THE PENNSYLVANIA STATE UNIVERSITY
Department of Mineral Engineering

Mining Engineering Section

COAL MINE ELECTRICAL SYSTEM EVALUATION
VOLUME IV — COMPUTER MODELING

Prepared for
UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

by
Lloyd A. Morley
Frederick C. Trutt
Richard A. Rivell

December 4, 1976

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The thrust of this research has been divided into three main areas.
1. Modification of a previously developed model (Mine Power System Simulation or MPSS) to include interactive operation and the use of default (average) load data.
2. Development of a dynamic simulation of interdependent mine power system induction motors.
3. Development of an approach to modeling of motor shaft loading of induction machines for mining operations.

During the course of the current year's research, significant results have been achieved in all areas. Construction of an interactive MPSS model has been completed and checked. This simulation was written in APL code and is fully interactive. In addition, default data representing 158 different pieces of mining equipment has been developed for use with the interactive model. Additional work described includes the construction of a dynamic simulation of interdependent continuous miner induction motors and the development of an approach for motor shaft load torque computation from experimental data.

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DISCLAIMER NOTICE

CERTIFICATION OF THE ABSENCE OF PATENTS AND INVENTIONS

This statement certifies that at the grant report date, no inventions have been developed from Grant G0155003. Consequently, no patents are pending.
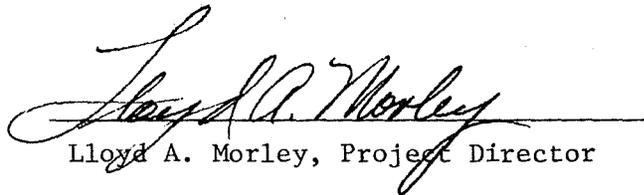
Lloyd A. Morley, Project Director

FOREWORD

This report was prepared by The Pennsylvania State University, College of Earth and Mineral Sciences, Department of Mineral Engineering, in conjunction with the College of Engineering, Department of Electrical Engineering, University Park, Pennsylvania, under USBM Grant No. G0155003. The grant was initiated under the Coal Mine Health and Safety Research Program. It was administered under the technical direction of the Pittsburgh Mining and Safety Research Center with Mr. G. J. Conroy acting as the technical project officer. Mr. J. A. Herickes was the grant administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this grant during the period 5 November, 1975 to 4 November, 1976. This report was submitted by the authors on 4 December, 1976.

This technical report has been reviewed and approved.

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Research performed on computer modeling of mine power systems under USBM Grant G0155003 is described. The work was performed at The Pennsylvania State University from 5 November, 1975 through 4 November, 1976. Results presented are interim in nature, and future research is planned to integrate the simulations which have been developed.

The thrust of this research has been divided into three main areas.

1. Modification of a previously developed model (Mine Power System Simulation or MPSS) to include interactive operation and the use of default (average) load data.

2. Development of a dynamic simulation of interdependent mine power system induction motors.

3. Development of an approach to modeling of motor shaft loading of induction machines for mining operations.

During the course of the current year's research, significant results have been achieved in all areas. Construction of an interactive MPSS model has been completed and checked. This simulation was written in APL code and is fully interactive. In addition, default data representing 158 different pieces of mining equipment has been developed for use with the interactive model. Additional work described includes the construction of a dynamic simulation of interdependent continuous miner induction motors and the development of an approach for motor shaft load torque computation from experimental data.

INTRODUCTION

The future use of high horsepower three-phase induction motors in continuous coal mining operations should continue to increase in order to meet the nation's expanding energy requirements. As a result of this projected electrical mechanization increase, related electrical accidents may be expected to grow unless power systems are properly designed for these loads.

New ideas are constantly being suggested to overcome such problems as poor voltage regulation, poor power-factor, and nuisance circuit breaker tripping. Obviously, the cost of trying each new proposed solution is prohibitive. Yet, the industry can easily turn to computer simulation for the evaluation and prediction of design alternatives.

