',4/0',2/0',
      1,'1/0',, #1',, #2',, #4',, #6',, #10',, #12',,
      1 #8',,MATRL*5(7)/, AL',, CU',,AL-UG',,CU-UG',,CU-CN',, CSN',
      1,'C&CSN'//
C
      READ, DATE1,DATE2,DATE3,F
500 READ, CKTNO,NOSCT
      IF (CKTNO.EQ.0) GO TO 110
      WRITE(6,1) DATE1,DATE2,DATE3
      WRITE(6,2) CKTNO
      WRITE(6,3)
      WRITE(6,4)
      WRITE(6,5)
      WRITE(6,6)
      DO 300 K=1,NOSCT
      SEGNO(K)=0

```

```

SB(K)=0
EN(K)=0
LENGTH(K)=0.0
LENT HQ(K)=0.0
ZHOLD1(K)=CMPLX(0.0,0.0)
ZHOLD0(K)=CMPLX(0.0,0.0)
NUMB(K)=0
300 CIRTYP(K)=0
L=0
DO 7 I=1,NBSECT
  READ, SEGN(I),CIRTYP(I),LENGTH(I),SB(I),EN(I)
  LLL=CIRTYP(I)
  IF (CIRTYP(I).EQ.11) GO TO 116
  IF (CIRTYP(I).EQ.12) GO TO 115
  IF (CIRTYP(I).EQ.13) GO TO 150
  READ,CNDTYP,MAT,R,GMR,D,HA,H6,HC,HHAB,HHAC,RHD
  GO TO (11,11,19,19,11,11,11,19,19,11,11),LLL
11 READ,CNDTYP,MAT,N,RN,GMRN,DN,HN,HHAN
19 HHBC=ABS(HHAC-HHAB)
  GO TO (600,600,601,601,600,601,601,601,600,600),LLL
600 HHBN=ABS(HHAN-HHAB)
  HHCN=ABS(HHAN-HHAC)
601 SAB=SQRT((HHAB**2)+(HA-H3)**2)
  SAC=SQRT((HHAC**2)+(HA-HC)**2)
  SBC=SQRT((HHBC**2)+(HB-HC)**2)
  GO TO (602,602,603,603,602,602,603,603,602,602),LLL
602 SAN=SQRT((HHAN**2)+(HA-HN)**2)
  SBN=SQRT((HHBN**2)+(HB-HN)**2)
  SCN=SQRT((HHCN**2)+(HC-HN)**2)
603 SSAB=SQRT((HHAB**2)+(HA+HB)**2)
  SSAC=SQRT((HHAC**2)+(HA+HC)**2)
  SSBC=SQRT((HHBC**2)+(HB+HC)**2)

```

```

GO TO (604,604,605,605,604,604,605,605,604,604),LLL
604 SSAN=SQRT((HHAN**2)+(HA+HN)**2)
SSBN=SQRT((HHBN**2)+(HB+HN)**2)
SSCN=SQRT((HHCN**2)+(HC+HN)**2)
605 IF (CIRTP(I).GT.4) GO TO 8
S=(SAB*SAC+SBC)**(1.0/3.0)
SS=(1.0/3.0)*(SSAP+SSBC+SSAC)
H=(1.0/3.0)*(HA+HB+HC)
HH=(1.0/3.0)*(HHA3+HHBC+HHAC)
IF (CIRTP(I).GT.2) GO TO 9
SN=(SAN+SBN+SCN)**(1.0/3.0)
SSN=(1.0/3.0)*(SSAN+SSBN+SSCN)
HHN=(1.0/3.0)*(HHAN+HHBN+HHCN)
GO TO 9
3 IF (CIRTP(I).GT.3) GO TO 10
S=SA3
SS=SSAB
H=(HA+HB)/2
HH=HHAB
IF (CIRTP(I).GT.6) GO TO 9
SN=SQRT(SAN+SBN)
SSN=(SSAN+SSBN)/2
HHN=(HHAN+HHBN)/2
GO TO 9
10 H=HA
SN=SAN
SSN=SSAN
HHN=HHAN
HH=HHN
S=SN
SS=SSN
9 OMEGA=2.0*3.14159*F

```

```

      GO TO (12,12,13,13,12,12,13,13,14,14),LLL
12  CAPH(2)=HHN
    CAPS(2)=SSN
    LITH(2)=HN
    LITS(2)=SN
    DD(2)=DN
    RE(2)=RN
    GMR(2)=GMRN
13  CAPH(1)=HH
    CAPS(1)=SS
    LITH(1)=H
    LITS(1)=S
    GO TO 15
14  CAPH(2)=HHN
    CAPS(2)=SSN
    LITH(2)=HN
    LITS(2)=SN
    LITH(1)=H
    DD(2)=DN
    RE(2)=RN
    GMR(2)=GMRN
    LITS(1)=SN
    CAPH(1)=HHN
    CAPS(1)=SSN
15  DD(1)=D
    RE(1)=R
    GMR(1)=GMR
    DO 18 J=1,2
    IF (J.EQ.2) GO TO (17,17,18,18,17,17,18,18,17,17),LLL
17  THETA(J)=ARSIN(CAPH(J)/CAPS(J))
    THETA(J)=THETA(J)/(180/3.14159)
    RR(J)=OMEGA*((2.5235-4)-2.5995-7*LITH(J)*SQRT(F/RHO))+2.7175-10

```

```

1*(LITH(J)**2)*(F/RHO)*(3.36+ALOG10((1/LITH(J))*SQRT(RHO/F)))+
15.084E-14*(LITH(J)**3)*(F/RHO)**1.5)
RM(J)=OMEGA*(2.528E-4-1.299E-7*SQRT(F/RHO)*CAPS(J)*COS(THETA(J))+
16.785E-11*(F/RHO)*(CAPS(J)**2)*COS(2*THETA(J))* (3.661+ALOG10((
11/CAPS(J))*SQRT(RHO/F)))+2.951E-11*(F/RHO)*CAPS(J)**2*THETA(J)*
1SIN(2*THETA(J))+6.355E-15*((F/RHO)**1.5)*(CAPS(J)**3)*COS(3*THETA(
1J)))
XM(J)=OMEGA*(2.4715E-3+7.4113E-4*ALOG10((1/LITH(J))*SQRT(RHO/F))+
11.299E-7*SQRT(F/RHO)*CAPS(J)*COS(THETA(J))-2.318E-11*(F/RHO)* (
1CAPS(J)**2)*COS(2*THETA(J)))
XX(J)=OMEGA*(3.4944E-3+7.4113E-4*ALOG10((1/DO(J))*SQRT(RHO/F))+
12.599E-7*LITH(J)*SQRT(F/RHO)-9.271E-11*(LITH(J)**2)*(F/RHO)+5.084E
1-14*(LITH(J)**3)*(F/RHO)**1.5)
701 X(J)=.2794*(F/60)*ALOG10(DO(J)/(24*GGR(J)))
ZZ(I,J)=CMPLX(KE(J)+RR(J),X(J)+XX(J))/5.28
ZM(I,J)=CMPLX(RN(J),XM(J))/5.28
18 CONTINUE
WRITE(6,30) SEGNO(I),CIRTP(I),SB(I),EN(I),MATR(MAT),NSIZE(CNDTYP
1),R,X(1),GMR,D,LENGTH(I)
GO TO (75,75,85,85,75,75,25,85,75,75),LLL
75 WRITE(6,62) MATR(MATN),NSIZE(CNDTYP),RN,X(2),GMRN,DN
GO TO 80
85 WRITE(6,36)
GO TO 80
115 READ,CNDTYP,MAT,R,GMR,D,S,RHO
READ,CNDTYP,MATN,RN,GMRN,DEE,NN
114 KN=NN*(1/(NN-1))
X(1)=J.2794*(F/60)*ALOG10(D/(24*GMR))
WRITE(6,120) SEGNO(I),CIRTP(I),SB(I),EN(I),MATR(MAT),NSIZE(CNDTYP),
R,X(1),GMR,D,LENGTH(I)
WRITE(6,121) MATR(MATN),NN,NSIZE(CNDTYP),RN,GMRN,DEE
GO TO 80

```

```

116 READ,CNDTYP,MAT,R,GMR,D,DAB,DBC,DCA,RHO
    READ,CNDTYN,MATN,RN,GMRN,DEE,RN
    S=(DAB*DBC*DCA)**(1.0/3.0)
    GO TO 114

150 READ,CNDTYP,MAT,R,GMR,D,RHC
    READ,CNDTYN,MATN,RN,GMRN,DN
    X(1)=(.2794*(F/60)*ALOG10(D/(24*GMR)))/5.23
    X(2)=(.2794*(F/60)*ALOG10(DN/(24*GMRN)))/5.28
    WRITE(6,152) SECOND(I),CIRTYP(I),SB(I),EN(I),MATRL(MAT),NSIZE(CNDTY
    LP),R,X(1),GMR,D,LENGTH(I)
    WRITE(6,153) MATRL(MATN),NSIZE(CNDTYN),RN,X(2),GMRN,DN
80 L=L+1
    IF (L-12) 7,7,81
81 WRITE(6,82) DATE1,DATE2,DATES
    WRITE(6,2) CKTG
    WRITE(6,3)
    WRITE(6,4)
    WRITE(6,5)
    WRITE(6,6)
    L=0
7 CONTINUE
83 CONTINUE
    K=0
    DO 89 I=1,NSECT
        LLL=CIRTYP(I)
        IF (CIRTYP(I).EQ.11) GO TO 140
        IF (CIRTYP(I).EQ.12) GO TO 140
        IF (CIRTYP(I).EQ.13) GO TO 151
        Z11(I)=ZZ(I,1)-Z1(I,1)
        Z001(I)=ZZ(I,1)+2*Z4(I,1)
        GO TO (91,90,92,92,91,90,92,92,91,90),LLL
90 Z002(I)=Z001(I)+3*ZZ(I,2)-6*Z5(I,2)

```

```

91 Z003(I)=Z001(I)-(3*(ZM(I,2)**2)/ZZ(I,2))
92 CONTINUE
   GO TO 89
151 ZZ(I,1)=CMPLX(R,X(1))
    ZM(I,1)=ZM(I,2)=0
    ZZ(I,2)=CMPLX(RN,X(2))
    Z11(I)=ZZ(I,1)
    RRRR=R+RN
    XXXX=X(1)-X(2)
    Z003(I)=CMPLX(RRRR,XXXX)
   GO TO 89
140 RR(1)=R/5.28+4.738E-5*2*3.14159*F
    XX(1)=2*3.14159*F*(4.681E-4+6.096E-5*ALOG((1/GMR)*SQRT(RHO/F)))
    ZZ(I,1)=CMPLX(RR(1),XX(1))
    RM(1)=4.738E-5*2*3.14159*F
    XM(1)=2*3.14159*F*(4.681E-4+6.096E-5*ALOG((1/S)*SQRT(RHO/F)))
    ZM(I,1)=CMPLX(RM(1),XM(1))
    IF (CIRTP(I).EQ.1) GO TO 160
    RR(2)=(RN/RN)+(4.738E-5*2*3.14159*F)
    XX(2)=(2*3.14159*F)/RN*(4.681E-4+(6.096E-5*ALOG((1/GMRN)*(RHO/F))))
    I+((NN-1)*4.681E-4)+(NN-1)*6.096E-5*ALOG((2/(KN*DEE))*SQRT(RHO/F)))
    ZZ(I,2)=CMPLX(RR(2),XX(2))
    RM(2)=4.738E-5*2*3.14159*F
    XM(2)=2*3.14159*F*(4.681E-4+6.096E-5*ALOG((2/DEE)*SQRT(RHO/F)))
    ZM(I,2)=CMPLX(RM(2),XM(2))
    Z11(I)=ZZ(I,1)-ZM(I,1)
    Z003(I)=ZZ(I,1)+2*ZM(I,1)-(3*(ZM(I,2)**2)/ZZ(I,2))
   GO TO 89
160 RR(2)=RN/(3*NN)+(4.738E-5*2*3.14159*F)
    XX(2)=2*3.14159*F*(4.681E-4+6.096E-5*ALOG(SQRT(RHO/F))+6.096E-5*
    IALOG(1/(S**2)*(1.0/3.0)))+6.096E-5*1/(3*NN)*[ALOG(1/GMRN)+
    1(NN-1)*ALOG(1/(KN*(DEE/2)))]

```

```

ZZ(1,2)=CMPLX(RR(2),XX(2))
RM(2)=4.788E-5*2*3.14159*F
XM(2)=2*3.14159*F*(4.681E-4+6.096E-5*ALOG(1/((DEE/2)*(S**2))**
11.0/3.0))*(SQRT(RHQ/F)))
ZH(1,2)=CMPLX(RM(2),XN(2))
RR(3)=RM/NN
XX(3)=2*3.14159*F*6.096E-5*((NN-1)/NN)*ALOG(2/(KN*DEE))+(1/NN)*
1ALOG(1/GMRN)-ALOG(1/S))
ZZ(1,3)=CMPLX(RR(3),XX(3))
RM(3)=0.0
XM(3)=2*3.14159*F*6.096E-5*(ALOG(2/DEE)-ALOG(1/S))
ZH(1,3)=CMPLX(RM(3),XN(3))
Z11(1)=ZZ(1,1)-ZM(1,1)-(ZM(1,3)**2/ZZ(1,3))
Z003(1)=ZZ(1,1)+2*ZM(1,1)-(3*(ZM(1,2)**2)/ZZ(1,2))
89 CONTINUE
DO 302 I=1,NDSECT
LLL=CIRTP(I)
LENTHO(I)=LENGTH(I)/1000
GO TO (310,308,309,310,310,308,309,310,310,310,310,310),LLL
308 Z002(I)=Z002(I)*LENTHO(I)
309 Z001(I)=Z001(I)*LENTHO(I)
310 Z11(I)=Z11(I)*LENTHO(I)
GO TO (311,311,312,312,311,311,312,312,311,311,311,311),LLL
311 Z003(I)=Z003(I)*LENTHO(I)
312 CONTINUE
302 CONTINUE
READ, VN, SBASE, ZS1, ZS0, ZN
V=VN*SQRT(3.0)
VBASE=V
ZBASE=(VBASE**2)/(SBASE*1E6)
WRITE(6,324) DATE1, DATE2, DATE3
WRITE(6,325) CKTNO, V, VN, SBASE, V, ZBASE

```

