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SELECTED ASPECTS OF POWER ENGINEERING AS RELATED TO THE WESTERN AREA POWER ADMINISTRATION

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SELECTED ASPECTS OF POWER ENGINEERING
AS RELATED TO THE
WESTERN AREA POWER ADMINISTRATION

by

John Raynor Sundberg

A Thesis Submitted to the Faculty of the

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STATEMENT BY AUTHOR

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12/1/82
Date

PREFACE

Industrial interaction is an essential element of the Energy Systems Option for the Masters Degree in electrical engineering. This thesis is presented to fulfill that internship requirement. It documents some of the projects undertaken by the author while employed by the Western Area Power Administration at their Phoenix District Office.

I wish to express my appreciation to the personnel of the Phoenix District and Boulder City Area Offices of the Western Area Power Administration and to the Bureau of Reclamation's Electrical Power and Field Test Branches, located in the Engineering and Research Center in Denver, Colorado, for their support and assistance.

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ABSTRACT

Several Power Engineering activities performed by the author while employed by the Western Area Power Administration, an agency within the Department of Energy, are discussed. The agency's organization and responsibilities are described.

The protection of Extra High Voltage transmission lines against the damaging effects of faults, especially those caused by lightning, is discussed. A method of predicting the number of tripouts per year is applied to an existing 345 kV transmission line and the results are compared to the actual tripouts averaged over 7 years. A computer method to determine the currents that result during fault conditions is applied to a model power system.

Staged fault tests are described to demonstrate the effectiveness of a protection system. The calculated and measured fault currents are compared for tests performed on the 345 kV Mead-Liberty transmission line.

CHAPTER 1

INTRODUCTION

As a power system engineer with the Technical Analysis Branch of the Western Area Power Administration, the author performed analytic studies such as fault studies and load flow studies which affected the design and operation of portions of the Federal power system.

The first part of this thesis describes the Western Area Power Administration and the Technical Analysis Branch. The major portion details applications of power systems analysis that I accomplished while a member of the above organization. The last section describes actual fault tests on a high-voltage transmission line that I observed as one of my assignments.

Organization of Western Area Power Administration

The Western Area Power Administration, hereafter referred to as W.A.P.A., an agency within the Department of Energy, was created by Congress with the passage of the Energy Organization Act of 1977. The mission of W.A.P.A. is the marketing of electric power and energy generated at Federal projects in fifteen western states to wholesale customers. The agency maintains and operates an extensive high-voltage transmission system in this area.

W.A.P.A. markets power and energy from 46 power plants constructed and operated by the United States Bureau of Reclamation, the United States Army Corps of Engineers, and the powerplant operated by the International Boundary and Water Commission in Texas.

Most of the Reclamation and Corps projects are multi-purpose. They are designed to provide flood control, navigable waters, irrigation, municipal and industrial water supplies, fish and wildlife enhancement, recreation, and other public benefits, in addition to the generation of power.

W.A.P.A. activities are financed principally from appropriated funds. By law, W.A.P.A. is required to repay the United States Treasury for all costs of operating and maintaining the power system and to repay the Government's investment in power facilities at the dams, with interest, from revenues received through its marketing activities. Power revenues also repay a substantial share of the construction cost of Federal irrigation projects.

The total installed capacity of the 46 powerplants within the W.A.P.A. system is 7,766 megawatts. This power is moved over 15,897 circuit miles of transmission lines with voltage ratings up to 500 kV. W.A.P.A. maintains 208 substations throughout the system to serve 426 preference customers who, in turn, deliver electric power to over 7,000,000 customers. In 1977 W.A.P.A. marketed 35.9 billion kWH for an annual revenue from power sales totaling $247 million. W.A.P.A.'s full service area includes the states of Arizona, California, Colorado, western Iowa, Kansas, western Minnesota, Montana, Nebraska, Nevada, New Mexico, North Dakota, South Dakota, western Texas, Utah, and Wyoming, a marketing area of 1,269,958 square miles. Of the existing lines, about 50 percent of the circuit miles are 230 kV or higher. Besides scheduling and dispatching power from Federal generating facilities, W.A.P.A. wheels, or exchanges over its grid, power for both Federal and non-federal utilities.

W.A.P.A.'s headquarters office is located in Golden, Colorado and the Area Offices are in Denver, Colorado; Salt Lake City, Utah; Billings, Montana; Sacramento, California; and Boulder City, Nevada. The W.A.P.A. system and mission were transferred from the Bureau of Reclamation to the Department of Eenrgy on October 1, 1977.

The responsibility for power deliveries and marketing in Arizona, southern Nevada, and southern California fall under the Boulder City Area Office and a district office in Phoenix, Arizona, where the author completed the projects which are presented in this thesis.

Operation and maintenance responsibilities for the

Area power system are handled out of the Phoenix District Office, which comprises the Boulder City Area transmission system, consisting of 2,116 miles of high-voltage line, 32 substations, and related structures.

Technical Analysis Responsibilities

The Technical Analysis Branch of W.A.P.A.'s Phoenix District Office had the responsibility for performing fault studies, setting relays for proper operation of the protection system, using the Power Systems Analysis Package, hereafter referred to as PSAP, to run the power flows to determine loading on the system and performing technical studies to support the operation of the power system of the Boulder City Area.

The writer performed most of the fault studies and power flows that were run at the Phoenix District Office during his assignment with the Technical Analysis Branch. In order to demonstrate the capabilities of the computer package, he developed model systems and ran the analysis package on them. The studies by the author form a major portion of Chapters 2 and 3 of this study.

Two other projects that were the responsibility of this writer were: (1) an analysis of a lightning prediction method applied to a 345 kV transmission line within the Boulder City Area; and (2) a staged fault test performed on the 345 kV line with which the author was involved in coordination work with personnel from the Denver Engineering and Research Center who conducted the test. These projects are detailed in Chapter 3.

CHAPTER 2

PROTECTION

Like any other major system, an electric power system is thought of as in normal operation. It is taken so much for granted that only when a disruption of service occurs do we realize how dependent upon electric power highly developed societies have become.

This dependency was illustrated vividly by the Consolidated Edison system breakdown of July 13, 1977. Here, the largest city in the United States was immobilized by the loss of electric power. The major cause of electrical power failure is lightning, and this was the initiating phenomenon in the New York outage also. As conditions worsened, out of synchronism, low frequency, and overcurrent problems developed, finally leading to the blackout of the city.

From an idealistic viewpoint, complete prevention of electrical failure should be the goal in the protection of the electrical system. However, the economic costs of such an approach would be astronomical. Therefore, mitigating the effects of electrical failures has to be a major goal of power system protection instead of 100% prevention.