As a step towards the achievement of such a user oriented simulation, a mine power (electrical) system simulation (MPSS) was developed at The Pennsylvania State University under USBM Grant G0101729. This model has proven itself as a useful tool for mine power system design, but has also been known to have some important limitations. The most serious of these were:

1. Program operation was not totally user oriented and interactive. In addition, large amounts of input data was required.

2. Motor and motor load modeling was not included except as a large data input set derived from in mine voltage, current, power, and power factor measurements.

3. Dynamic response and individual motor interaction was not considered.

4. The power system voltage was not easily matched to the corresponding utility voltage.

The purpose of the current year's work under USBM Grant G0155003 has been to upgrade and modify the MPSS in these areas. In order to achieve this goal, research has been conducted in five major areas. These are:

1. translation of the original MPSS into the APL language to achieve a user oriented and totally interactive interum model,

2. development of a default data set for system loads which considerably reduces required interim simulation input,

3. development of a dynamic model for interdependent continuous miner induction motors,

4. investigation into the feasibility of determining continuous miner motor shaft loading from trailing cable input voltage, current, power, and power factor measurements, plus

5. development of an iterative approach to MPSS which will be fully interactive and user oriented and will allow matching of power system and utility voltages.

The first four of these research areas will be described in this report. The fifth will be touched upon as needed to clarify overall modeling objectives, but its detailed description will be deferred to a subsequent report due at the end of the present grant continuation period.

FORMATION OF INTERACTIVE MPSS AND DEFAULT DATA

Two goals of the present year research were to provide a com-
pletely interactive user oriented MPSS interim model, and to reduce
required input load data. It was decided that the first of these
could best be achieved by translation of the original MPSS (in
FORTRAN - batch mode) into APL (an interactively oriented language).
The second goal has been attained by construction of a default data
set.

Interactive Model

Construction of the interactive MPSS model has been completed.
The program is essentially a one-to-one mapping of FORTRAN into APL in
order to preserve continuity. This will allow anyone with a knowledge
to FORTRAN coding to apply his own logic to make modifications without
a tedious and exhaustive analysis of the present APL code. The trans-
lated simulation has been thoroughly checked and is in good working
order.

Detailed descriptions of execution instructions, functions, storage
considerations, departures from original MPSS, input/output,
optimization, program listings, data structures, and four sample execu-
tion sequences are given in Appendix A. The first execution sequences
are similar to those described for the original MPSS in a report titled
"Evaluation of Mine Electrical Systems with Respect to Safety, Tech-
nology, Economics and Legal Considerations" by R. Stefanko, L. A. Morley,
and A. K. Sinha, NTIS PB 225 476/AS, which was submitted to the U. S.
Bureau of Mines in July, 1973. However, one transformer load has been

modified to obtain a more realistic situation. The sample runs are self-explanatory and include computer interaction data. It should be noted, however, that the example runs labeled "dynamic" are simply manual changes in input loading and do not represent a complete time varying situation.

Default Characteristics

The last sample execution sequence given in Appendix A demonstrates the use of default data. This data is actually average power, current, and power factor at rated voltage for 53 types of mining equipment including continuous miners, belt drives, feeder-breakers, roof bolters, fans, and shuttle cars. Each type includes up to four variations in rated horsepower and rated ac or dc voltage. Thus, 158 different pieces of mining equipment are represented as shown in Table I. The equipment in this table is numbered 20-176 such that specification of the corresponding number as input results in program specification of the required loading. Parameters in the table are in terms of three-phase power, phase current, and line-to-line voltage. The last column titled coding is not utilized in the APL program version. The average loading parameters given were obtained from in-mine measurements (taken during USBM Grants G0101729 and G0133077) in most cases, although some are predicted average values.

Table 1. Default Data.