```

WRITE(6,326)
WRITE(6,327)
WRITE(6,328)
WRITE(6,329)
ZF=CMPLX(0.0,0.0)
ZS2=ZS1
DO 330 I=1,2
  950 IF3PH0(I)=CABS(VN/(ZS1+ZF))
  951 IFLL0(I)=CABS((VN*SQRT(3.0))/(ZS1+ZS2+ZF))
  952 IFLG0(I)=CABS((3*VN)/(ZS0+ZS1+ZS2+3*ZF))
  AA=C4PLX(-.5,.866)
  953 IFLLG0(I)=CABS((VN*SQRT(3.0)*(ZS0+3*ZF-AA*ZS2))/(ZS1*ZS2+(ZS1+ZS2)
    1*(ZS0+3*ZF)))
  ZF=CMPLX(ZN,0.0)
330 CONTINUE
WRITE(6,331) IF3PH0(1),IFLL0(1),IFLLG0(1),IFLG0(1)
WRITE(6,331) ZN,IF3PH0(2),IFLL0(2),IFLLG0(2),IFLG0(2)
DO 333 I=1,NJSECT
  LLL=CIRTP(I)
  IF (I.GT.1) GO TO 334
  ZT1(I)=ZS1+ZLIT(I)
  ZT0(I)=ZS0+Z003T(I)
  334 ZT2(I)=ZT1(I)
  IF (I.EQ.NJSECT) GO TO 333
  ZHOLD1(I)=ZT1(I)
  ZHOLD0(I)=ZT0(I)
  NU48(I)=EN(I)
DO 332 J=1,NJSECT
  IF (I.EQ.J) GO TO 332
  IF (SB(J).EQ.NUMB(I)) GO TO 919
332 CONTINUE
GO TO 339

```

```

919 M=I
    J=I+1
337 ZT1(J)=ZHOLD1(M)+Z11T(J)
    GO TO (338,238,340,341,330,238,340,341,333,238,338,338,338),LLL
238 ZZ1=CABS(Z001T(J))
    ZZ2=CABS(Z002T(J))
    ZZ3=CABS(Z003T(J))
    IF (ZZ1.LE.ZZZ2) GO TO 239
    GO TO 240
239 IF (ZZ1.LE.ZZZ3) GO TO 241
    GO TO 242
241 ZTJ(J)=ZHOLD0(M)+Z001T(J)
    GO TO 333
242 ZTJ(J)=ZHOLD0(M)+Z003T(J)
    GO TO 333
240 IF (ZZ2.GT.ZZZ3) GO TO 242
    ZTJ(J)=ZHOLD0(M)+Z002T(J)
    GO TO 333
338 ZTJ(J)=ZHOLD0(M)+Z003T(J)
    GO TO 333
340 ZTJ(J)=ZHOLD0(M)+Z001T(J)
    GO TO 333
341 ZTJ(J)=ZHOLD0(M)
    GO TO 333
339 N=I+1
    DO 917 K=1,NOSCT
    IF (N.EQ.K) GO TO 917
    IF (SB(N).EQ.NUMB(K)) GO TO 918
917 CONTINUE
918 J=N
    4=K

```



```

1.4,T54,F7.5,T64,F6.4,T72,F6.4,T80,F6.1)
121 FORMAT(T28,'N',T30,A5,T36,I2,'-',A6,F6.4,T64,F6.4,T72,F6.4)
152 FORMAT('O',T6,I2,T11,I2,T18,I2,T24,I2,T28,'P',T30,A5,T36,A6,T45,F6
1.4,T54,F7.5,T64,F6.4,T72,F6.4,T80,F6.1)
153 FORMAT(T28,'N',T30,A5,T36,A6,T45,F6.4,T54,F7.5,T64,F6.4,T72,F6.4)
324 FORMAT('I',T5,'VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PE
IRFORMED ',I2,'/',I2,'/',I2)
325 FORMAT(T5,'CIRCUIT NO. ',I3,4X,F7.1,'/',F7.1,IX,'VOLTS',T5,'SRASE=
1 ',F4.1,IX,'MVA',4X,'VBASE= ',F7.1,IX,'VOLTS',4X,'ZBASE= ',F6.2,IX
1,'OHMS')
326 FORMAT('O',T40,'FAULT CURRENT MAGNITUDES')
327 FORMAT(T5,'NODE',T11,'SEG',T16,'CIRC',T24,'FAULT')
328 FORMAT(T11,'NO.',T16,'TYPE',T22,'IMPEDANCE',T34,'3-PHASE',T46,'LL'
1,T55,'LLG',T66,'LG')
329 FORMAT(T24,'(CH4S)',T34,'(AMPS)',T44,'(AMPS)',T54,'(AMPS)',T64,'(A
MPS)')
331 FORMAT('O',T7,'O',T12,'O',T18,'1',T26,'O',T33,F8.2,T43,F6.2,T53,F8
1.2,T63,F8.2)
336 FORMAT('O',T6,I2,T11,I2,T17,I2,T26,'O.O',T33,F8.2,T43,F8.2,T53,F8.
12,T63,F8.2)
367 FORMAT(T24,F5.1,T33,F8.2,T43,F8.2,T53,F8.2,T63,F8.2)
368 FORMAT('O',T6,I2,T11,I2,T17,I2,T26,'O.O',T43,F8.2,T53,F8.2,T63,F8.
12)
369 FORMAT(T24,F5.1,T43,F8.2,T53,F8.2,T63,F8.2)
370 FORMAT('O',T6,I2,T11,I2,T17,I2,T26,'O.O',T63,F8.2)
371 FORMAT(T24,F5.1,T63,F8.2)
374 FORMAT('I',T5,'VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PE
IRFORMED ',I2,'/',I2,'/',I2,' (CONT.)')
375 FORMAT('I',T5,'SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER ',I3)
376 FORMAT('O',T9,'2 CYCLE BREAKER',T30,'4 CYCLE BREAKER',T51,'5 CYCLE
1 BREAKER')
377 FORMAT(T10,'RATING (MVA)',T31,'RATING (MVA)',T52,'RATING (MVA)')