Power outages can be caused by events other than lightning. Vandalism is a serious problem, particularly in sparsely populated parts of the country such as the southwest. Insulator strings on transmission lines make good targets for rifles; unfortunately, they tend to explode when hit due to the strain on them. Airplanes have hit lines because they are difficult to see. Large birds, such as hawks and eagles, can cause a phase-to-phase or phase-to-ground fault, and recently efforts have been made to lessen this problem.

As mentioned above, a major cause of outages on transmission lines is lightning. A methodology for predicting an outage rate is discussed below and applied to the Bureau of Reclamation's 345 kV line between Flagstaff and Pinnacle Peak substations in Arizona. Because an actual lightning stroke that results in an outage depends upon the chance combination of many factors, an exact, measurable, single value cannot be obtained for the probability of an outage occurring. A statistical approach, using a modification of the Monte Carlo method has been found to be reasonably accurate for EHV lines, those of 345 kV and higher.

The probabilities involved in a prediction method are listed below in chronological order:

1. The probability of a thunderstorm occurring over the line.

2. The probability that a strike will occur to the line from the thunderstorm.
3. The probability that a stroke will contact a particular spot on the line, e.g., tower, quarterspan, midspan, or phase conductor.
4. The probability that the tower in the vicinity of the stroke will have a certain footing resistance. (Footing resistances on lines are rarely constant--either along the line or at a given tower.)
5. The probability that the stroke will exceed a certain amplitude of current and have a front time less than a prescribed value. (No two strokes are alike.)
6. The probability that the magnitude and polarity of power frequency voltages at the instant of stroke contact will be such as to aid the initiation of breakdown streamers across the insulator.
7. The probability that a power-follow current will initiate across the line insulators provided it does flash over.

In order to obtain a predicted annual outage rate for an EHV line, the preceeding probabilities must be quantified.

The writer calculated a predicted tripout rate for the Bureau of Reclamation's 345 kV transmission line between Flagstaff and Pinnacle Peak in Arizona. Records are kept of all outages occurring on the Bureau's system, and from these records the number of outages caused by lightning could be determined for a number of years. The two values were compared and found to be in good agreement. The method used to obtain the predicted tripout rate and a brief discussion of the theory are shown below.

A good starting point for finding the tripout rate is the isokeraunic level of the region in question. The United States Weather Service publishes maps of these levels. The isokeraunic level is the mean annual number of days that thunder is heard. A value of 35 was used as representative of the level in the vicinity of the Flagstaff-Pinnacle Peak line.

An approximation of the expected number of strokes, N, to earth per square mile per year is given by $N = KI$ where I is thunderstorm-days per year and K is a numerical coefficient. Values in the literature range from 0.25 to 0.5. Muller-Hillebrand, Johansen and Saraoja (1965) have concluded that the above relationship is non-linear, with $I^{1.7}$ being closer fit to the data available.

If a transmission line involving ground wires is placed in an area where N has been determined, the grounding wires act to shield an area of the earth in the vicinity of the line, depending upon the height of the ground wire conductors and the distance between them. The effective height of the line, taking into consideration sag between towers, is given by $H = h_T - 1/3\ (h_T - h_{GW})$ where h_T is the height of the wires at the tower and h_{GW} is the height at mid-span. The protected width of the shielded area is shown in Figure 1 and indicates this width is about four times the height. The importance of the shielding angle, alpha, is also shown by this diagram. The shielding angle of the Flagstaff-Pinnacle Peak line is 20°.

We are interested in finding the number of strokes striking the conductors, not those terminating on the ground wires, and this relationship is shown by $F = P\ (1.90h_T + 3.8h_{GW} + 1.44b)$ where P is the shielding failure probability, h_T is the height of the tower above ground, h_{GW} is the height of the ground wire above ground at mid-span, and b is the spacing between ground wires. All dimensions are in meters. P is a function of shield angle and tower height. Figure 2 is used to determine a value of P of .005 for the Flagstaff-Pinnacle Peak line. Then F is determined to be 0.62.

Since the magnitudes and wave-shapes of the lightning voltages depend on where the lightning strikes, the distribution of strokes that strike the line must be determined. It has been found that strikes near or to the tower contribute the major number of outages. This has been shown by Wagner and Hileman (1964) and is also borne out by computer analysis (Anderson, Fisher and Magnusson, 1968). From some

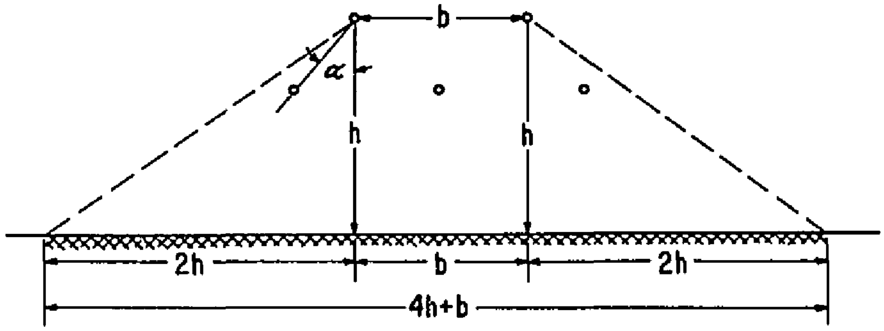


Figure 1. Width of the right-of-way shielded from lightning strokes (Anderson et al., 1968).

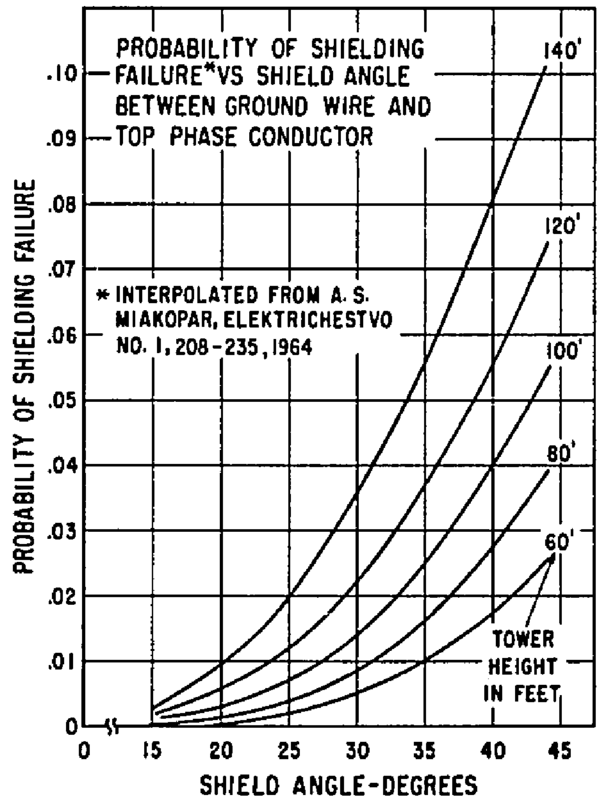


Figure 2. Probability of shielding failure versus shield angle between ground wire and top phase conductor (Anderson et al., 1968).

existing data for tall towers with a span of about 1000 feet, 60 percent of the line strokes make contact near the towers.