I. CONTINUOUS MINERS (Cutting and Loading)

   A. Lee-Norse

			$\underline{P}$	$\underline{I}$	$\underline{V}$	p.f.	Code
20.	CM11	(525hp)	181kW	422A	550V	0.45	1111131
21.			181kW	528A	440V	0.45	1111121
22.	CM26	(400hp)	130kW	303A	550V	0.45	1111231
23.			130kW	379A	440V	0.45	1111221
24.	CM28	(200hp)	90kW	157A	550V	0.60	1111331
25.			90kW	197A	440V	0.60	1111321
26.	CM35	(225hp)	120kW	180A	550V	0.7	1111431
27.			120kW	225A	440V	0.7	1114421
28.	CM45	(500hp)	175kW	367A	550V	0.5	1111531
29.			175kW	459A	440V	0.5	1111521
30.	CM60	(500hp)	175kW	367A	550V	0.5	1111631
31.			175kW	459A	440V	0.5	1111621
32.	CM100	(525hp)	181kW	422A	550V	0.45	1111731
33.			181kW	528A	440V	0.45	1111721
34.	CM245	(290hp)	151kW	226A	550V	0.7	1111831
35.			151kW	283A	440V	0.7	1111821
36.	HH105	(450hp)	150kW	350A	550V	0.45	1112131
37.			150kW	437A	440A	0.45	1112121
38.	HH115	(450hp)	150kW	350A	550V	0.45	1112231
39.			150kW	437A	440V	0.45	1112221
40.	HH265	(300hp)	157kW	235A	550V	0.7	1112331
41.			157kW	294A	440V	0.7	1112321
42.	HH455	(450hp)	150kW	350A	550V	0.45	1112431
43.			150kW	437A	440V	0.45	1112421
44.	HH605	(450hp)	150kW	350A	550V	0.45	1112531
45.			150kW	437A	440V	0.45	1112521

   B. Joy

			$\underline{P}$	$\underline{I}$	$\underline{V}$	p.f.	Code
46.	ICM	405hp a-c	181kW	316.7A	550V	0.6	1411131
47.			181kW	395.8A	440V	0.6	1411121
48.		d-c	171kW	329A	550V	--	1421131

Table 1. Continued.

B. Joy (continued)

				P	I	V	p.f.	Code
49.				181kW	724A	250V	--	1421111
50.		475hp	a-c	177kW	371.6A	550V	0.5	1411231
51.				177kW	464.5A	440V	0.5	1411221
52.			d-c	177kW	321.8	550V	--	1421231
53.				177kW	708A	250V	--	1421211
54.	8CM	350hp	a-c	147kW	342.9A	550V	0.45	1421331
55.				147kW	428.6	440V	0.45	1411321
56.	9CM	395hp	a-c	120kW	210.0A	550V	0.6	1411431
57.				120kW	262.4A	440V	0.6	1411421
58.	10CM	535hp	a-c	181kW	244.5A	950V	0.45	1411541
59.				181kW	422.2A	550V	0.45	1411531
60.				181kW	527.8A	440V	0.45	1411521
61.	12CM	385hp	a-c	172kW	174.2A	950V	0.6	1411641
62.				172kW	300.9A	550V	0.6	1411631
63.				172kW	376.2	440V	0.6	1411621
64.		530hp	a-c	214kW	216.8A	950V	0.6	1411741
65.				214kW	374.4A	550V	0.6	1411731
66.				214kW	468.0A	440V	0.6	1411721
67.	14CM	350hp	a-c	170kW	172.2A	950V	0.6	1411841
68.				170kW	297.4A	550V	0.6	1411831
69.				170kW	371.8A	440V	0.6	1411821

II. BELT DRIVES (All Makes)

				P	I	V	p.f.	Code
70		75hp	a-c	39kW	58.5A	550V	0.7	2011131
71.				39kW	73.1A	440V	0.7	2011121
72.			d-c	39kW	70.9A	550V	--	2021131
73.				39kW	156.0A	250V	--	2021111
74.		100hp	a-c	52kW	78.0A	550V	0.7	2011231
75.				52kW	97.5A	440V	0.7	2011221
76.			d-c	52kW	94.6A	550V	--	2021231
77.				52kW	208A	250V	--	2021211
78.		125hp	a-c	65kW	97.5A	550V	0.7	2011331
79.				65kW	121.8A	440V	0.7	2011321
80.			d-c	65kW	118.2A	550V	--	2021331
81.				65kW	260A	250V	--	2021311

Table 1. Continued.