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```
378 FORMAT('0',T13,F6.2,T34,F6.2,T55,F6.2)  
931 FORMAT(T24,F5.1,T33,F8.2,T43,F8.2,T53,F8.2,T63,F8.2)  
STOP  
END
```

APPENDIX C - PROGRAM RESULTS

Table of Contents

<u>Results of Circuit Number</u>	<u>Page</u>
1.	58
2.	63
4.	72
5.	77
6.	84
7.	93
8.	104
11.	113
12.	126
110.	143
140.	140
210.	153
220.	161
240.	166
320.	169
340.	174
410.	177
420.	181
510.	186
520.	190
1A.	195
2B.	202

In the pages that follow, the point numbers correspond to points on system maps provided by the author for the Electric Service.

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 1

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R C/MILE	REACT X C/MILE	GMR (FT)	DIAM D (IN)
1	1	0	1	P AL N CU	336MCM 4/0	0.3060 0.3030	0.02321 0.03886	0.0255 0.0153	0.7410 0.5220
2	9	1	2	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
3	1	1	3	P CU N CU	1/0 #2	0.6070 0.9450	0.03888 0.03051	0.0111 0.0084	0.3680 0.2580
4	9	3	4	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
5	1	3	5	P CU N CU	1/0 #2	0.6070 0.9450	0.03888 0.03051	0.0111 0.0084	0.3680 0.2580
6	1	5	6	P AL N AL	#2 #2	1.5500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
7	9	5	7	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
8	1	5	8	P CU N CU	1/0 #2	0.6070 0.9450	0.03888 0.03051	0.0111 0.0084	0.3680 0.2580

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 1

LINE INFORMATION

SEC NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
9	1	8	9	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010
10	1	9	10	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
11	1	9	11	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 1 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
0	0	1	0 10.0	20335.62 239.93	17554.44 415.58	25874.54 17714.44	26494.93 239.99	
1	1	1	0.0 10.0	9083.03 239.10	7866.12 408.90	8221.84 7922.77	6560.22 237.44	
2	2	9	0.0 10.0				3729.61 230.71	
3	3	1	0.0 10.0	4472.04 233.50	3872.90 393.04	3905.94 3922.35	2937.16 231.22	
4	4	9	0.0 10.0				1757.22 219.38	
5	5	1	0.0 10.0	3752.05 231.24	3249.37 387.39	5259.78 3297.13	2436.41 228.94	
6	6	1	0.0 10.0	3567.48 231.05	3039.53 354.81	3038.94 3135.12	2332.12 228.04	
7	7	9	0.0 10.0				1738.00 220.29	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)

CIRCUIT NO. 1 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

FAULT CURRENT MAGNITUDES									
NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)		
8	8	1	0.0 10.0	3392.30 230.80	2937.82 383.88	2944.07 2934.79	2202.05 227.52		
9	9	1	0.0 10.0	2814.05 227.00	2437.04 371.79	2400.88 2478.37	1884.66 223.37		
10	10	1	0.0 10.0	2349.90 223.03	2034.20 359.67	1932.27 2070.85	1628.04 219.13		
11	11	1	0.0 10.0	2449.39 224.34	2121.23 363.44	2078.21 2159.82	1670.04 220.33		

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER		1
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)
205.49	176.13	161.45

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 2

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATH	COND SIZE	RESIS R G/MILE	REACT X G/MILE	GMR (FT)	DIAM D (IN)
1	1	0	1	P AL N CU	336MCM 4/0	0.3060 0.3030	0.02321 0.03886	0.0255 0.0158	0.7410 0.5220
2	1	1	2	P AL N CU	336MCM 4/0	0.3060 0.3030	0.02321 0.03886	0.0255 0.0158	0.7410 0.5220
3	1	2	3	P AL N AL	336MCM 336MCM	0.3060 0.3060	0.02321 0.02321	0.0255 0.0255	0.7410 0.7410
4	1	3	4	P AL N AL	336MCM 336MCM	0.3060 0.3060	0.02321 0.02321	0.0255 0.0255	0.7410 0.7410
5	1	4	5	P CU N CU	#2 #2	0.9450 0.9450	0.03051 0.03051	0.0084 0.0084	0.2580 0.2530
6	9	5	6	P CU N CU	#4 #4	1.5030 1.5030	0.03015 0.03015	0.0066 0.0066	0.2040 0.2040
7	1	5	7	P CU N CU	#2 #2	0.9450 0.9450	0.03051 0.03051	0.0084 0.0084	0.2580 0.2530
8	1	7	8	P CU N CU	#4 #4	1.5030 1.5030	0.03015 0.03015	0.0066 0.0066	0.2040 0.2040

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 2

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATH	COND SIZE	PESIS R C/MILE	REACT X C/MILE	GMR (FT)	DIAM D (IN)
9	1	7	9	P CU	#2	0.9450	0.03051	0.0084	0.2530
				N CU	#2	0.9450	0.03051	0.0084	0.2530
10	1	4	10	P CU	#2	0.9450	0.03051	0.0084	0.2530
				N CU	#2	0.9450	0.03051	0.0084	0.2530
11	9	10	11	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010
12	9	11	12	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010
13	9	11	13	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010
14	1	10	14	P CU	#2	0.9450	0.03051	0.0084	0.2530
				N CU	#2	0.9450	0.03051	0.0084	0.2530
15	1	14	15	P CU	#2	0.9450	0.03051	0.0084	0.2530
				N CU	#2	0.9450	0.03051	0.0084	0.2530
16	9	14	16	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CUNT
CIRCUIT NO. 2

LINE INFORMATION

SEC NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
17	1	15	17	P CU	#2	0.9450	0.03051	0.0084	0.2580
				N CU	#2	0.9450	0.03051	0.0084	0.2580
18	9	17	18	P CU	#2	0.9450	0.03051	0.0084	0.2580
				N CU	#2	0.9450	0.03051	0.0084	0.2580
19	1	17	19	P CU	#2	0.9450	0.03051	0.0084	0.2580
				N CU	#2	0.9450	0.03051	0.0084	0.2580
20	1	19	20	P CU	#2	0.9450	0.03051	0.0084	0.2580
				N CU	#2	0.9450	0.03051	0.0084	0.2580
21	9	15	21	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040
22	9	21	22	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040
23	9	21	23	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040
24	1	19	24	P CU	#2	0.9450	0.03051	0.0084	0.2580
				N CU	#2	0.9450	0.03051	0.0084	0.2580

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 2

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R Ω/MILE	REACT X Ω/MILE	GMP (FT)	DIAM D (IN)
25	9	24	25	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010
26	1	24	26	P CU	#2	0.9450	0.03051	0.0084	0.2580
				N CU	#2	0.9450	0.03051	0.0084	0.2580
27	9	26	27	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010
28	1	26	28	P CU	#2	0.9450	0.03051	0.0084	0.2580
				N CU	#2	0.9450	0.03051	0.0084	0.2580
29	9	28	29	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010
30	9	28	30	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 2 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

			FAULT CURRENT MAGNITUDES				
NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLC (AMPS)	LG (AMPS)
0	0	1	0 10.0	20385.62 239.98	17654.44 415.58	25874.54 17714.44	26494.93 239.99
1	1	1	0.0 10.0	8909.36 233.03	7715.72 408.67	8050.10 7772.26	6394.68 237.36
2	2	1	0.0 10.0	3983.83 233.91	3450.15 394.06	3457.93 3502.20	2446.99 231.52
3	3	1	0.0 10.0	3702.15 233.18	3206.16 391.56	3208.62 3257.40	2250.57 230.39
4	4	1	0.0 10.0	3237.91 232.16	2804.11 387.90	2808.42 2854.87	1978.97 228.90
5	5	1	0.0 10.0	3049.08 231.19	2640.58 334.68	2636.22 2690.19	1872.36 227.69
6	6	9	0.0 10.0				1606.38 223.38
7	7	1	0.0 10.0	2550.91 228.09	2209.16 374.51	2187.75 2255.44	1589.16 223.82

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 2 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
8	8	1	0.0 10.0	2152.89 224.16	1864.45 362.08	1826.66 1906.46	1373.08 219.20	
9	9	1	0.0 10.0	2537.47 226.42	2024.30 369.14	1998.04 2069.01	1466.39 221.74	
10	10	1	0.0 10.0	2775.17 229.73	2406.33 379.82	2396.34 2454.94	1729.22 225.83	
11	11	9	0.0 10.0				1503.84 220.99	
12	12	9	0.0 10.0				1116.53 209.76	
13	13	9	0.0 10.0				1309.26 215.93	
14	14	1	0.0 10.0	2532.84 226.11	2193.51 374.54	2177.48 2240.05	1592.32 223.87	
15	15	1	0.0 10.0	2510.92 227.95	2174.43 374.01	2157.76 2220.81	1579.44 223.67	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)

CIRCUIT NO. 2 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

FAULT CURRENT MAGNITUDES

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
16	16	9	0.0 10.0				1336.03 218.36
17	17	1	0.0 10.0	2395.75 227.05	2074.78 371.12	2054.97 2120.30	1512.00 222.55
18	18	9	0.0 10.0				1425.40 220.99
19	19	1	0.0 10.0	2110.95 224.48	1828.13 362.91	1802.41 1871.39	1343.95 219.34
20	20	1	0.0 10.0	1750.64 220.19	1516.10 349.64	1486.45 1556.13	1128.30 214.00
21	21	9	0.0 10.0				1237.27 215.74
22	22	9	0.0 10.0				1078.74 210.77
23	23	9	0.0 10.0				1007.62 208.14

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 2 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= +156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
24	24	1	0.0 10.0	1960.01 222.85	1697.41 357.82	1669.58 1739.37	1254.07 217.31	
25	25	9	0.0 10.0				1032.69 208.96	
26	26	1	0.0 10.0	1846.59 221.48	1599.19 353.56	1570.22 1640.13	1186.11 215.60	
27	27	9	0.0 10.0				1047.65 210.14	
28	28	1	0.0 10.0	1735.53 219.98	1503.06 348.99	1473.33 1542.94	1119.19 213.74	
29	29	9	0.0 10.0				994.47 208.35	
30	30	9	0.0 10.0				872.61 202.16	

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER		2
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)
205.49	176.13	161.45

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 4

LINE INFORMATION

SEC NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
1	1	0	1	P N	336MCM 4/0	0.3060 0.3030	0.02321 0.03886	0.0255 0.0158	0.7410 0.5220
2	1	1	2	P N	AL AL #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
3	9	1	3	P N	CU CU #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
4	1	1	4	P N	AL CU 336MCM 4/0	0.3060 0.3030	0.02321 0.03886	0.0255 0.0158	0.7410 0.5220
5	1	4	5	P N	AL CU 336MCM 4/0	0.3060 0.3030	0.02321 0.03886	0.0255 0.0158	0.7410 0.5220
6	5	5	6	P N	CU CU #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
7	1	5	7	P N	AL CU 336MCM 4/0	0.3060 0.3030	0.02321 0.03886	0.0255 0.0158	0.7410 0.5220
8	1	7	8	P N	AL AL #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 4

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R G/MILE	REACT X G/MILE	GMR (FT)	DIAM D (IN)
9	1	7	9	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
10	9	9	10	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010
11	1	9	11	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
12	1	7	12	P AL	336MCM	0.3060	0.02321	0.0255	0.7410
				N CU	4/0	0.3030	0.03886	0.0158	0.5220
13	1	12	13	P CU	#2	0.9450	0.03051	0.0084	0.2580
				N CU	#2	0.9450	0.03051	0.0084	0.2580
14	1	13	14	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 4 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

FAULT CURRENT MAGNITUDES

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
0	0	1	0 10.0	20385.62 239.98	17654.44 415.58	25874.54 17714.44	26494.93 239.99
1	1	1	0.0 10.0	10432.99 238.52	9035.23 410.42	9589.48 9092.62	7926.86 238.03
2	2	1	0.0 10.0	8364.45 236.89	7243.82 404.80	7494.36 7296.44	6243.71 236.16
3	3	9	0.0 10.0				5857.55 235.20
4	4	1	0.0 10.0	8651.74 237.93	7492.61 408.31	7796.91 7549.00	6153.11 237.22
5	5	1	0.0 10.0	4922.31 235.33	4262.34 399.08	4299.70 4316.13	3105.46 233.57
6	6	5	0.0 10.0		3913.69 394.47	3906.61 3964.29	2894.57 232.05
7	7	1	0.0 10.0	4676.52 235.01	4049.99 397.96	4078.03 4102.98	2929.42 233.11

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)

CIRCUIT NO. 4 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

FAULT CURRENT MAGNITUDES

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
8	8	1	0.0 10.0	3529.09 230.72	3056.28 383.74	3007.34 3102.15	2269.30 228.16
9	9	1	0.0 10.0	3387.09 230.04	2933.31 381.55	2878.92 2976.19	2209.12 227.39
10	10	9	0.0 10.0				1741.77 220.99
11	11	1	0.0 10.0	2543.25 224.90	2205.34 365.23	2135.78 2245.48	1722.92 221.46
12	12	1	0.0 10.0	3972.24 233.37	3440.15 393.98	3447.70 3492.19	2439.12 231.49
13	13	1	0.0 10.0	3546.01 232.35	3070.93 380.80	3059.35 3120.91	2195.42 229.57
14	14	1	0.0 10.0	3217.63 230.59	2786.59 583.04	2753.56 2833.99	2013.88 227.51

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER			
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)	
205.49	176.13	161.45	4

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 5

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATERIAL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIA D (IN)
1	11	0	1	P AL-UG N CU-CN	350MCM 21-#10	0.2950 5.5651	0.03032	0.0198 0.0033	0.6110 1.3600
2	1	1	2	P AL N AL	336MCM 336MCM	0.3060 0.3060	0.02321 0.02321	0.0255 0.0255	0.7410 0.7410
3	9	2	3	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
4	1	2	4	P CU N CU	#2 #2	0.9450 0.9450	0.03051 0.03051	0.0084 0.0034	0.2530 0.2530
5	9	4	5	P AL N AL	#4 #4	2.5700 2.5700	0.10540 0.10540	0.0044 0.0044	0.2500 0.2500
6	1	4	6	P CU N CU	#2 #2	0.9450 0.9450	0.03051 0.03051	0.0084 0.0084	0.2530 0.2530
7	9	6	7	P AL N AL	#2 #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
8	1	6	8	P CU N CU	#2 #2	0.9450 0.9450	0.03051 0.03051	0.0084 0.0034	0.2530 0.2530

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 5

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
9	1	8	9	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
10	9	9	10	P CU	#5	2.4100	0.04712	0.0057	0.2010
				N CU	#5	2.4100	0.04712	0.0057	0.2010
11	1	9	11	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040
12	9	11	12	P CU	#5	2.4100	0.04712	0.0057	0.2010
				N CU	#5	2.4100	0.04712	0.0057	0.2010
13	1	8	13	P CU	#2	0.9450	0.03051	0.0084	0.2580
				N CU	#2	0.9450	0.03051	0.0084	0.2580
14	1	13	14	P CU	#5	2.4100	0.04712	0.0057	0.2010
				N CU	#5	2.4100	0.04712	0.0057	0.2010
15	9	13	15	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010
16	9	15	16	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 5

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMP (FT)	DIAM D (IN)
17	9	15	17	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010
13	9	17	18	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 5 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

FAULT CURRENT MAGNITUDES									
NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)		
0	0	1	0 10.0	20385.62 239.96	17554.44 415.58	25374.54 17714.44	26494.93 239.99		
1	1	11	0.0 10.0	15661.52 230.64	13563.27 410.91	19686.33 13618.84	18682.49 238.59		
2	2	1	0.0 10.0	13983.18 258.42	12109.79 410.17	15509.48 12155.00	15027.97 238.30		
3	3	9	0.0 10.0				5567.02 232.38		
4	4	1	0.0 10.0	7736.93 235.53	6702.96 400.42	7156.70 6750.02	6456.54 234.85		
5	5	9	0.0 10.0				2617.46 223.65		
6	6	1	0.0 10.0	4642.61 231.76	4020.52 387.62	4119.03 4062.79	3608.32 230.20		
7	7	9	0.0 10.0				2770.37 226.49		

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)

CIRCUIT NO. 5 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

FAULT CURRENT MAGNITUDES

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
8	8	1	0.0 10.0	4301.11 231.02	3724.87 335.17	3300.60 3766.40	3320.19 229.30
9	9	1	0.0 10.0	2216.16 220.32	1919.25 351.74	1885.83 1950.29	1698.93 217.08