By actually applying a scaled-down version of a simulated lightning stroke to scale models of a base case transmission line tower, a response curve can be obtained. This will give the peak voltage across an insulator string and, by use of software, a complete picture of the possible voltages can be obtained for different combinations of parameters that exist for the actual case.

The only other parameters that need to be determined in order to calculate tripouts is ground resistance and the resulting footing resistance for the tower. This determination is very important as it is instrumental in determining the voltage that will occur across the insulator string.

A representative base case structure and its associated computer-generated curves are shown in Figures 3 and 4. The base case tripout rate for strikes in the vicinity of the tower can be determined by using Figure 4. A value of 55 ohms was used for footing resistance. T^1, the base case tripout rate equals 5. The tripout rate from these curves must still be modified for the actual design case. These modifications consist of a term B, which depends upon the ratio of the design tower height to the base case height, and e^{-S/S_0}, which is a function of the ratio of design span to base span. B is found using Figure 5. Using typical values

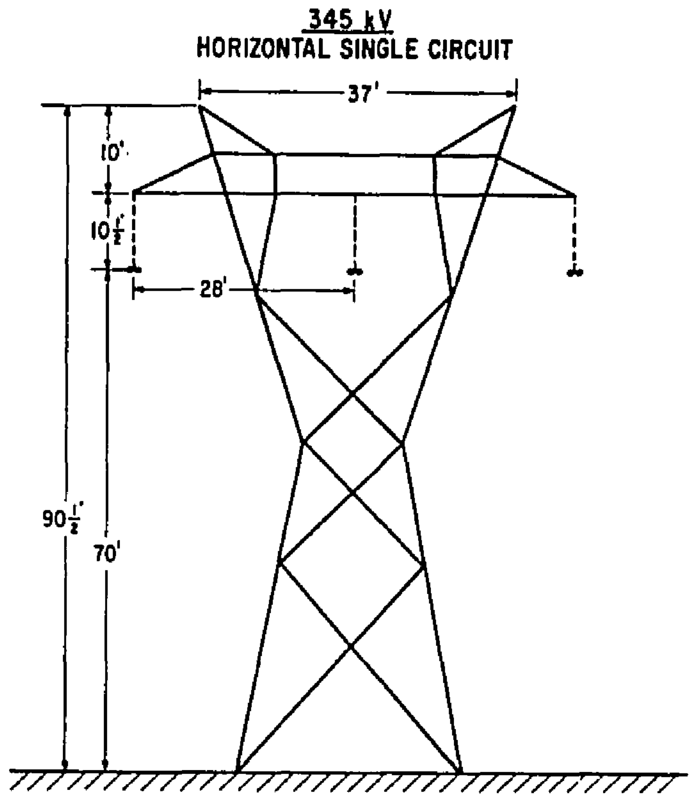


Figure 3. Base-case structure for lightning calculation of 345 kV horizontal single-circuit lines (Anderson et al., 1968).

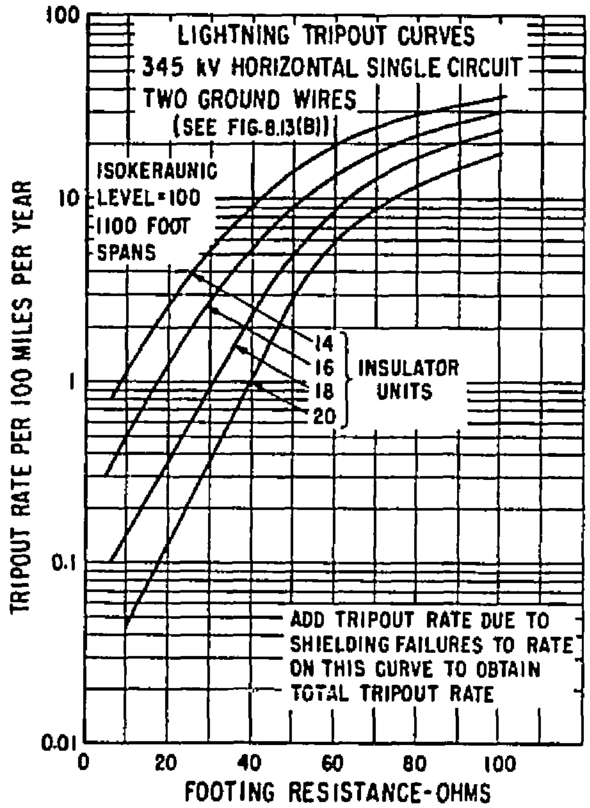


Figure 4. Lightning tripout curves, 345 kV horizontal single-circuit, two ground wires (Anderson et al., 1968).

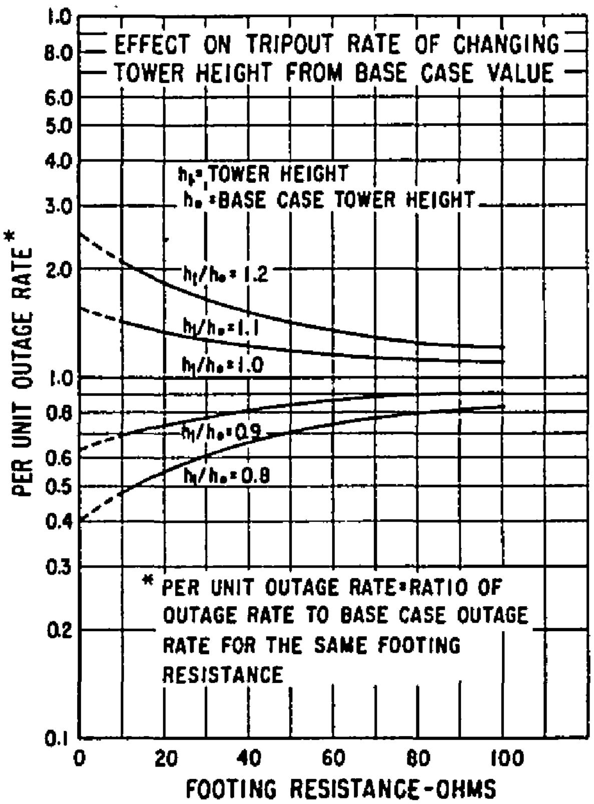


Figure 5. Effect on tripout rate of changing tower height from base-case value, B (Anderson et al., 1968, pp. 287-297).

for the Flagstaff-Pinnacle Peak line, B is 1.4 and e^{-S/S_0} is 0.58.

The failures due to the probability of strikes to the conductors and the modifiers for the distribution of the strikes can now be combined by the relationship

$$T = [F + 1.65BT'e^{-S/2(S_0)}]\frac{I}{100}$$

to give a tripout rate for the design case in tripouts per 100 line-miles per year. For the Flagstaff-Pinnacle Peak line

$$T = [0.62 + (1.65)(1.4)(5)(.58)]\frac{35}{100} = 2.56$$

The actual tripout averaged over seven years was 2.68, which is a good correlation considering the probabilistic nature of the problem.

Since there are only two possible results from a lightning strike to a transmission line, flashover (failure) or no flashover (success), the probability is determined by binomial statistics. This probability, b (k;n,p) = $\binom{n}{k}$ p^k q^{n-k} with p = q = 1 and $\binom{n}{k} = \frac{n!}{k!(n-k)!}$. To obtain a good probability figure, perhaps 40,000 lightning strokes would have to be observed. Depending upon the isokeraunic level, hundreds of years would have to go by for lines having low tripout rates to be accurately evaluated.

The importance of a prediction method as given here is that the builder of a transmission line is given a predictable trend. From this he can decide what tradeoffs are necessary. Even though high towers for EHV lines would, by themselves, cause a greater number of outages than on the lower-voltage lines, increased line insulations and a greater effort to keep footing resistances low offset the adverse effects. With the trend of inter-connection between the various power systems gaining acceptance, it is not economical or necessary to achieve extremely low tripout rates.

Model Systems

To illustrate the analysis of a power system under faulted conditions, a model was constructed by the writer using a portion of the Parker-Davis system from Parker Dam on the Colorado River to Gila Substation near Yuma, Arizona. The system is shown in Figure 6. A radial load is shown connected to the Gila Sub. Actual impedances and system voltages were used for the calculations.

It is out of the question to solve practical, large networks by hand calculations; but to illustrate the method, the model system was solved by hand and by use of the Power Systems Analysis Package (PSAP), one of the computer programs available for fault analysis on the Bureau of Reclamation's computer system. Only Single Line to Ground (SLG) and Three

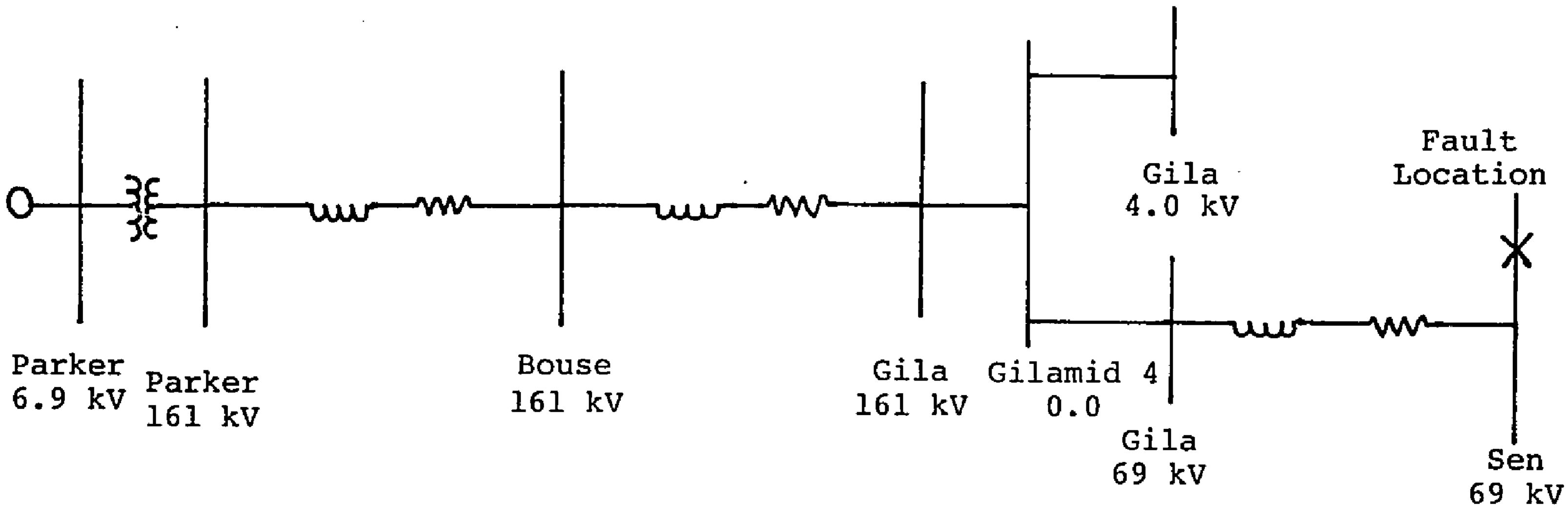
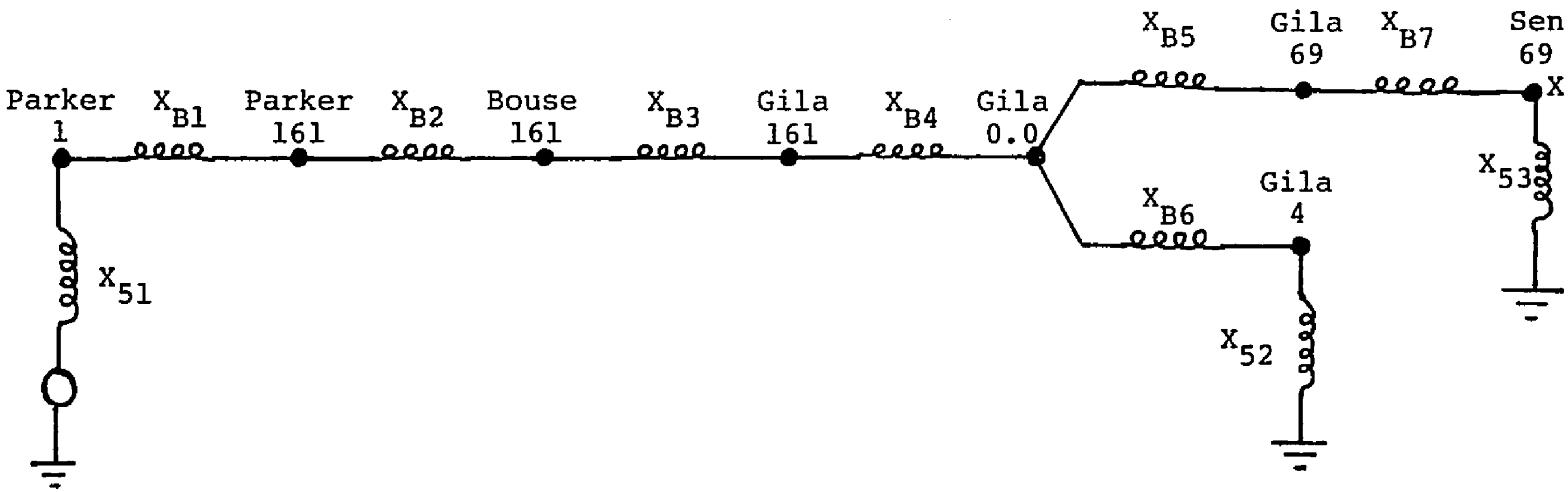


Figure 6. Model power system fault analysis.