10	10	9	0.0 10.0				1411.74 211.88
11	11	1	0.0 10.0	1939.13 218.01	1722.69 344.86	1685.78 1752.41	1522.69 214.40
12	12	9	0.0 10.0				957.35 200.39
13	13	1	0.0 10.0	3155.93 227.43	2733.11 373.49	2752.44 2772.14	2382.62 224.92
14	14	1	0.0 10.0	2662.67 224.27	2305.94 363.67	2299.69 2341.17	2035.89 221.47
15	15	9	0.0 10.0				2078.82 221.96

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 5 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES			
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
16	16	9	0.0 10.0				1571.31 214.86
17	17	9	0.0 10.0				1628.18 215.89
18	18	9	0.0 10.0				1311.88 210.14

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER		5
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)
205.49	176.13	161.45

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 6

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MTRL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GPR (FT)	DIAM D (IN)
1	11	0	1	P AL-UG N CU-CN	350MCM 21-#10	0.2950 5.5651	0.03032	0.0193 0.0033	0.6110 1.3600
2	1	1	2	P AL N AL	336MCM 356MCM	0.3060 0.3060	0.02321 0.02321	0.0255 0.0255	0.7410 0.7410
3	1	2	3	P CU N CU	#4 #4	1.5030 1.5030	0.03015 0.03015	0.0066 0.0066	0.2040 0.2040
4	9	3	4	P CU N CU	#4 #4	1.5030 1.5030	0.03015 0.03015	0.0066 0.0066	0.2040 0.2040
5	9	4	5	P CU N CU	#4 #4	1.5030 1.5030	0.03015 0.03015	0.0066 0.0066	0.2040 0.2040
6	9	4	6	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
7	1	3	7	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
8	5	7	3	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 6

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MTRL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
9	9	8	9	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
10	5	8	10	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
11	9	10	11	P AL N AL	#2 #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
12	9	10	12	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
13	1	2	13	P AL N AL	336MCM 336MCM	0.3060 0.3060	0.02321 0.02321	0.0255 0.0255	0.7410 0.7410
14	1	13	14	P AL N AL	#4 #4	2.5700 2.5700	0.10540 0.10540	0.0044 0.0044	0.2500 0.2500
15	1	14	15	P AL N AL	#4 #4	2.5700 2.5700	0.10540 0.10540	0.0044 0.0044	0.2500 0.2500
16	1	14	16	P AL N AL	#4 #4	2.5700 2.5700	0.10540 0.10540	0.0044 0.0044	0.2500 0.2500

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 6

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
17	1	16	17	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
18	1	15	18	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
19	9	18	19	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
20	1	18	20	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
21	9	20	21	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
22	1	20	22	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
23	5	22	23	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
24	1	22	24	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 6

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
25	5	24	25	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
26	1	24	26	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
27	9	26	27	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 6 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
0	0	1	0 10.0	20385.62 239.98	17654.44 415.56	25874.54 17714.44	26494.93 239.99	
1	1	11	0.0 10.0	10219.36 236.13	8850.21 402.40	11610.70 8393.02	10795.39 235.92	
2	2	1	0.0 10.0	5098.36 233.57	4415.30 393.49	4625.08 4462.88	4100.74 232.45	
3	3	1	0.0 10.0	4840.05 232.98	4191.60 391.53	4365.27 4238.06	3866.70 231.76	
4	4	9	0.0 10.0				2709.16 226.85	
5	5	9	0.0 10.0				2287.97 223.95	
6	6	9	0.0 10.0				1312.95 209.25	
7	7	1	0.0 10.0	3180.03 226.63	2753.99 371.30	2769.64 2769.76	2530.80 224.77	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)

CIRCUIT NO. 6 4156.9/ 2400.0 VOLTS

SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

FAULT CURRENT MAGNITUDES

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
8	8	5	0.0 10.0		1336.27 324.46	1309.18 1360.34	1259.03 207.43
9	9	9	0.0 10.0				1125.90 203.72
10	10	5	0.0 10.0		1224.97 317.46	1197.54 1247.89	1156.21 204.50
11	11	9	0.0 10.0				1013.29 200.31
12	12	9	0.0 10.0				1025.14 200.39
13	13	1	0.0 10.0	4462.93 232.85	3865.00 390.95	4007.23 3912.90	3476.28 231.45
14	14	1	0.0 10.0	1992.36 217.85	1725.43 344.45	1704.53 1754.88	1605.92 215.14
15	15	1	0.0 10.0	1754.51 214.66	1519.45 335.25	1495.50 1546.81	1422.46 211.68

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 6 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
16	16	1	0.0 10.0	1004.10 195.53	869.57 287.79	846.74 839.42	831.03 192.47	
17	17	1	0.0 10.0	933.13 194.13	808.11 281.06	785.97 827.51	769.57 189.40	
18	18	1	0.0 10.0	953.12 195.43	838.42 234.31	816.02 857.84	802.11 190.96	
19	19	9	0.0 10.0				700.40 184.92	
20	20	1	0.0 10.0	463.52 100.75	401.42 208.00	388.35 413.40	390.12 154.04	
21	21	9	0.0 10.0				358.74 149.09	
22	22	1	0.0 10.0	424.15 157.12	375.99 200.99	353.62 387.38	365.75 150.24	
23	23	5	0.0 10.0		346.43 192.29	335.28 357.19	337.55 145.43	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 6 +156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
24	24	1	0.0 10.0	338.66 150.82	336.59 159.21	325.36 347.09	327.91 143.67	
25	25	5	0.0 10.0		328.90 136.77	318.00 339.14	320.57 142.29	
26	26	1	0.0 10.0	360.99 146.53	312.62 181.43	302.11 322.41	304.84 139.20	
27	27	9	0.0 10.0				292.40 136.63	

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER			6
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)	
205.49	176.13	161.45	

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 7

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
1	1	0	1	P N	AL CU	0.3060 0.3030	0.02321 0.03886	0.0255 0.0158	0.7410 0.5220
2	1	1	2	P N	AL CU	0.3060 0.3030	0.02321 0.03886	0.0255 0.0153	0.7410 0.5220
3	1	2	3	P N	AL AL	0.3060 0.6950	0.02321 0.15717	0.0255 0.0051	0.7410 0.4470
4	1	3	4	P N	AL AL	0.3060 0.3060	0.02321 0.02321	0.0255 0.0255	0.7410 0.7410
5	1	4	5	P N	AL AL	0.3060 0.3060	0.02321 0.02321	0.0255 0.0255	0.7410 0.7410
6	1	4	6	P N	CU CU	0.4310 0.9450	0.03889 0.03051	0.0125 0.0084	0.4140 0.2580
7	1	6	7	P N	AL AL	0.3060 0.3050	0.02321 0.15717	0.0255 0.0051	0.7410 0.4470
8	1	7	8	P N	CU CU	1.5030 1.5030	0.03015 0.03015	0.0066 0.0066	0.2040 0.2040

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 7

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MTRL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
9	1	8	9	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
10	1	7	10	P AL	336MCM	0.3060	0.02321	0.0255	0.7410
				N AL	2/0	0.6950	0.15717	0.0051	0.4470
11	1	2	11	P AL	336MCM	0.3060	0.02321	0.0255	0.7410
				N AL	2/0	0.6950	0.15717	0.0051	0.4470
12	1	11	12	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040
13	1	12	13	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040
14	9	12	14	P CU	#2	0.9450	0.03051	0.0084	0.2580
				N CU	#2	0.9450	0.03051	0.0084	0.2580
15	9	12	15	P CU	#2	0.9450	0.03051	0.0084	0.2580
				N CU	#2	0.9450	0.03051	0.0084	0.2580
16	1	11	16	P AL	336MCM	0.3060	0.02321	0.0255	0.7410
				N AL	2/0	0.6950	0.15717	0.0051	0.4470

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/29/77 CONT
CIRCUIT NO. 7

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R Ω/MILE	REACT X Ω/MILE	GMR (FT)	DIAM D (IN)
17	1	16	17	P CU	#2	0.9450	0.03051	0.0084	0.2580
				N CU	#2	0.9450	0.03051	0.0084	0.2530
18	1	17	18	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040
19	1	18	19	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
20	1	19	20	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
21	1	19	21	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
22	9	21	22	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
23	1	21	23	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
24	1	23	24	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 7

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
25	9	24	25	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040
26	1	24	26	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040
27	11	26	27	P AL-UG	1/0	0.9730	0.03030	0.0118	0.3620
				N CU-CN	10-#12	8.6490		0.0026	1.0200
28	5	27	28	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040
29	9	28	29	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040
30	1	16	30	P CU	#2	0.9450	0.03051	0.0084	0.2580
				N CU	#2	0.9450	0.03051	0.0084	0.2580
31	1	30	31	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010
32	9	31	32	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 7

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
33	1	30	33	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040
34	1	33	34	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010
35	9	34	35	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010
36	9	34	36	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010
37	1	33	37	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 7 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
0	0	1	0	14448.26	12512.55	15527.06	16181.84	
			10.0	719.11	1240.93	12692.47	719.29	
1	1	1	0.0	11397.33	9870.37	11357.93	10830.43	
			10.0	714.09	1222.14	10047.74	712.51	
2	2	1	0.0	6618.80	5732.04	6118.79	5120.04	
			10.0	697.44	1160.32	5898.27	699.31	
3	3	1	0.0	6546.66	5669.57	6045.44	5037.85	
			10.0	696.98	1153.63	5835.44	688.52	
4	4	1	0.0	6502.15	5631.03	5999.63	4986.68	
			10.0	696.58	1157.26	5796.58	697.90	
5	5	1	0.0	6306.09	5461.23	5798.84	4765.72	
			10.0	694.79	1151.03	5625.32	685.09	
6	6	1	0.0	4863.00	4211.48	4389.17	3433.58	
			10.0	679.03	1096.95	4364.30	661.73	
7	7	1	0.0	4651.23	4028.08	4191.53	3250.42	
			10.0	675.65	1036.57	4179.47	657.76	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 7 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
8	8	1	0.0 10.0	3549.10 642.03	3073.60 986.66	3110.86 3198.89	2470.09 617.77	
9	9	1	0.0 10.0	2979.47 618.85	2580.30 923.38	2582.95 2690.71	2099.51 591.76	
10	10	1	0.0 10.0	4007.42 667.82	3470.52 1058.03	3595.13 3616.73	2716.08 642.91	
11	11	1	0.0 10.0	4804.23 682.55	4160.59 1106.41	4364.95 4316.84	3380.65 664.31	
12	12	1	0.0 10.0	4569.19 676.72	3974.35 1088.24	4146.57 4126.27	3222.66 657.58	
13	13	1	0.0 10.0	3794.52 652.71	3286.15 1016.32	3365.58 3420.34	2663.77 629.94	
14	14	9	0.0 10.0				2566.48 629.46	
15	15	9	0.0 10.0				2583.48 630.33	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 7 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES			
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
16	16	1	0.0 10.0	3854.40 669.17	3338.00 1059.59	3473.81 3466.13	2591.23 641.83
17	17	1	0.0 10.0	3548.98 658.81	3073.51 1028.19	3174.92 3214.81	2374.62 629.10
18	18	1	0.0 10.0	3013.37 633.36	2609.66 956.80	2650.49 2733.83	2022.42 600.24
19	19	1	0.0 10.0	2718.63 617.03	2354.40 913.54	2370.07 2468.26	1836.80 582.16
20	20	1	0.0 10.0	2347.34 593.36	2032.86 853.88	2024.84 2133.03	1604.03 556.14
21	21	1	0.0 10.0	2630.50 611.77	2278.08 899.93	2287.35 2388.76	1781.54 576.35
22	22	9	0.0 10.0				1763.75 574.45
23	23	1	0.0 10.0	2177.56 580.99	1885.32 824.05	1869.68 1979.46	1497.23 542.65

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 7 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

		FAULT CURRENT MAGNITUDES					
NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
24	24	1	0.0 10.0	2090.45 574.39	1810.39 808.39	1791.77 1900.88	1442.65 535.41
25	25	9	0.0 10.0				1274.44 510.92
26	26	1	0.0 10.0	2026.39 569.46	1756.64 796.87	1736.46 1644.86	1403.59 530.02
27	27	11	0.0 10.0	1839.19 552.83	1592.78 759.09	1572.52 1674.95	1308.99 513.76
28	28	5	0.0 10.0		1434.72 720.30	1418.38 1510.23	1189.43 494.61
29	29	9	0.0 10.0				1044.29 468.58
30	30	1	0.0 10.0	3820.29 666.11	3308.46 1050.32	3440.71 3455.91	2567.96 640.54
31	31	1	0.0 10.0	2919.59 622.06	2523.44 929.31	2545.09 2643.63	2015.74 591.92

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 7 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES			
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
32	32	9	0.0 10.0				1609.70 547.38
33	33	1	0.0 10.0	3363.79 649.12	2913.13 1000.95	2990.19 3047.75	2268.89 619.00
34	34	1	0.0 10.0	3010.32 629.91	2607.44 948.86	2642.23 2723.82	2055.82 598.81
35	35	9	0.0 10.0				1359.02 514.88
36	36	9	0.0 10.0				1691.82 559.43
37	37	1	0.0 10.0	2968.25 630.45	2570.57 949.19	2611.40 2693.17	2016.09 597.98

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER			7
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)	
436.91	374.50	343.29	

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 8

LINE INFORMATION

SEC NO.	CIRC TYPE	START NODE	END NODE	COND MATERIAL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
1	1	0	1	P AL	336MCM	0.3060	0.02321	0.0255	0.7410
				N CU	4/0	0.3030	0.03886	0.0158	0.5220
2	1	1	2	P AL	336MCM	0.3060	0.02321	0.0255	0.7410
				N CU	4/0	0.3030	0.03886	0.0158	0.5220
3	1	2	3	P CU	1/0	0.6070	0.03888	0.0111	0.3680
				N CU	#2	0.9450	0.03051	0.0084	0.2580
4	1	3	4	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
5	9	4	5	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
6	1	4	6	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
7	1	6	7	P CU	1/0	0.6070	0.03888	0.0111	0.3680
				N CU	#2	0.9450	0.03051	0.0084	0.2530
8	1	7	8	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 8

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
9	11	8	9	P AL-UG N CU-CN	1/0 10-#12	0.9730 8.3490	0.03030	0.0118 0.0026	0.3620 1.0200
10	1	7	10	P AL N AL	2/0 #2	0.8950 1.6500	0.15717 0.11993	0.0051 0.0050	0.4470 0.3250
11	5	10	11	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
12	9	11	12	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
13	1	10	13	P AL N AL	2/0 #2	0.8950 1.6500	0.15717 0.11993	0.0051 0.0050	0.4470 0.3250
14	1	13	14	P AL N AL	2/0 #2	0.8950 1.6500	0.15717 0.11993	0.0051 0.0050	0.4470 0.3250
15	12	14	15	P AL-UG N CU-CN	1/0 10-#12	0.9730 8.3490	0.03030	0.0118 0.0026	0.3620 1.0200
16	5	13	16	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 8

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
17	12	16	17	P AL-UG N CU-CN	1/0 10-#12	0.9730 8.8490	0.03030	0.0113 0.0026	0.3620 1.0200
18	1	7	18	P CU N CU	1/0 #2	0.6070 0.9450	0.03888 0.03051	0.0111 0.0084	0.3680 0.2580
19	1	13	19	P CU N CU	#2 #2	0.9450 0.9450	0.03051 0.03051	0.0084 0.0084	0.2580 0.2580