Phase faults were considered as these are the faults usually encountered in power system analysis and will give the information necessary in setting up the protective relaying system.

The hand calculation method results in a phase current of 0.93A pu for the SLG case and 0.97A pu for the 3Ø. The computer output results give 0.9344A pu and 0.9725A pu respectively. Individual branch currents are also obtained with PSAP, which would be very involved using the hand calculation even for a system as simple as the model.

The first step in solving the model system by hand calculations is to construct a positive sequence diagram from the system diagram of Figure 6. This diagram is shown as Figure 7 and lists the branch and source positive sequence reactances. For a fault on the Sen 69 bus, the positive sequence diagram reduces to that of Figure 8. The positive sequence equivalent reactance is calculated to be 1.03 pu. Since no machines are involved, the negative sequence reactance is this value also. The zero sequence diagram is shown on Figure 9, and from this diagram the zero sequence equivalent reactance is found to be 1.15 pu. Finally, the sequences are combined as shown on Figure 10, and the positive sequence current is calculated to be 0.31 pu and $Ia = 3(Ia_1) = 0.93$ pu for the SLG case. For the 3Ø case, $Ia_1 = Ia$ and $Ia_Ø = Ia_2 = 0$. Therefore, $Ia = Ib = Ic = 1/1.03 = 0.97$



<u>Source Reactances</u>

X_{51} = 0.8270 pu

X_{52} = 3.05 pu

X_{53} = 3.851 pu

<u>Branch Reactances</u>

X_{B1} = 0.3233 pu

X_{B2} = 0.070 pu

X_{B3} = 0.2984 pu

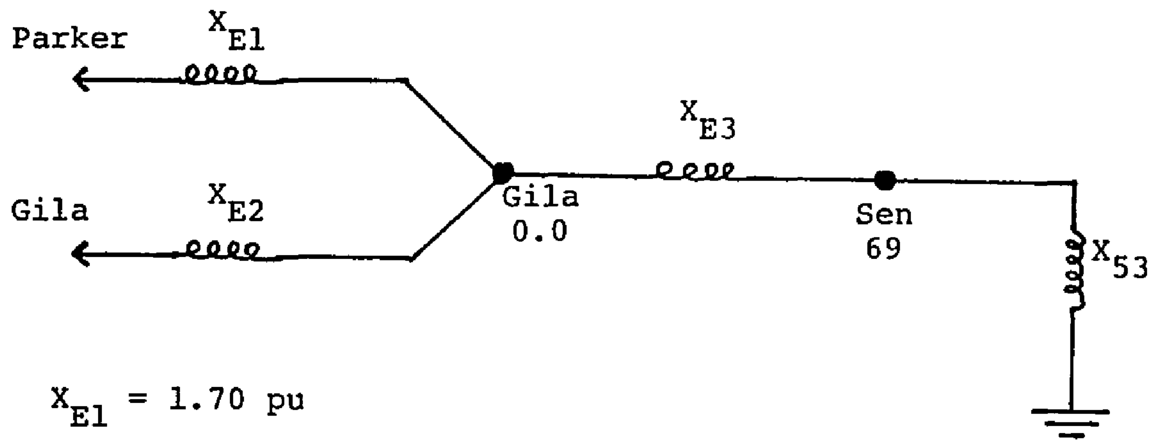
X_{B4} = 0.1837 pu

X_{B5} = 0.021 pu

X_{B6} = 0.4087 pu

X_{B7} = 0.283 pu

Figure 7. Positive sequence diagram for the system.



$X_{E1} = 1.70$ pu

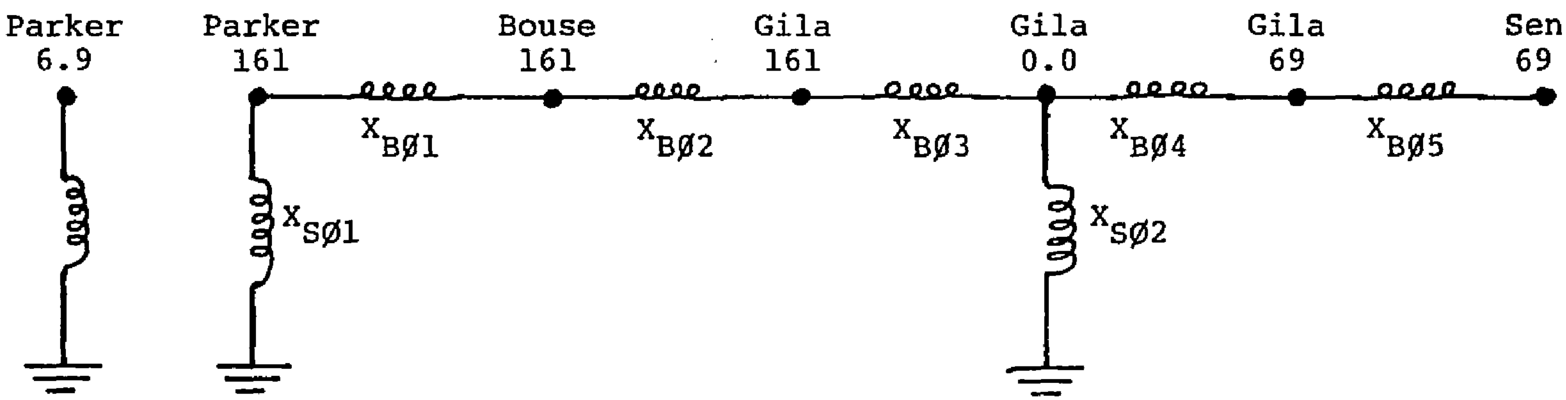
$X_{E2} = 3.45$ pu

$X_{E3} = 0.26$ pu

$X_{53} = 3.851$ pu

$$X_1 = X_{2_{neg}} = \frac{\left[\frac{(1.7)(3.45)}{1.7 + 3.45} + .26\right](3.85)}{\left[\frac{(1.7)(3.45)}{1.7 + 3.45} + .26\right] + 3.85} = 1.03 \text{ pu}$$

Figure 8. Reduced equivalent circuit diagram for the positive sequence system.



The Zero Sequence Reactances are:

<u>Source Reactances</u>

$Xs\emptyset 1 = 0.3233$ pu

$Xs\emptyset 2 = 0.4087$ pu

<u>Branch Reactances</u>

$X_{B\emptyset 1} = 0.21$ pu

$X_{B\emptyset 2} = 0.8952$ pu

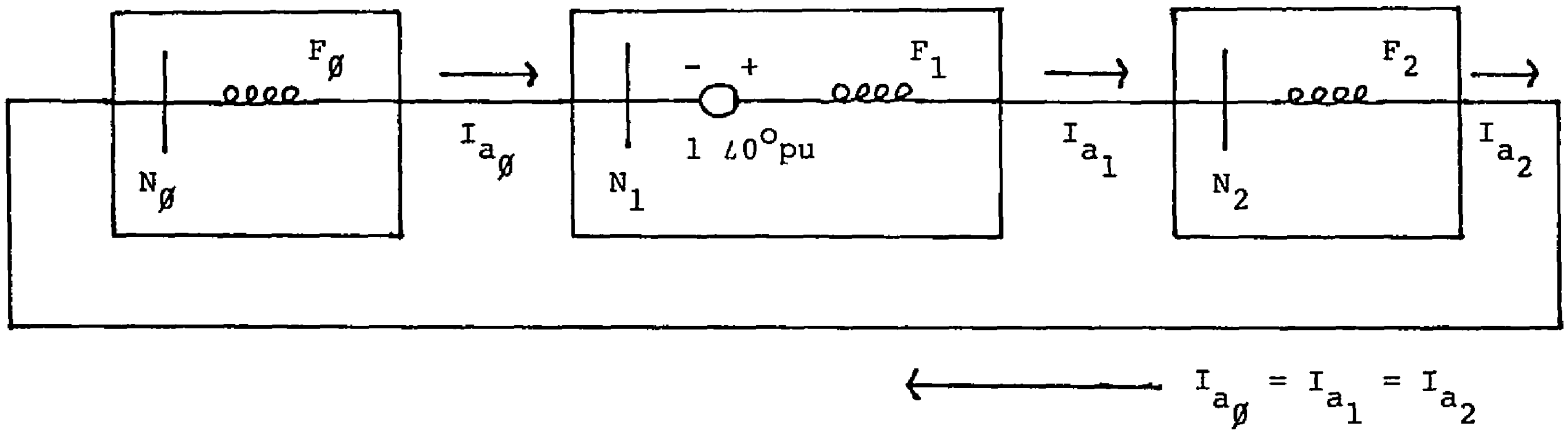
$X_{B\emptyset 3} = 0.1837$ pu

$X_{B\emptyset 4} = -0.021$ pu

$X_{B\emptyset 5} = 0.849$ pu

$$X_{\emptyset} = \frac{(.4087)(1.61)}{.4087 + 1.61} + (-.021) + (.849) = \underline{1.15 \text{ pu}}$$

Figure 9. Zero sequence diagram for the system.



Assuming $X_1 = X_2$

$$X = 1.15 + 1.03 + 1.03 = 3.21 \text{ pu}$$

$$I_{a_1} = \frac{1}{3.21} = .31 \text{ A pu}$$

$$I_a = 3\ (.31) = .93 \text{ A pu}$$

Figure 10. Sequence network connections for a SLG fault.

pu. The computer output showing the results of the preceding calculations and also faults placed on each of the model system buses is shown as Appendix A.

The reduction process becomes very time-consuming as the system becomes larger, but the computer is able to solve systems as large as that of the Western Systems Coordinating Council (WSCC) which comprises the West, Southwest, and part of Canada. After the source impedance for a large portion of the system is found by computer, hand calculations can be used to find fault currents for different changes to the system.

CHAPTER 3

MEAD-LIBERTY LINE STAGED FAULT TESTS

As a member of the Technical Analysis Branch, the writer performed fault current analysis on the power system under Western's jurisdiction (as described in Chapter 1). From the values of fault currents obtained from the PSAP computer runs, the relay settings were determined which would protect the line in question from faults and yet not cause false trips due to normal load currents. When a new line is installed, particularly one having features different from others in the system, it is desirable to conduct tests using staged faults to confirm proper operation of the protective relaying system.

An interesting assignment was being a representative from the Phoenix District Office on such a series of tests performed on the Mead-Liberty 345 kV line in October of 1977. The tests were conducted to examine, under field conditions, the operation and coordination of the protective relays and to demonstrate that the series capacitor protective gaps would flash rapidly enough for various faults, to ensure correct relay performance.

The 238-mile Mead-Liberty line was designed in the mid-1960's as part of the Pacific Northwest-Pacific Southwest intertie for the purpose of connecting the Phoenix, Arizona load center with sources in the Hoover-Mead area of southern Nevada. These sources included not only hydro-generation at Hoover powerplant, but also the southern terminus of a second Pacific d-c intertie which was planned to connect Celilo Substation, in Oregon, to Mead Substation in Nevada. Construction of that d-c transmission system was later indefinitely postponed.

The Mead-Liberty transmission line was initially placed into service in 1969. A transmission line test series planned for late 1970 was postponed after an earthquake severely damaged the Sylmar terminal of the existing d-c intertie, significantly reducing the electrical resources in the Southwest. Subsequently, series capacitors and a phase shifter were added to the transmission system at Liberty. The controlled field tests, with instrumentation at both ends, furnished considerable operating information on the line and terminal facilities with a minimum of risk to the power system. As shown previously, in the section on lightning, it would have taken years to obtain similar data from on-line oscillographic recordings of incidental power system faults.

The relay coordinating tests consisted of one line-to-line and one line-to-ground fault at each of the four locations shown in Figure 11. To minimize the disturbance to the inter-connected power system, these tests were conducted during the early morning hours when system loading is lightest. The series capacitors as well as all shunt reactors were in service at both ends of the line.

Fault locations one and two are external to the Mead-Liberty line and were intended to demonstrate the immunity of the line relays to mis-operation from faults external to their zone of protection. Those faults were particularly useful for examining any tendency for the line relays to operate due to improper sensing of the direction of the fault prior to capacitor bypassing by the protective gaps. The faults at locations one and two were conducted with the local adjacent system isolated from the fault and were initiated by closing the respective Power Circuit Breaker (PCB) into solidly bolted shorting cables.