20	1	19	20	P CU N CU	#5 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
21	1	20	21	P AL N AL	#2 #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
22	5	21	22	P AL N CU	#2 #2	1.6500 0.9450	0.11993 0.03051	0.0050 0.0084	0.3250 0.2580
23	9	22	23	P AL N AL	#2 #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
24	5	20	24	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 8

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
25	9	24	25	P CU	#6	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 8 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES			
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
0	0	1	0 10.0	14448.26 719.11	12512.55 1240.93	15527.06 12692.47	16181.84 719.29
1	1	1	0.0 10.0	11380.57 713.33	9855.87 1219.60	11070.00 10032.52	10244.56 711.35
2	2	1	0.0 10.0	10599.81 711.62	9179.70 1213.22	10194.02 9355.20	9241.54 709.00
3	3	1	0.0 10.0	8963.59 704.38	7762.70 1187.65	8407.10 7932.00	7225.07 699.11
4	4	1	0.0 10.0	7731.25 690.29	6695.46 1141.65	7050.23 6849.04	6039.02 683.67
5	5	9	0.0 10.0				3931.40 641.32
6	6	1	0.0 10.0	4868.39 648.78	4216.15 1015.89	4231.93 4325.76	3827.75 638.37
7	7	1	0.0 10.0	4512.84 643.96	3908.23 1001.31	3914.20 4016.97	3494.37 631.75

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)

CIRCUIT NO. 8 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

		FAULT CURRENT MAGNITUDES					
NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
8	8	1	0.0 10.0	4173.40 636.70	3614.27 900.67	3607.80 3718.38	3231.08 623.43
9	9	11	0.0 10.0	4010.06 632.49	3472.81 969.02	3471.92 3574.14	3128.46 618.90
10	10	1	0.0 10.0	4180.69 636.15	3620.58 984.29	3616.81 3727.14	3203.45 624.26
11	11	5	0.0 10.0		3414.77 967.03	3402.45 3516.99	3035.75 617.53
12	12	9	0.0 10.0				1993.32 558.75
13	13	1	0.0 10.0	3623.02 626.26	3137.62 950.18	3121.73 3239.91	2728.47 608.93
14	14	1	0.0 10.0	3093.63 611.47	2679.16 909.22	2658.16 2776.36	2292.51 589.94
15	15	12	0.0 10.0				2112.17 575.63

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 8 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
16	16	5	0.0 10.0		2796.25 913.67	2769.05 2890.07	2459.10 594.15	
17	17	12	0.0 10.0				1890.07 550.78	
18	18	1	0.0 10.0	4247.57 639.72	3678.50 958.71	3672.77 3786.01	3242.27 625.88	
19	19	1	0.0 10.0	3929.42 630.70	3316.37 962.95	3296.27 3419.58	2893.00 614.67	
20	20	1	0.0 10.0	3054.90 603.88	2645.69 892.09	2602.46 2732.31	2350.33 585.69	
21	21	1	0.0 10.0	2715.74 589.84	2351.90 856.35	2306.98 2432.65	2093.20 569.80	
22	22	5	0.0 10.0		1853.34 780.79	1813.79 1923.33	1667.43 535.25	
23	23	9	0.0 10.0				1438.25 511.18	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/29/77 (CONT.)
 CIRCUIT NO. 8 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

FAULT CURRENT MAGNITUDES						
NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)
24	24	5	0.0 10.0	1857.38 777.23	1814.39 1923.70	1697.48 535.01
25	25	9	0.0 10.0			1522.72 516.69

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER		8
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)
436.91	374.50	343.29

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 11

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
1	1	0	1	P AL	336MCM	0.3060	0.02321	0.0255	0.7410
				N AL	336MCM	0.3060	0.02321	0.0255	0.7410
2	9	1	2	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
3	1	1	3	P AL	336MCM	0.3060	0.02321	0.0255	0.7410
				N AL	336MCM	0.3060	0.02321	0.0255	0.7410
4	9	3	4	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
5	1	3	5	P AL	336MCM	0.3060	0.02321	0.0255	0.7410
				N AL	336MCM	0.3060	0.02321	0.0255	0.7410
6	9	5	6	P CU	#5	2.4100	0.04712	0.0057	0.2010
				N CU	#6	2.4100	0.04712	0.0057	0.2010
7	1	5	7	P AL	336MCM	0.3060	0.02321	0.0255	0.7410
				N AL	4/0	0.5920	0.12843	0.0081	0.5630
8	5	7	3	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 11

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
9	9	8	9	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
10	1	7	10	P AL	336MCM	0.3060	0.02321	0.0255	0.7410
				N AL	4/0	0.5920	0.12843	0.0081	0.5630
11	1	10	11	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
12	1	10	12	P AL	336MCM	0.3060	0.02321	0.0255	0.7410
				N AL	4/0	0.5920	0.12843	0.0081	0.5630
13	1	12	13	P CU	2/0	0.4810	0.03889	0.0125	0.4140
				N CU	2/0	0.4310	0.03889	0.0125	0.4140
14	1	13	14	P CU	2/0	0.4810	0.03889	0.0125	0.4140
				N CU	2/0	0.4310	0.03889	0.0125	0.4140
15	1	14	15	P CU	2/0	0.4810	0.03889	0.0125	0.4140
				N CU	2/0	0.4310	0.03889	0.0125	0.4140
16	1	15	16	P CU	2/0	0.4810	0.03889	0.0125	0.4140
				N CU	2/0	0.4310	0.03889	0.0125	0.4140

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 11

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
17	9	15	17	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
18	9	17	18	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
19	9	17	19	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
20	9	19	20	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
21	9	19	21	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
22	9	14	22	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
23	9	22	23	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
24	9	23	24	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 11

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
25	1	13	25	P AL	2/0	0.8950	0.15717	0.0051	0.4470
				N AL	#2	1.6500	0.11993	0.0050	0.3250
26	1	25	26	P AL	2/0	0.8950	0.15717	0.0051	0.4470
				N AL	#2	1.6500	0.11993	0.0050	0.3250
27	1	26	27	P AL	2/0	0.8950	0.15717	0.0051	0.4470
				N AL	#2	1.6500	0.11993	0.0050	0.3250
28	9	27	28	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
29	1	27	29	P AL	2/0	0.8950	0.15717	0.0051	0.4470
				N AL	#2	1.6500	0.11993	0.0050	0.3250
30	11	29	30	P AL-UG	2/0	0.7710	0.03038	0.0132	0.4060
				N CU-CN	13-#12	8.8499		0.0026	1.0600
31	1	26	31	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N CU	#6	2.4100	0.04712	0.0057	0.2010
32	9	31	32	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 11

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R G/MILE	REACT X G/MILE	GMR (FT)	DIA ^M D (IN)
33	1	31	33	P AL N CU	#2 #5	1.6500 2.4100	0.11993 0.04712	0.0050 0.0057	0.3250 0.2010
34	12	33	34	P AL-UG N CU-CN	1/0 10-#12	0.9730 8.8490	0.03030	0.0118 0.0026	0.3620 1.0200
35	12	34	35	P AL-UG N CU-CN	1/0 10-#12	0.9730 8.8490	0.03030	0.0118 0.0026	0.3620 1.0200
36	12	34	36	P AL-UG N CU-CN	1/0 10-#12	0.9730 8.8490	0.03030	0.0118 0.0026	0.3620 1.0200
37	12	36	37	P AL-UG N CU-CN	1/0 10-#12	0.9730 8.8490	0.03030	0.0118 0.0026	0.3620 1.0200
38	12	36	38	P AL-UG N CU-CN	1/0 10-#12	0.9730 8.8490	0.03030	0.0118 0.0026	0.3620 1.0200
39	12	38	39	P AL-UG N CU-CN	1/0 10-#12	0.9730 8.8490	0.03030	0.0118 0.0026	0.3620 1.0200
40	9	33	40	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 11

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
41	1	12	41	P AL	336MCM 4/0	0.3960 0.5920	0.02321 0.12843	0.0255 0.0081	0.7410 0.5630
42	9	41	42	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
43	1	41	43	P AL	336MCM 4/0	0.3960 0.5920	0.02321 0.12843	0.0255 0.0081	0.7410 0.5630
44	9	43	44	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
45	1	43	45	P AL	#2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 11 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.3 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
0	0	1	0 10.0	14448.25 719.11	12512.55 1240.93	15527.06 12692.47	16181.84 719.29	
1	1	1	0.0 10.0	11649.85 714.60	10089.07 1224.04	11708.57 10266.75	11253.11 713.15	
2	2	9	0.0 10.0				9305.64 702.83	
3	3	1	0.0 10.0	10757.99 712.70	9316.69 1216.94	10625.76 9493.14	9958.35 710.55	
4	4	9	0.0 10.0				9516.28 707.12	
5	5	1	0.0 10.0	9899.49 710.56	8573.22 1208.96	9630.69 8748.22	8813.01 707.59	
6	6	9	0.0 10.0				7536.37 695.19	
7	7	1	0.0 10.0	9485.50 709.40	8214.68 1204.62	9155.30 8338.84	8263.30 705.82	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 11 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
8	8	5	0.0 10.0		7799.92 1190.90	8627.24 7970.68	7724.58 701.17	
9	9	9	0.0 10.0				6375.92 687.53	
10	10	1	0.0 10.0	8296.87 705.43	7135.29 1139.85	7874.71 7356.56	6812.61 699.72	
11	11	1	0.0 10.0	7479.04 696.35	6477.03 1159.53	6976.89 6640.17	5990.78 689.26	
12	12	1	0.0 10.0	7728.19 703.37	6744.77 1182.20	7340.60 6914.55	6242.63 696.53	
13	13	1	0.0 10.0	7271.13 700.34	6297.03 1171.35	6807.35 6464.63	5730.94 692.49	
14	14	1	0.0 10.0	6564.08 695.49	5684.65 1154.14	6090.91 5848.85	5061.47 686.01	
15	15	1	0.0 10.0	6330.32 693.66	5482.21 1147.73	5857.19 5645.16	4847.31 683.56	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 11 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES			
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
16	16	1	0.0 10.0	6008.00 590.93	5203.08 1138.17	5537.33 5354.19	4557.48 679.90
17	17	9	0.0 10.0				4261.58 670.01
18	18	9	0.0 10.0				4040.99 664.23
19	19	9	0.0 10.0				4098.82 665.79
20	20	9	0.0 10.0				3847.08 658.78
21	21	9	0.0 10.0				3375.01 643.66
22	22	9	0.0 10.0				4512.60 674.34
23	23	9	0.0 10.0				4219.77 667.31

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 11 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
24	24	9	0.0 10.0				3552.48 648.32	
25	25	1	0.0 10.0	6879.22 696.73	5957.57 1159.01	6399.28 6122.28	5343.48 687.85	
26	26	1	0.0 10.0	5905.71 686.24	5114.48 1123.84	5410.19 5270.80	4441.21 674.34	
27	27	1	0.0 10.0	5582.53 682.13	4334.61 1110.33	5089.08 4987.73	4158.02 669.05	
28	28	9	0.0 10.0				3275.44 637.25	
29	29	1	0.0 10.0	5372.60 679.26	4652.98 1100.96	4882.53 4803.91	3978.07 665.34	
30	30	11	0.0 10.0	4274.38 654.12	3701.72 1025.13	3880.65 3833.35	3313.39 638.16	
31	31	1	0.0 10.0	5410.44 677.35	4685.57 1095.77	4900.88 4834.11	4032.34 664.11	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 11 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES			
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
32	32	9	0.0 10.0				3563.88 650.16
33	33	1	0.0 10.0	4873.11 666.63	4220.23 1062.85	4363.95 4359.63	3608.61 651.79
34	34	12	0.0 10.0				3540.93 649.03
35	35	12	0.0 10.0				3271.28 637.48
36	36	12	0.0 10.0				3365.22 641.61
37	37	12	0.0 10.0				3132.63 631.14
38	33	12	0.0 10.0				3255.11 636.76
39	39	12	0.0 10.0				3050.92 527.26

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 11 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.6 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
40	40	9	0.0 10.0				2780.39 615.89	
41	41	1	0.0 10.0	7231.74 700.79	6262.87 1172.64	6767.24 6430.82	5650.33 692.52	
42	42	9	0.0 10.0				4475.33 666.44	
43	43	1	0.0 10.0	6486.84 696.64	5617.77 1157.37	6015.78 5782.88	4904.09 686.06	
44	44	9	0.0 10.0				4494.96 675.13	
45	45	1	0.0 10.0	5570.92 680.83	4824.55 1106.69	5061.79 4976.30	4145.13 667.98	

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER 11		
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)
436.91	374.50	343.29

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 12

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
1	11	0	1	P AL-UG N CU-CN	350MCM 21-#10	0.2950 5.5651	0.03032	0.0193 0.0033	0.6110 1.3600
2	9	1	2	P AL N AL	#2 #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
3	1	1	3	P AL N AL	336MCM 336MCM	0.3060 0.3060	0.02321 0.02321	0.0255 0.0255	0.7410 0.7410
4	1	3	4	P AL N AL	336MCM 336MCM	0.3060 0.3060	0.02321 0.02321	0.0255 0.0255	0.7410 0.7410
5	1	4	5	P CU N CU	2/0 2/0	0.4810 0.4810	0.03889 0.03889	0.0125 0.0125	0.4140 0.4140
6	1	5	6	P AL N AL	336MCM 2/0	0.3060 0.8950	0.02321 0.15717	0.0255 0.0051	0.7410 0.4470
7	1	6	7	P AL N AL	#4 #4	2.5700 2.5700	0.10540 0.10540	0.0044 0.0044	0.2500 0.2500
8	1	7	8	P AL N AL	#4 #4	2.5700 2.5700	0.10540 0.10540	0.0044 0.0044	0.2500 0.2500

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 12

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MTRL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
9	9	8	9	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
10	1	8	10	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
11	9	10	11	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
12	1	10	12	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
13	1	12	13	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
14	1	12	14	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
15	1	14	15	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
16	9	15	16	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 12

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
17	5	14	17	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
18	9	14	18	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
19	9	18	19	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
20	9	18	20	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
21	9	20	21	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
22	9	20	22	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
23	1	6	23	P AL	336MCM	0.3060	0.02321	0.0255	0.7410
				N AL	2/0	0.8950	0.15717	0.0051	0.4470
24	1	23	24	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 12

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
25	1	24	25	P AL N AL	#2 #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
26	1	24	26	P AL N AL	#2 #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
27	1	26	27	P AL N AL	#2 #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
28	9	26	28	P AL N AL	#2 #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
29	1	26	29	P AL N AL	#2 #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
30	1	23	30	P AL N AL	336MCM 2/O	0.3060 0.8950	0.02321 0.15717	0.0255 0.0051	0.7410 0.4470
31	1	30	31	P CU N CU	#6 #6	2.4100 2.4100	0.04712 0.04712	0.0057 0.0057	0.2010 0.2010
32	1	30	32	P AL N AL	336MCM 2/O	0.3060 0.8950	0.02321 0.15717	0.0255 0.0051	0.7410 0.4470

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 12

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
33	1	32	33	P AL	2/0	0.8950	0.15717	0.0051	0.4470
				N AL	#2	1.6500	0.11993	0.0050	0.3250
34	5	33	34	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500
35	1	33	35	P AL	2/0	0.8950	0.15717	0.0051	0.4470
				N AL	#2	1.6500	0.11993	0.0050	0.3250
36	9	35	36	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
37	1	35	37	P AL	2/0	0.8950	0.15717	0.0051	0.4470
				N AL	#2	1.6500	0.11993	0.0050	0.3250
38	11	37	38	P AL-UG	2/0	0.7710	0.03038	0.0132	0.4360
				N CU-CN	13-#12	8.8490		0.0026	1.0600
39	1	38	39	P AL	2/0	0.8950	0.15717	0.0051	0.4470