Fault locations three and four within the protective zone of the Mead-Liberty line relays were established to verify that line faults are quickly and reliably isolated by the primary line relaying. Proper sensing of faults at location three depends on quick, reliable capacitor bypass, for until the capacitors bypass, that location appears to be behind the relays. Proper operation was anticipated if the capacitor gaps bypassed within one cycle. The line faults

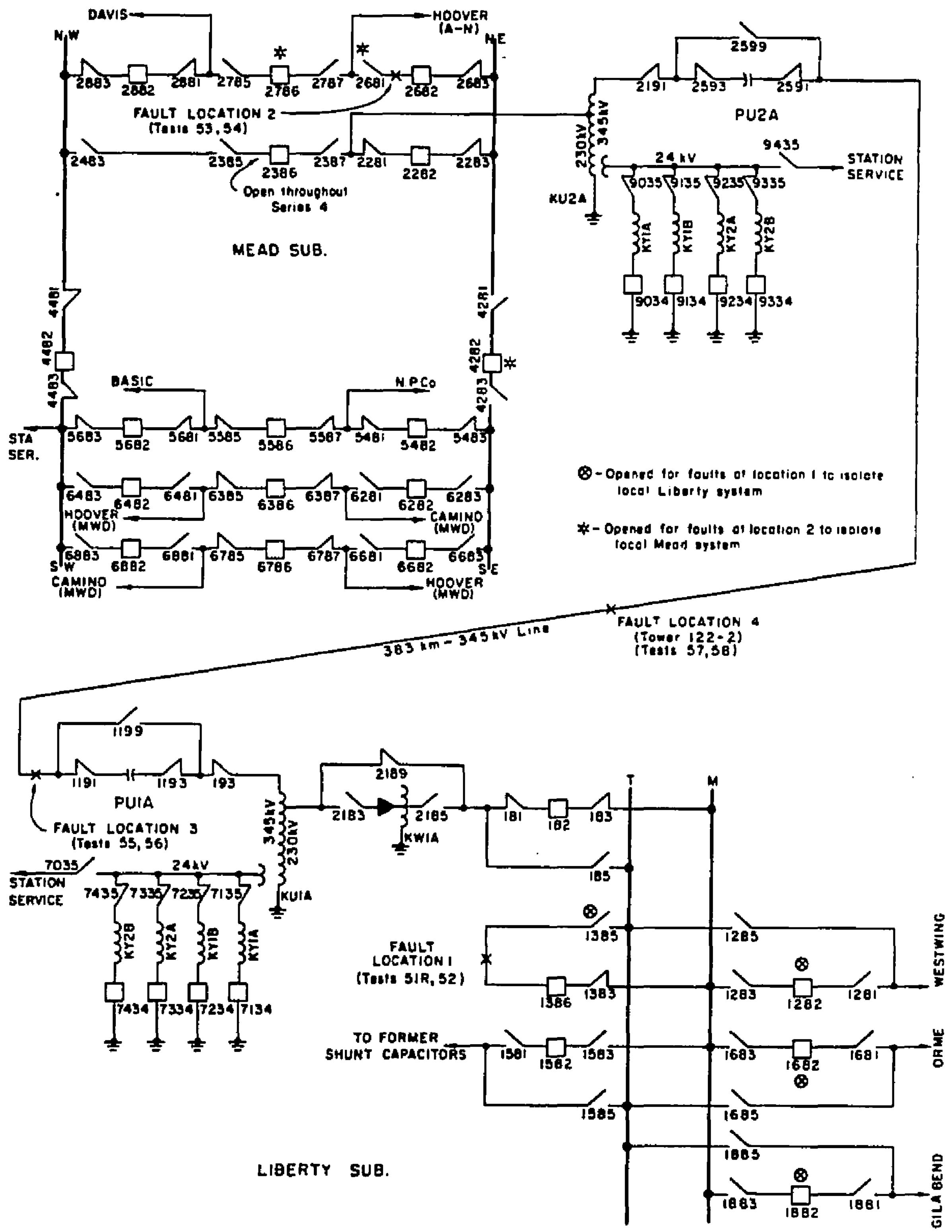


Figure 11. Relay coordination staged fault locations.

at locations three and four were initiated by releasing a weighted rope and pulling a small wire against the transmission line; these were conducted with the maximum system available at both terminals.

The staged faults of series four provided additional data on capacitor bank performance, particularly verification that the banks bypass quickly enough to preclude interference with the protective relaying systems of either the Mead-Liberty or the adjacent 230 kV transmission systems.

The results of the tests confirmed proper operation of the protective relaying system. The series capacitor protective bypass gaps bypassed the fault currents in less than one cycle. Capacitor sparkover voltages compared well with quoted settings. No line relay operations were recorded during the external faults. The staged faults on the transmission lines were quickly and reliably detected and cleared by relay action at Liberty.

Line current signals at Liberty and Mead were obtained from the bushing current transformers on the high side of the auto-transformers. Current amplitudes for the tests are shown in Table 1. Since the system was in a normal operating configuration during the relay coordination portion of the fault tests, the values of current for the faults at location number 3, measured at Mead, are considerably lower than those measured at Liberty (e.g., 730 amps vs. 3350 amps). The

Table 1. Summary of calculated and measured fault currents.

Fault Type and Location	Measurement Location	Calculated** Value (Amps)	Measured** Value (Amps)
Phase A-C Liberty 230 kV (1)*	Liberty	890	890
	Mead	890	740
Phase B-G Liberty 230 kV (1)*	Liberty	250	210
	Mead	250	270
Phase B-C Mead 230 kV (2)*	Liberty	790	710
	Mead	790	800
Phase A-B Liberty 345 kV (3)*	Liberty	3380	3350
	Mead	690	730
Phase C-G Liberty 345 kV (3)*	Liberty	4090	5000
	Mead	690	460
Phase B-C Midline (4)*	Liberty	1390	1300
	Mead	1640	1460
Phase A-G Midline (4)*	Liberty	1210	1460
	Mead	1370	1180

* Location numbers refer to Figure 1.

**On 345 kV bus.

source at Liberty was very close to the fault while that at Mead was separated from the fault location by the length of the Mead-Liberty line. The corresponding current values at location number 4 (e.g., 1460 amps versus 1300 amps) are approximately the same due to the fault location being at about the midpoint of the line.

By performing a series of staged fault tests on a line with new protective relaying equipment, it is possible to verify qualitatively and quantitatively how the transmission line will perform when subjected to fault conditions. If problems develop at a later time or additions are made, the results of the tests can be an invaluable aid.

APPENDIX A

MODEL SYSTEM COMPUTER OUTPUT

The Appendix consists of copies of the computer output from the fault study portion of the PSAP program which was used to analyze the model system in Chapter 2.

```
FILE NAME            FAULTI

FAULTI,CM167777,T200,P4.
ACCOUNT,3G22000.
CHARGE,8OWP3G,3G05.
NOEXIT.
PURGE, FO79BAS.
ONEXIT.
GET,INPUT=FI79BAS.
DEFINE,FO79BAS/CT=PU,M=W,PW=JOHN.
GET,DOPSAP/UN=8A2320A.
CALL,DOPSAP.
REWIND,OUTPUT.
COPYBF,OUTPUT,FO79BAS.
GOTO,DAYFILE.
EXIT.
DAYFILE,FD79BAS.
SUMMARY,OP=R,O=FD79BAS.
REPLACE,FD79BAS.
CHANGE,FD79BAS/PW=JOHN.
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FILE NAME           F19THES

( FICHID )
( FAULT )           FAULT THES
( PSCUT,,001 )
( ZSCUT,,001 )
( OUTPUT PARALLELS )
BF     PARKER1  6.9LC UNIT1              1        .8270        .9933
BF     GILA       4.LC YUMAMESAPP4UNITS1        3.05
BF     GILA     161.LC TRANSF 1AND4       1
BF     PARKER   161.LC UNIT1              1                     .3233
BF     BOUSE    161.LC BOUSE TAP          1
BF     SEN       69.LC SENATOR WASH       1        3.851
BF     GILA      69.LC                    1
BF     GILAMID4 0.0LC MIDPOINTBK4         1                     .4087
FL     BOUSE    161. PARKER  161.         1        .070         .21
FL     PARKER   161. PARKER1   6.9        1        .3223
FL     GILA      69. SEN       69.        1        .283         .849
FL     BOUSE    161. GILA    161.         1        .2984        .8052
FL     GILA       4. GILAMID4 0.0         1        .4087
FL     GILA      69. GILAMID4 0.0         1        -.0210       -.0210
FL     GILA     161. GILAMID4 0.0         1        .1837        .1837
FZ LC
( STOP )
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FAULT STUDY FAULT TIES

IMPEDANCE DATA PAGE 1

										Z-POS	Z-ZERO
1		SOURCE	0.0	-	LC	GILA	4.0	1	YUMABESAPP4UNITS	3.05000	0.00000
2		SOURCE	0.0	-	LC	GILAMID4	0.0	1	MIDPOINTBK4	0.00000	.40870
3		SOURCE	0.0	-	LC	PARKER	161.0	1	UNIT1	0.00000	.32330
4		SOURCE	0.0	-	LC	PARKER1	6.9	1	UNIT1	.82700	.99330
5		SOURCE	0.0	-	LC	SEN	69.0	1	SENATOR WASH	3.85100	0.00000
6	LC	BOUSE	161.0	-	LC	GILA	161.0	1		.29840	.89520
7	LC	BOUSE	161.0	-	LC	PARKER	161.0	1		.07000	.21000
8	LC	GILA	4.0	-	LC	GILAMID4	0.0	1		.40870	0.00000
9	LC	GILA	69.0	-	LC	GILAMID4	0.0	1		-.02100	-.02100
10	LC	GILA	69.0	-	LC	SEN	69.0	1		.28300	.84900
11	LC	GILA	161.0	-	LC	GILAMID4	0.0	1		.18370	.18370
12	LC	PARKER	161.0	-	LC	PARKER1	6.9	1		.32330	0.00000

END FAULT READF TOOK .1000 SECONDS 11.34.08.

END FAULT REDUCEF TOOK .1160 SECONDS 11.34.12.

FAULT STUDY FAULT TIES

SEN 69.0 (THREE-PHASE) ZONE LC

POSITIVE SEQUENCE IMPEDANCE (100 MVA BASE) 1.0283

TOTAL FAULT CURRENT -(PER UNIT) .9725

					CURRENTS -(PER UNIT)
SOURCE	0.0 TO	GILA	4.0	I	.24
SOURCE	0.0 TO	PARKER1	6.9	I	.48
SOURCE	0.0 TO	SEN	69.0	I	.26
BOUSE	161.0 TO	GILA	161.0	I	.48
BOUSE	161.0 TO	PARKER	161.0	I	-.48
GILA	4.0 TO	GILAMID4	0.0	I	.24
GILA	69.0 TO	GILAMID4	0.0	I	-.71
GILA	69.0 TO	SEN	69.0	I	.71
GILA	161.0 TO	GILAMID4	0.0	I	.48
PARKER	161.0 TO	PARKER1	6.9	I	-.48

SEN 69.0 (SL-G) ZONE LC

POSITIVE SEQUENCE IMPEDANCE (100 MVA BASE) 1.0283

ZERO-SEQUENCE IMPEDANCE (100MVA BASE) 1.1540

TOTAL FAULT CURRENT -(PER UNIT-3I0) .9344

ARRESTER-DUTY = .83

					CURRENTS -3I0 -(PER UNIT)
SOURCE	0.0 TO	GILAMID4	0.0	I	.75
SOURCE	0.0 TO	PARKER	161.0	I	.19
BOUSE	161.0 TO	GILA	161.0	I	.19
BOUSE	161.0 TO	PARKER	161.0	I	-.19
GILA	69.0 TO	GILAMID4	0.0	I	-.93
GILA	69.0 TO	SEN	69.0	I	.93
GILA	161.0 TO	GILAMID4	0.0	I	.19

END FAULT FAULTS0 TOOK .5410 SECONDS 11.34.15.
(STOP)

END FAULT FCONTR TOOK .0040 SECONDS 11.34.15.

END FAULT TOOK .8 SEC. - ELAPSED TIME= .836 SEC. 11.34.15. GOING TO STOP

E N D P S A P PS124 ** AH4ICNR 11.34.15 .863 .61 2 6.053 7.344

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    FULL  DAYFILE.            11.34.18.*11.33.52* PAGE     1

11.33.52.FAULTI,CM167777,T200.
11.33.52. PRIORITY= 2
11.33.52.ACCOUNT,3022000.
11.33.54.CHARGE,80WP30,3005.
11.33.55.NOEXIT.
11.33.55.PURGE,FO9THES.
11.33.56.ONEXIT.
11.33.56.GET,INPUT=FI9THES.
11.33.56.DEFINE,FO9THES/CT=PU,M=W,PW=
11.33.56.GET,DOPSAP/UN=8A2320A.
11.33.57.CALL,DOPSAP.
11.33.57.ATTACH,ABPS24M/UN=8A2320A.
11.33.58.REWIND,OUTPUT.
11.34.00.ABPS24M,INPUT,OUTPUT,PL=50000.
11.34.17.     STOP  END OF PSAP 124
11.34.17.       .849 CP SECONDS EXECUTION TIME
11.34.17.REWIND,OUTPUT.
11.34.17.COPYBF,OUTPUT,FO9THES.
11.34.17. END OF INFORMATION ENCOUNTERED.
11.34.17.GOTO,DAYFILE.
11.34.18.DAYFILE,FD9THES.
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