				N AL	#2	1.6500	0.11993	0.0050	0.3250
40	1	39	40	P AL	2/0	0.8950	0.15717	0.0051	0.4470
				N AL	#2	1.6500	0.11993	0.0050	0.3250

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 12

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATERIAL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
41	12	39	41	P AL-UG N CU-CN	2/O 13-#12	0.7710 8.8490	0.03038	0.0132 0.0026	0.4060 1.0600
42	1	32	42	P AL N AL	336MCM 2/O	0.3060 0.8950	0.02321 0.15717	0.0255 0.0051	0.7410 0.4470
43	1	42	43	P AL N AL	#2 #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
44	1	43	44	P AL N AL	#2 #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
45	1	43	45	P AL N AL	#2 #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
46	1	42	46	P AL N AL	336MCM 2/O	0.3060 0.8950	0.02321 0.15717	0.0255 0.0051	0.7410 0.4470
47	1	46	47	P AL N AL	#2 #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250
48	1	47	48	P AL N AL	#2 #2	1.6500 1.6500	0.11993 0.11993	0.0050 0.0050	0.3250 0.3250

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 12

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R C/MILE	REACT X C/MILE	GMR (FT)	DIAM D (IN)
49	1	47	49	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
50	1	46	50	P AL	336MCM	0.3060	0.02321	0.0255	0.7410
				N AL	2/0	0.8950	0.15717	0.0051	0.4470
51	9	50	51	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
52	1	50	52	P AL	336MCM	0.3060	0.02321	0.0255	0.7410
				N AL	2/0	0.8950	0.15717	0.0051	0.4470
53	1	52	53	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040
54	1	52	54	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#4	1.5030	0.03015	0.0066	0.2040
55	1	53	55	P CU	#4	1.5030	0.03015	0.0066	0.2040
				N CU	#2	0.9450	0.03051	0.0084	0.2530
56	1	55	56	P AL	#4	2.5700	0.10540	0.0044	0.2500
				N AL	#4	2.5700	0.10540	0.0044	0.2500

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 12

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAH D (IN)
57	5	55	57	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250
58	9	57	58	P AL	#2	1.6500	0.11993	0.0050	0.3250
				N AL	#2	1.6500	0.11993	0.0050	0.3250

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 12 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
0	0	1	0 10.0	14448.26 719.11	12512.55 1240.93	15527.06 12692.47	16181.84 719.29	
1	1	11	0.0 10.0	12872.73 711.26	11148.12 1213.74	14197.76 11322.84	14184.96 710.81	
2	2	9	0.0 10.0				12014.84 704.31	
3	3	1	0.0 10.0	8376.78 700.73	7254.51 1175.09	8039.29 7421.43	7287.15 696.36	
4	4	1	0.0 10.0	7055.38 695.13	6119.23 1154.69	6627.99 6282.57	5799.06 688.52	
5	5	1	0.0 10.0	5567.14 683.18	4921.28 1113.27	5114.91 4976.68	4328.50 672.54	
6	6	1	0.0 10.0	5187.44 679.83	4492.45 1101.60	4742.10 4645.89	3935.99 667.03	
7	7	1	0.0 10.0	4811.39 669.86	4166.78 1071.17	4350.46 4311.63	3643.31 656.17	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 12 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

			FAULT CURRENT MAGNITUDES				
NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
8	8	1	0.0	4280.21	3706.77	3817.29	3246.97
			10.0	654.84	1027.03	3938.86	639.93
9	9	9	0.0				3026.71
			10.0				629.90
10	10	1	0.0	3365.86	2914.92	2941.15	2585.32
			10.0	623.96	941.48	3023.55	606.69
11	11	9	0.0				2305.64
			10.0				591.00
12	12	1	0.0	3004.08	2601.61	2606.22	2324.74
			10.0	608.80	901.82	2700.43	590.44
13	13	1	0.0	2644.49	2290.20	2278.96	2064.18
			10.0	591.13	857.45	2378.94	571.59
14	14	1	0.0	2393.68	2072.99	2053.75	1830.89
			10.0	576.78	322.74	2154.47	556.32
15	15	1	0.0	2192.84	1899.05	1876.47	1722.17
			10.0	564.65	793.90	1975.88	542.67

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 12 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES			
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
16	16	9	0.0 10.0				1410.58 509.32
17	17	5	0.0 10.0		1838.39 783.53	1817.98 1914.07	1670.42 537.33
18	18	9	0.0 10.0				1590.01 527.63
19	19	9	0.0 10.0				1255.72 484.98
20	20	9	0.0 10.0				1208.74 477.87
21	21	9	0.0 10.0				1162.88 470.60
22	22	9	0.0 10.0				1138.03 466.51
23	23	1	0.0 10.0	4359.39 670.65	3775.34 1069.46	3947.05 3923.51	3142.62 651.60

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 12 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES			
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
24	24	1	0.0 10.0	4203.04 665.91	3639.94 1055.19	3790.01 3784.59	3026.86 646.22
25	25	1	0.0 10.0	3800.74 652.87	3291.53 1016.82	3393.28 3426.67	2735.62 631.44
26	26	1	0.0 10.0	4047.75 661.04	3505.45 1040.59	3635.67 3646.50	2913.44 640.65
27	27	1	0.0 10.0	3882.54 655.64	3362.37 1024.85	3473.14 3499.49	2794.19 634.57
28	28	9	0.0 10.0				2789.68 634.36
29	29	1	0.0 10.0	3918.39 656.83	3393.42 1028.33	3508.27 3531.41	2819.96 635.92
30	30	1	0.0 10.0	4028.03 665.83	3438.37 1053.14	3634.70 3633.91	2846.98 643.63
31	31	1	0.0 10.0	3006.01 620.36	2603.28 927.26	2625.91 2715.94	2168.64 595.01

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 12 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VSASE= 12470.6 VOLTS ZBASE= 15.55 OHMS

		FAULT CURRENT MAGNITUDES				
NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)
32	32	1	0.0 10.0	3639.29 659.13	3151.72 1030.55	3271.80 3293.65
33	33	1	0.0 10.0	3219.11 645.25	2787.83 983.91	2872.03 2921.30
34	34	5	0.0 10.0		2633.07 961.39	2695.02 2759.77
35	35	1	0.0 10.0	2784.31 627.50	2411.29 938.21	2465.03 2534.77
36	36	9	0.0 10.0			1706.22 571.59
37	37	1	0.0 10.0	2646.20 620.93	2291.68 920.07	2337.11 2411.68
38	38	11	0.0 10.0	2356.51 600.62	2040.80 869.13	2077.01 2150.72
39	39	1	0.0 10.0	2157.78 588.58	1868.69 837.83	1894.82 1973.03
						1515.21 549.49

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 12 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

		FAULT CURRENT MAGNITUDES					
NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
40	40	1	0.0 10.0	2117.67 585.90	1833.95 831.10	1858.22 1937.11	1485.67 546.17
41	41	12	0.0 10.0				1431.16 535.55
42	42	1	0.0 10.0	3386.19 654.00	2932.53 1013.36	3037.40 3071.72	2306.14 623.81
43	43	1	0.0 10.0	3229.71 646.51	2797.01 992.14	2882.87 2931.29	2203.32 615.49
44	44	1	0.0 10.0	3139.79 642.06	2719.14 979.73	2794.96 2850.54	2144.76 610.55
45	45	1	0.0 10.0	2968.78 633.23	2571.03 955.54	2629.43 2696.83	2034.16 600.78
46	46	1	0.0 10.0	3176.17 649.07	2750.64 997.26	2843.90 2887.27	2137.64 615.64
47	47	1	0.0 10.0	2594.57 615.59	2246.96 907.12	2281.26 2363.05	1768.93 578.88

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 12 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

		FAULT CURRENT MAGNITUDES					
NODE	SEG ND.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
48	48	1	0.0 10.0	2379.66 601.17	2060.85 870.60	2079.46 2168.81	1633.97 563.20
49	49	1	0.0 10.0	2428.67 604.59	2103.28 879.13	2125.21 2213.13	1664.76 566.90
50	50	1	0.0 10.0	3066.69 646.24	2655.83 933.12	2743.39 2791.01	2051.39 610.96
51	51	9	0.0 10.0				1892.76 595.06
52	52	1	0.0 10.0	2871.95 640.68	2487.18 970.39	2565.16 2619.54	1900.53 601.82
53	53	1	0.0 10.0	2805.32 636.55	2429.47 959.17	2499.89 2559.35	1858.63 597.26
54	54	1	0.0 10.0	2753.46 633.61	2388.90 951.22	2454.22 2517.00	1829.28 594.01
55	55	1	0.0 10.0	2702.12 630.01	2340.11 941.57	2399.89 2466.13	1796.54 590.20

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 12 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES			
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
56	56	1	0.0 10.0	2577.94 620.33	2232.56 916.78	2276.35 2352.59	1724.27 580.39
57	57	5	0.0 10.0		2284.21 930.45	2338.00 2407.81	1758.07 585.68
58	58	9	0.0 10.0				1658.92 573.58

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER 12		
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)
436.91	374.50	343.29

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 110

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
1	13	0	7	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
2	13	7	8	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
3	13	7	15	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
4	13	15	16	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
5	13	15	57	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
6	13	57	17	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
7	13	17	18	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
8	13	57	19	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2530

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 110

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
9	13	19	20	P CU-UG N C&CSN	#6 #6	2.6190 2.1800	0.00573 0.00573	0.0053 0.0053	0.1620 0.1620
10	13	19	21	P CU-UG N C&CSN	#1 #2	0.8448 0.3640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2500
11	13	21	22	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
12	13	21	23	P CU-UG N C&CSN	1/0 1/0	0.6758 0.5550	0.00736 0.00736	0.0111 0.0111	0.3680 0.3680
13	13	23	24	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
14	13	23	25	P CU-UG N C&CSN	1/0 1/0	0.6758 0.5550	0.00736 0.00736	0.0111 0.0111	0.3680 0.3680
15	13	25	26	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
16	13	26	27	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 110

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIA ^M D (IN)
17	13	26	28	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
18	13	25	29	P CU-UG N C&CSN	1/0 1/0	0.6758 0.5550	0.00736 0.00736	0.0111 0.0111	0.3680 0.3680
19	13	29	30	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
20	13	29	31	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00573	0.0102 0.0084	0.3600 0.2580
21	13	31	32	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
22	13	31	33	P CU-UG N C&CSN	#8 #8	4.1500 3.4700	0.00574 0.00574	0.0042 0.0042	0.1285 0.1285
23	13	31	34	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00573	0.0102 0.0084	0.3600 0.2580

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 110 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

			FAULT CURRENT MAGNITUDES			
NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)
0	0	1	0 10.0	20305.62 239.98	17654.44 415.58	25874.54 17714.44
7	1	13	0.0 10.0	3492.01 224.79	3024.17 366.10	3322.77 3034.82
8	2	13	0.0 10.0	2600.01 221.72	2494.16 356.81	2722.70 2503.11
15	3	13	0.0 10.0	2055.72 214.81	1762.99 336.70	1907.59 1769.67
16	4	13	0.0 10.0	1875.21 212.86	1623.98 331.26	1754.25 1630.25
57	5	13	0.0 10.0	1809.07 212.80	1618.66 331.03	1748.39 1624.92
17	6	13	0.0 10.0	1809.77 212.01	1597.31 328.82	1691.88 1573.42
13	7	13	0.0 10.0	1690.70 210.36	1469.38 324.27	1594.31 1475.21
						1269.07 201.87

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 110 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
19	8	13	0.0 10.0	1248.27 201.37	1081.03 300.40	1160.20 1085.80	932.52 190.90	
20	9	13	0.0 10.0	1210.06 200.35	1047.94 297.78	1124.24 1052.62	903.90 189.67	
21	10	13	0.0 10.0	907.71 189.86	786.10 272.00	840.71 790.17	677.62 177.25	
22	11	13	0.0 10.0	857.09 187.54	742.26 266.55	793.42 746.24	639.73 174.55	
23	12	13	0.0 10.0	900.52 189.54	779.88 271.25	833.99 783.93	672.25 176.58	
24	13	13	0.0 10.0	836.49 183.91	767.72 269.76	820.88 771.75	661.75 176.14	
25	14	13	0.0 10.0	849.41 187.17	735.61 265.68	736.24 739.57	634.04 174.11	
26	15	13	0.0 10.0	801.52 184.74	694.13 250.07	741.55 698.02	598.24 171.30	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 110 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
27	16	13	0.0 10.0	795.91 184.44	889.28 259.38	736.31 693.15	594.05 170.95	
28	17	13	0.0 10.0	756.71 182.25	655.33 254.42	699.77 659.14	564.76 168.44	
29	18	13	0.0 10.0	796.58 184.47	689.86 259.46	736.94 693.73	594.55 170.99	
30	19	13	0.0 10.0	765.57 163.83	680.32 258.10	726.68 684.19	586.32 170.31	
31	20	13	0.0 10.0	707.38 179.24	612.61 247.71	653.82 616.34	527.90 165.00	
32	21	13	0.0 10.0	705.62 179.12	611.09 247.46	652.18 614.81	526.59 164.37	
33	22	13	0.0 10.0	673.84 177.00	583.56 242.82	622.60 587.24	502.84 162.47	
34	23	13	0.0 10.0	624.94 173.44	541.22 235.16	577.14 544.83	466.32 158.46	

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER 110			
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)	
205.49	176.13	161.45	

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 140

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
1	13	0	1	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
2	13	1	2	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
3	13	1	4	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 140 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEC NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
0	0	1	0 10.0	20385.62 239.93	17654.44 415.58	25874.54 17714.44	26494.93 239.99	
1	1	13	0.0 10.0	3025.70 222.55	2620.33 359.31	2354.83 2629.68	2275.78 217.13	
2	2	13	0.0 10.0	2455.49 218.73	2125.51 343.13	2311.03 2134.31	1341.82 212.39	
4	3	13	0.0 10.0	2588.71 219.83	2241.89 351.11	2439.83 2250.05	1942.90 213.68	

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER 140			
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)	
205.49	176.13	161.45	

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 210

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
1	13	0	7	P CU-UG N C&CSN	2/0 2/0	0.5336 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
2	13	7	3	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
3	13	7	15	P CU-UG N C&CSN	2/0 2/0	0.5336 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
4	13	15	16	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
5	13	15	57	P CU-UG N C&CSN	2/0 2/0	0.5336 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
6	13	57	17	P CU-UG N C&CSN	2/0 2/0	0.5336 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
7	13	17	18	P CU-UG N C&CSN	2/0 2/0	0.5336 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
8	13	57	19	P CU-UG N C&CSN	1/0 1/0	0.6758 0.5550	0.00736 0.00736	0.0111 0.0111	0.3680 0.3680

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 COIT
CIRCUIT NO. 210

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MTRL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
9	13	19	20	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
10	13	19	21	P CU-UG N C&CSN	1/0 1/0	0.6758 0.5550	0.00736 0.00736	0.0111 0.0111	0.3680 0.3680
11	13	21	22	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
12	13	21	23	P CU-UG N C&CSN	1/0 1/0	0.6758 0.5550	0.00736 0.00736	0.0111 0.0111	0.3680 0.3680
13	13	23	24	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
14	13	23	25	P CU-UG N C&CSN	1/0 1/0	0.6758 0.5550	0.00736 0.00736	0.0111 0.0111	0.3680 0.3680
15	13	25	26	P CU-UG N C&CSN	#6 #6	2.6190 2.1800	0.00573 0.00573	0.0053 0.0053	0.1620 0.1620
16	13	26	27	P CU-UG N C&CSN	#6 #6	2.6190 2.1800	0.00573 0.00573	0.0053 0.0053	0.1620 0.1620

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 210

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R Ω/MILE	REACT X Ω/MILE	GMR (FT)	DIA D (IN)
17	13	26	28	P CU-UG N C&CSN	#8 #3	4.1500 3.4700	0.00574 0.00574	0.0042 0.0042	0.1285 0.1285
18	13	25	29	P CU-UG N C&CSN	1/0 1/0	0.6758 0.5550	0.00736 0.00736	0.0111 0.0111	0.3680 0.3680
19	13	29	30	P CU-UG N C&CSN	#4 #6	1.6470 2.1300	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
20	13	29	31	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00573	0.0102 0.0084	0.3600 0.2530
21	13	31	32	P CU-UG N C&CSN	#4 #6	1.6470 2.1300	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
22	13	31	33	P CU-UG N C&CSN	#3 #3	4.1500 3.4700	0.00574 0.00574	0.0042 0.0042	0.1285 0.1285
23	13	31	34	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00573	0.0102 0.0084	0.3600 0.2530
24	13	29	14	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00573	0.0102 0.0084	0.3600 0.2530

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 210 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
0	0	1	0 10.0	20385.62 239.98	17654.44 415.58	25874.54 17714.44	26494.93 239.99	
7	1	13	0.0 10.0	3492.01 224.79	3024.17 366.10	3322.77 3034.82	2633.51 220.05	
8	2	13	0.0 10.0	2880.01 221.72	2494.16 356.81	2722.70 2503.11	2164.56 216.12	
15	3	13	0.0 10.0	2035.72 214.81	1762.99 336.70	1707.59 1769.67	1524.40 207.40	
16	4	13	0.0 10.0	1875.21 212.88	1623.98 331.26	1754.25 1630.25	1403.41 205.00	
57	5	13	0.0 10.0	1869.07 212.80	1618.66 331.03	1748.39 1624.92	1398.73 204.90	
17	6	13	0.0 10.0	1809.77 212.01	1567.31 329.82	1691.88 1573.42	1354.14 203.91	
18	7	13	0.0 10.0	1696.70 210.36	1469.38 324.27	1584.31 1475.21	1269.07 201.37	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 210 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
19	8	13	0.0 10.0	1248.27 201.37	1081.03 300.40	1160.20 1085.80	932.52 190.90	
20	9	13	0.0 10.0	1210.06 200.35	1047.94 297.78	1124.24 1052.62	903.90 189.67	
21	10	13	0.0 10.0	907.71 189.66	786.10 272.00	840.71 790.17	677.62 177.25	
22	11	13	0.0 10.0	857.09 187.54	742.26 265.55	793.42 746.24	639.78 174.55	
23	12	13	0.0 10.0	900.52 189.54	779.88 271.25	833.99 793.93	672.25 176.88	
24	13	13	0.0 10.0	886.49 188.91	767.72 269.76	820.88 771.75	661.75 176.14	
25	14	13	0.0 10.0	849.41 187.17	735.61 265.63	786.24 739.57	634.04 174.11	
26	15	13	0.0 10.0	801.52 184.74	694.13 260.07	741.55 696.02	598.24 171.30	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 210 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
27	16	13	0.0 10.0	795.91 134.44	689.28 259.38	736.31 693.15	594.05 170.95	
28	17	13	0.0 10.0	756.71 132.25	655.33 254.42	699.77 659.14	564.76 168.44	
29	18	13	0.0 10.0	796.58 134.47	689.86 259.45	736.94 693.73	594.55 170.99	
30	19	13	0.0 10.0	785.57 133.88	680.32 259.10	726.68 684.18	586.32 170.31	
31	20	13	0.0 10.0	707.38 179.24	612.61 247.71	653.82 616.34	527.90 165.00	
32	21	13	0.0 10.0	705.62 179.12	611.09 247.46	652.18 614.91	526.59 164.37	
33	22	13	0.0 10.0	673.84 177.00	583.56 242.82	622.60 587.24	502.84 162.47	
34	23	13	0.0 10.0	624.94 175.44	541.22 235.16	577.14 544.83	466.32 158.46	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)

CIRCUIT NO. 210 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES			
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
14	24	13	0.0 10.0	634.55 177.73	592.34 244.41	632.57 596.53	510.84 163.30

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER 210

2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)
205.49	176.13	161.45

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 220

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R C/MILE	REACT X C/MILE	GMR (FT)	DIAM D (IN)
1	13	0	35	P CU-UG N C&CSN	2/0 2/0	0.5336 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
2	13	35	36	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
3	13	36	37	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
4	13	36	38	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2530
5	13	38	39	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1520
6	13	38	40	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00573	0.0102 0.0084	0.3600 0.2580
7	13	40	41	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
8	13	40	42	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2530

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 220

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
9	13	42	43	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
10	13	42	44	P CU-UG N C&CSN	#1 #2	0.8443 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
11	13	44	45	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
12	13	44	46	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 220 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
0	0	1	0 10.0	20385.62 239.93	17654.44 415.59	25374.54 17714.44	26494.93 239.99	
35	1	13	0.0 10.0	649.26 175.25	552.27 239.04	592.36 555.49	450.70 156.61	
36	2	13	0.0 10.0	531.40 165.35	460.20 218.43	434.27 453.26	368.83 145.40	
37	3	13	0.0 10.0	518.17 164.04	448.75 215.82	472.15 451.79	359.65 143.95	
38	4	13	0.0 10.0	471.57 159.06	408.39 206.02	429.49 411.38	327.29 138.47	
39	5	13	0.0 10.0	455.35 157.18	394.36 202.39	414.67 397.33	316.04 136.41	
40	6	13	0.0 10.0	405.57 150.79	351.23 190.39	369.14 354.15	281.46 129.54	
41	7	13	0.0 10.0	585.71 147.95	334.03 185.22	351.00 336.93	267.68 126.54	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 220 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
42	8	13	0.0 10.0	362.86 144.46	314.24 178.97	330.13 317.11	251.81 122.88	
43	9	13	0.0 10.0	341.19 140.90	295.48 172.72	310.35 298.33	236.78 119.19	
44	10	13	0.0 10.0	291.80 131.69	252.71 157.17	265.30 255.49	202.49 109.83	
45	11	13	0.0 10.0	286.35 130.57	247.99 155.33	260.32 250.76	198.71 108.71	
46	12	13	0.0 10.0	250.78 122.64	217.18 142.65	227.91 219.39	174.02 100.88	

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER 220		
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)
205.49	176.13	161.45

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 240

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATERIAL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
1	13	0	1	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
2	13	1	2	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
3	13	1	3	P CU-UG N C&CSN	#1 #2	0.8448 0.3640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
4	13	1	4	P CU-UG N C&CSN	#1 #2	0.8448 0.3640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
5	13	1	58	P CU-UG N C&CSN	#1 #2	0.8448 0.3640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
6	13	58	5	P CU-UG N C&CSN	#1 #2	0.8448 0.3640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
7	13	58	6	P CU-UG N C&CSN	#1 #2	0.8448 0.3640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 240 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

FAULT CURRENT MAGNITUDES

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
0	0	1	0 10.0	20385.62 239.98	17654.44 415.53	25374.54 17714.44	26494.93 239.99
1	1	13	0.0 10.0	3025.70 222.55	2620.33 359.31	2854.83 2629.68	2275.73 217.18
2	2	13	0.0 10.0	2455.49 218.78	2126.51 348.13	2311.03 2134.31	1841.82 212.39
3	3	13	0.0 10.0	2763.47 221.00	2393.23 354.65	2609.32 2401.87	2075.77 215.20
4	4	13	0.0 10.0	2588.71 219.80	2241.89 351.11	2439.83 2250.05	1942.90 213.68
58	5	13	0.0 10.0	1767.16 211.41	1530.40 327.16	1651.31 1556.40	1322.07 203.17
5	6	13	0.0 10.0	1612.24 209.00	1396.24 320.55	1504.13 1401.85	1205.59 200.19
6	7	13	0.0 10.0	1368.27 204.26	1184.96 307.91	1273.31 1190.00	1022.47 194.41

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER 240			
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)	
205.49	170.13	161.45	

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 320

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R Ω/MILE	REACT X Ω/MILE	GMR (FT)	DIAM D (IN)
1	13	0	17	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
2	13	17	35	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
3	13	35	36	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
4	13	36	37	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
5	13	36	38	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
6	13	38	39	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
7	13	38	40	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
8	13	40	41	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 320

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
9	13	40	42	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
10	13	42	43	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2530
11	13	42	44	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2530
12	13	44	45	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2530
13	13	44	46	P CU-UG N C&CSN	1/0 1/0	0.6753 0.5550	0.00736 0.00736	0.0111 0.0111	0.3680 0.3680

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 320 4155.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4155.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
0	0	1	0 10.0	20355.62 239.98	17654.44 415.58	25374.54 17714.44	26494.93 239.99	
17	1	13	0.0 10.0	2256.75 217.07	1954.39 343.15	2142.31 1901.74	1780.21 211.55	
35	2	13	0.0 10.0	1510.25 207.18	1307.91 315.65	1422.32 1313.37	1188.45 159.71	
36	3	13	0.0 10.0	1246.79 201.33	1079.75 300.30	1170.93 1054.60	980.49 192.83	
37	4	13	0.0 10.0	1216.94 200.53	1053.90 298.26	1142.53 1058.69	956.95 191.90	
38	5	13	0.0 10.0	1111.24 197.43	962.36 290.43	1042.13 956.93	873.63 188.30	
39	6	13	0.0 10.0	1074.32 196.23	930.38 287.44	1007.11 934.88	844.54 186.91	
40	7	13	0.0 10.0	960.29 192.06	831.63 277.26	899.13 835.90	754.73 162.11	

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)

CIRCUIT NO. 320 4156.9/ 2400.0 VOLTS

SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

FAULT CURRENT MAGNITUDES

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
41	8	13	0.0 10.0	914.53 190.16	792.05 272.71	855.93 796.24	718.75 179.94
42	9	13	0.0 10.0	861.81 187.77	746.34 267.97	806.09 750.44	677.22 177.22
43	10	13	0.0 10.0	811.62 185.27	702.88 261.29	758.75 706.90	637.73 174.39
44	11	13	0.0 10.0	696.59 178.54	603.27 246.17	650.42 607.11	547.25 166.85
45	12	13	0.0 10.0	683.36 177.69	592.24 244.31	636.45 596.06	537.23 165.90
46	13	13	0.0 10.0	600.42 171.49	519.98 231.06	560.05 523.69	471.63 159.07

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER 320		
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)
205.49	176.13	161.45

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 340

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
1	13	0	3	P CU-UG	#1	0.3448	0.00895	0.0102	0.3600
				N C&CSN	#2	0.8640	0.00578	0.0084	0.2580
2	13	3	53	P CU-UG	#1	0.8448	0.00895	0.0102	0.3600
				N C&CSN	#2	0.8640	0.00578	0.0084	0.2580
3	13	58	5	P CU-UG	#1	0.8448	0.00895	0.0102	0.3600
				N C&CSN	#2	0.8640	0.00578	0.0084	0.2580
4	13	58	6	P CU-UG	#1	0.8448	0.00895	0.0102	0.3600
				N C&CSN	#2	0.8640	0.00578	0.0084	0.2580

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 340 4155.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4155.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEQ NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
0	0	1	0 10.0	20385.62 239.93	17654.44 415.53	25874.54 17714.44	26494.93 239.99	
3	1	13	0.0 10.0	2763.47 221.00	2393.24 354.65	2609.32 2401.87	2075.78 215.20	
53	2	13	0.0 10.0	1589.75 208.61	1376.76 319.51	1462.81 1332.32	1188.70 199.72	
5	3	13	0.0 10.0	1465.19 206.27	1267.15 313.21	1362.97 1272.42	1093.67 196.84	
6	4	13	0.0 10.0	1259.32 201.65	1090.60 301.13	1170.60 1095.39	940.80 191.25	

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER 340		
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)
205.49	176.13	161.45

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 410

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R Ω/MILE	REACT X Ω/MILE	GMR (FT)	DIAM D (IN)
1	13	9	9	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
2	13	9	10	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
3	13	10	11	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00573	0.0102 0.0084	0.3600 0.2530
4	13	10	12	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
5	13	12	13	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
6	13	12	14	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
7	13	9	17	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
8	13	17	13	P CU-UG N C&CSN	2/0 2/0	0.5386 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 410 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES			
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
0	0	1	0 10.0	20385.62 239.98	17654.44 415.58	25374.54 17714.44	26494.93 239.99
9	1	13	0.0 10.0	4548.02 228.28	3938.70 376.93	4431.55 3952.56	3640.27 225.29
10	2	13	0.0 10.0	2707.63 220.64	2344.87 353.58	2585.32 2353.59	2142.93 215.90
11	3	13	0.0 10.0	2316.46 217.62	2006.11 344.74	2202.53 2013.77	1830.24 212.24
12	4	13	0.0 10.0	1896.27 215.18	1643.95 332.10	1796.85 1650.51	1497.51 206.90
13	5	13	0.0 10.0	1835.96 212.37	1589.98 329.83	1736.71 1596.39	1448.05 205.93
14	6	13	0.0 10.0	1698.59 210.40	1471.02 324.37	1604.42 1477.08	1339.13 203.57
17	7	13	0.0 10.0	2819.68 221.36	2441.91 355.73	2695.57 2450.92	2232.79 216.79

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 410 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES			
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
13	8	13	0.0 10.0	2645.47 220.21	2291.05 352.32	2524.28 2299.58	2093.14 215.39

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER 410

2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)
205.49	176.13	161.45

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 420

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATERIAL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
1	13	0	47	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
2	13	47	43	P CU-UG N C&CSN	#4 #5	1.6470 2.1300	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
3	13	47	49	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
4	13	49	50	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00573	0.0102 0.0094	0.3600 0.2530
5	13	49	51	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
6	13	51	52	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00576	0.0102 0.0084	0.3600 0.2580
7	13	51	53	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
8	13	51	54	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 420

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	CONJ SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIA D (IN)
9	13	54	55	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
10	13	54	56	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 420 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

FAULT CURRENT MAGNITUDES							
NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
0	0	1	0 10.0	20385.62 239.98	17654.44 415.58	25874.54 17714.44	26494.93 259.99
47	1	13	0.0 10.0	19123.55 238.97	15561.45 412.10	25118.39 16617.71	22402.34 238.64
48	2	13	0.0 10.0	6086.53 233.65	7003.13 394.20	8111.46 7027.00	6395.01 231.57
49	3	13	0.0 10.0	9309.38 234.53	8062.15 397.45	9488.65 3089.58	7510.99 232.87
50	4	13	0.0 10.0	8647.79 234.13	7439.19 395.79	8737.12 7514.70	6899.00 232.20
51	5	13	0.0 10.0	5503.95 230.35	4770.39 333.51	5359.06 4787.29	4221.12 227.25
52	6	13	0.0 10.0	5080.76 229.51	4400.06 380.34	4918.86 4415.23	3877.54 226.16
53	7	13	0.0 10.0	3513.26 224.68	3042.59 566.38	3343.77 3053.30	2649.90 220.16

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 5/20/77 (CONT.)
 CIRCUIT NO. 420 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLS (AMPS)	LG (AMPS)	
54	8	13	0.0 10.0	3865.97 226.22	3348.03 370.52	3693.37 3359.73	2922.54 221.89	
55	9	13	0.0 10.0	3765.30 225.36	3260.84 369.40	3593.30 3272.26	2844.53 221.43	
56	10	13	0.0 10.0	2938.99 222.07	2545.24 357.85	2780.18 2554.35	2209.56 216.56	

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER 420		
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)
205.49	176.13	161.45

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 510

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MTRL	COND SIZE	RESIS R Ω/MILE	REACT X Ω/MILE	GMR (FT)	DIAM D (IN)
1	13	0	9	P CU-UG N C&CSN	2/0 2/0	0.5336 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
2	13	9	10	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
3	13	10	11	P CU-UG N C&CSN	#4 #6	1.0470 2.1800	0.00571 0.00573	0.0056 0.0053	0.2040 0.1620
4	13	10	12	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
5	13	12	13	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
6	13	12	14	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2580
7	13	9	17	P CU-UG N C&CSN	2/0 2/0	0.5336 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140
8	13	17	18	P CU-UG N C&CSN	2/0 2/0	0.5336 0.4400	0.00737 0.00737	0.0125 0.0125	0.4140 0.4140

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 510 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

		FAULT CURRENT MAGNITUDES					
NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
0	0	1	0 10.0	20385.62 239.98	17654.44 415.53	25874.54 17714.44	26494.93 239.99
9	1	13	0.0 10.0	4548.02 228.28	3933.70 376.93	4431.55 3952.55	3640.27 225.29
10	2	13	0.0 10.0	2707.63 220.64	2344.87 353.53	2535.32 2353.58	2142.93 215.90
11	3	13	0.0 10.0	2316.46 217.62	2006.11 344.74	2202.53 2013.77	1830.24 212.24
12	4	13	0.0 10.0	1898.27 213.18	1643.95 332.10	1796.85 1650.51	1497.51 206.90
13	5	13	0.0 10.0	1835.90 212.37	1539.93 329.93	1736.71 1596.39	1448.05 205.95
14	6	13	0.0 10.0	1698.59 210.40	1471.02 324.37	1604.42 1477.03	1339.13 203.57
17	7	13	0.0 10.0	2819.68 221.36	2441.91 355.73	2695.57 2450.92	2232.79 216.79

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)

CIRCUIT NO. 510 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
18	3	13	0.0 10.0	2645.47 220.21	2291.05 352.32	2524.28 2299.58	2093.14 215.39	

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER 510			
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)	
205.49	176.13	161.45	

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 520

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
1	13	0	47	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2530
2	13	47	43	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2530
3	13	47	49	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2530
4	13	49	50	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
5	13	49	51	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2530
6	13	51	52	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
7	13	51	53	P CU-UG N C&CSN	#4 #6	1.6470 2.1800	0.00571 0.00573	0.0066 0.0053	0.2040 0.1620
8	13	51	54	P CU-UG N C&CSN	#1 #2	0.8448 0.8640	0.00895 0.00578	0.0102 0.0084	0.3600 0.2530

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 520

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/WILE	REACT X O/WILE	GMR (FT)	DIAM D (IN)
9	13	54	55	P CU-UG	#4	1.6470	0.00571	0.0066	0.2040
				N C&CSN	#6	2.1800	0.00573	0.0053	0.1620
10	13	54	56	P CU-UG	#1	0.8448	0.00895	0.0102	0.3600
				N C&CSN	#2	0.3540	0.00578	0.0084	0.2580

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 520 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= 4156.9 VOLTS ZBASE= 1.73 OHMS

		FAULT CURRENT MAGNITUDES					
NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
0	0	1	0 10.0	20385.62 239.98	17654.44 415.58	25874.54 17714.44	26494.93 239.99
47	1	13	0.0 10.0	19123.55 238.97	16561.45 412.10	25118.39 16617.71	22402.34 238.64
48	2	13	0.0 10.0	8986.53 235.65	7003.13 394.20	8111.46 7027.00	6395.01 231.57
49	3	13	0.0 10.0	9609.38 234.63	8062.15 397.45	9433.65 8089.58	7510.99 232.87
50	4	13	0.0 10.0	8647.79 234.13	7489.19 395.79	8737.12 7514.70	6899.00 232.20
51	5	13	0.0 10.0	5508.95 230.35	4770.39 383.51	5359.06 4757.29	4221.12 227.25
52	6	13	0.0 10.0	5080.76 229.51	4400.06 360.34	4918.86 4415.23	3877.54 226.16
53	7	13	0.0 10.0	3513.28 224.66	3042.59 365.38	3343.77 3053.30	2649.90 220.16

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 520 4156.9/ 2400.0 VOLTS
 SBASE= 10.0 MVA VBASE= .4156.9 VOLTS ZBASE= 1.73 OHMS

NODE	SEC NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
54	8	13	0.0 10.0	3865.97 226.22	3348.03 370.52	3693.37 3359.73	2922.54 221.89	
55	9	13	0.0 10.0	3755.30 225.86	3250.84 359.40	3593.30 3272.26	2944.53 221.43	
56	10	13	0.0 10.0	2938.99 222.07	2545.24 357.85	2780.18 2554.35	2209.56 216.56	

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER 520

2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)
205.49	176.13	161.45

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 1

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
1	13	0	1	P CU-UG N C&CSN	750MCM 4/0	0.1072 0.2730	0.00607 0.00736	0.0319 0.0158	0.9970 0.5220
2	13	1	2	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2730	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
3	13	1	3	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2730	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
4	13	3	4	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2730	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
5	13	3	5	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2730	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
6	13	1	6	P CU-UG N C&CSN	750MCM 4/0	0.1072 0.2730	0.00607 0.00736	0.0319 0.0158	0.9970 0.5220
7	13	6	7	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2730	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
8	13	6	8	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2730	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 1

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MTRL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
9	13	6	9	P CU-UG N C&CSN	750MCM 4/0	0.1072 0.2780	0.00607 0.00736	0.0319 0.0158	0.9970 0.5220
10	13	9	10	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
11	13	9	11	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
12	13	11	12	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
13	13	11	13	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
14	13	13	14	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
15	13	13	15	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
16	13	15	16	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77 CONT
CIRCUIT NO. 1

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	RESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
17	13	15	17	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0153	0.4140 0.5220
18	13	15	18	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0153	0.4140 0.5220
19	13	18	19	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0153	0.4140 0.5220
20	13	18	20	P CU-UG N C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0153	0.4140 0.5220

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 1 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

		FAULT CURRENT MAGNITUDES					
NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
0	0	1	0 10.0	14448.26 719.11	12512.55 1240.93	15527.06 12692.47	16181.84 719.29
1	1	13	0.0 10.0	8115.90 670.44	7028.57 1084.49	8475.05 7125.63	7465.33 662.89
2	2	13	0.0 10.0	7648.73 666.44	6624.04 1072.46	7933.23 6715.32	6974.97 658.30
3	3	13	0.0 10.0	6961.23 659.86	6028.61 1053.00	7150.75 6111.44	6274.62 650.79
4	4	13	0.0 10.0	5366.45 639.97	4647.48 996.06	5397.78 4710.99	4730.90 628.22
5	5	13	0.0 10.0	5750.04 645.53	4979.63 1011.70	5812.04 5047.80	5093.27 634.51
6	6	13	0.0 10.0	5693.81 644.75	4930.98 1009.49	5751.04 4993.42	5029.83 633.62
7	7	13	0.0 10.0	5638.57 643.97	4823.14 1007.30	5691.20 4949.93	4987.44 632.75

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 1 12470.3/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.3 VOLTS ZBASE= 15.55 OHMS

FAULT CURRENT MAGNITUDES

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)
8	8	13	0.0 10.0	4616.05 627.06	3999.35 960.60	4601.95 4053.99	4037.53 613.69
9	9	13	0.0 10.0	3003.35 583.05	2601.41 847.58	2936.73 2637.58	2590.78 564.73
10	10	13	0.0 10.0	2934.17 582.29	2534.37 845.73	2916.83 2620.32	2573.47 563.95
11	11	13	0.0 10.0	2932.42 576.14	2452.94 830.86	2763.69 2487.24	2440.20 557.20
12	12	13	0.0 10.0	2811.96 575.27	2435.23 828.30	2743.10 2469.30	2422.26 556.25
13	13	13	0.0 10.0	2658.21 565.42	2302.08 812.54	2538.58 2334.49	2227.67 548.76
14	14	13	0.0 10.0	2635.00 567.34	2282.00 809.93	2555.34 2314.17	2267.41 547.57
15	15	13	0.0 10.0	2520.15 561.74	2132.52 796.90	2450.31 2213.46	2167.12 541.47

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77 (CONT.)
 CIRCUIT NO. 1 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.0 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
16	16	13	0.0 10.0	2250.25 546.92	1948.77 763.07	2181.27 1976.90	1932.21 525.38	
17	17	13	0.0 10.0	2483.26 559.86	2150.57 792.54	2413.44 2181.12	2134.95 539.42	
18	18	13	0.0 10.0	2410.44 556.02	2007.51 783.70	2340.75 2117.29	2071.51 535.24	
19	19	13	0.0 10.0	2358.02 553.14	2042.10 777.14	2268.49 2071.35	2025.69 532.12	
20	20	13	0.0 10.0	2138.18 539.96	1851.71 747.57	2070.04 1878.70	1824.96 517.87	

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER 1		
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)
436.91	374.50	343.29

IMPEDANCE CALCULATIONS FOR THE VPI ELECTRIC SERVICE, PERFORMED 6/20/77
CIRCUIT NO. 2

LINE INFORMATION

SEG NO.	CIRC TYPE	START NODE	END NODE	COND MATL	COND SIZE	PESIS R O/MILE	REACT X O/MILE	GMR (FT)	DIAM D (IN)
1	13	0	21 - N	CU-UG C&CSN	7504CM 4/0	0.1072 0.2780	0.00607 0.00736	0.0319 0.0158	0.9970 0.5220
2	13	21	22 N	CU-UG C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
3	13	21	23 N	CU-UG C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
4	13	23	24 N	CU-UG C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
5	13	23	25 N	CU-UG C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
6	13	25	27 N	CU-UG C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220
7	13	25	28 N	CU-UG C&CSN	2/0 4/0	0.5386 0.2780	0.00737 0.00736	0.0125 0.0158	0.4140 0.5220

VPI ELECTRIC SERVICE FAULT CURRENT CALCULATIONS, PERFORMED 6/20/77
 CIRCUIT NO. 2 12470.8/ 7200.0 VOLTS
 SBASE= 10.0 MVA VBASE= 12470.8 VOLTS ZBASE= 15.55 OHMS

NODE	SEG NO.	CIRC TYPE	FAULT IMPEDANCE (OHMS)	FAULT CURRENT MAGNITUDES				
				3-PHASE (AMPS)	LL (AMPS)	LLG (AMPS)	LG (AMPS)	
0	0	1	0	14448.26	12512.55	15527.06	16181.84	
			10.0	719.11	1240.93	12692.47	719.29	
21	1	13	0.0	7780.54	6738.14	8085.20	7112.03	
			10.0	667.50	1075.94	6831.05	659.63	
22	2	13	0.0	7328.07	6344.56	7563.80	6643.26	
			10.0	663.46	1063.62	6431.67	654.90	
23	3	13	0.0	5595.03	4845.43	5644.16	4946.27	
			10.0	643.35	1005.56	4911.74	632.04	
24	4	13	0.0	5346.52	4630.21	5376.37	4712.21	
			10.0	639.66	995.21	4693.49	627.87	
25	5	13	0.0	4889.24	4234.20	4888.48	4286.84	
			10.0	622.10	974.32	4292.04	619.35	
27	6	13	0.0	4726.22	4093.02	4715.98	4156.72	
			10.0	629.13	956.20	4148.93	616.01	
28	7	13	0.0	4153.16	3596.74	4115.43	3614.75	
			10.0	617.22	934.30	3645.93	602.67	

SHORT CIRCUIT CAPACITY OF CIRCUIT BREAKER		2
2 CYCLE BREAKER RATING (MVA)	4 CYCLE BREAKER RATING (MVA)	5 CYCLE BREAKER RATING (MVA)
436.91	374.50	343.29

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A COMPUTER-AIDED FAULT ANALYSIS OF THE
VPI ELECTRIC SERVICE POWER DISTRIBUTION SYSTEM

by

George L. Hogshead

(ABSTRACT)

In this thesis, a general-purpose digital computer program to perform fault analyses is developed and discussed in detail. The program is utilized to perform a complete fault study of the distribution system of the VPI Electric Service, as an example test case. Equations are gathered and a computer program is written to calculate the fault current magnitudes on a distribution system when three phase, phase to phase, phase to phase to ground, or phase to ground faults occur.

The program is written to include basic circuit types that are in use in the utility industry today. The program provides results that are in tabular form for easy use.

The VPI Electric Service system is discussed and results are included for the major distribution circuits in the system. System maps have been prepared for the circuits and are available at the Electric Service.

A user's guide is included so that the program can be used whenever system changes demand a new study.