B. Joy (continued)

			P	I	V	p.f.	Code
82.	150hp	a-c	78kW	116.9A	550V	0.7	2011431
83.			78kW	146.2A	440V	0.7	2011421
84.		d-c	78kW	141.8A	550V	--	2021431
85.			78kW	312A	250V	--	2021411
86.	175hp	a-c	91kW	136.5A	550V	0.7	2011531
87.			91kW	170.6A	440V	0.7	2011521
88.		d-c	91kW	165.5A	550V	--	2021531
89.			91kW	364A	250V	--	2021511
90.	200hp	a-c	104kW	156.0A	550V	0.7	2011631
91.			104kW	195.0A	440V	0.7	2011621
92.		d-c	104kW	189.1A	550V	--	2021631
93.			104kW	416A	250V	--	2021611
94.	225hp	a-c	117kW	175.5A	550V	0.7	2011731
95.			117kW	219.3A	440V	0.7	2011721
96.		d-c	117kW	212.7A	550V	--	2021731
97.			117kW	468A	250V	--	2021711
98.	250hp	a-c	130kW	195.0A	550V	0.7	2011831
99.			130kW	243.7A	440V	0.7	2011821
100.		d-c	130kW	236.4A	550V	--	2021831
101.			130kW	529A	250V	--	2021811
102.	275hp	a-c	143kW	214.4A	550V	0.7	2011931
103.			143kW	268.1A	440V	0.7	2011921
104.		d-c	143kW	260A	550V	--	2021931
105.			143kW	572A	250V	--	2021911
106.	300hp	a-c	156kW	233.9A	550V	0.7	2012031
107.			156kW	292.4A	440V	0.7	2012021
108.		d-c	156kW	283.6A	550V	--	2022031
109.			156kW	624A	250V	--	2022011

III. FEEDERS-BREAKERS (All Makes)

			P	I	V	p.f.	Code
110.	100hp	a-c	60kW	78.7A	550V	0.8	3011131
111.			60kW	112.5A	440V	0.8	3011121
112.	125hp	a-c	65kW	97.5A	550V	0.7	3011231
113.			65kW	121.8A	440V	0.7	3011221
114.	150hp	a-c	75.0kW	112.5A	550V	0.7	3011331
115.			75.0kW	140.6A	440V	0.7	3011321

Table 1. Continued.

B. Joy (continued)

		P	I	V	p.f.	Code
116.	175hp a-c	78.3kW	137A	550V	0.6	3011431
117.		78.3kW	171.2A	440V	0.6	3011421
118.	200hp a-c	81.2kW	142.1A	550V	0.6	3011531
119.		81.2kW	177.6A	440V	0.6	3011521
120.	225hp a-c	83.9kW	176.1A	550V	0.5	3011631
		83.9kW	220.2A	440V	0.5	3011621

IV. FEEDERS (All Makes)

		P	I	V	p.f.	Code
122.	50hp a-c	26kW	39.0A	550V	0.7	5011131
123.		26kW	48.7A	440V	0.7	5011121
124.	d-c	26kW	47.3A	550V	--	5021131
125.		26kW	104A	250V	--	5021111
126.	75hp a-c	33.6kW	58.8A	550V	0.6	5011231
127.		33.6kW	73.5A	440V	0.6	5011221
128.	d-c	33.6kW	61.1A	550V	--	5021231
129.		33.6kW	134.4A	250V	--	5021211
130.	100hp a-c	37.3kW	78.3A	550V	0.5	5011331
131.		37.3kW	97.9A	440V	0.5	5011311
132.		37.3kW	67.8A	550V	--	5021331
133.		37.3kW	84.8A	440V	--	5021311

V. ROOF BOLTERS

A. Fletcher, Galis

		P	I	V	p.f.	Code
134.	Single Boom 40hp a-c	15kW	26.2A	550V	0.6	6211131
135.		15kW	32.8A	440V	0.6	6211121
136.	d-c	15kW	27.3A	550V	--	6221131
137.		15kW	60A	250V	--	6221111
138.	Double Boom 80hp a-c	30kW	52.5A	550V	0.6	6211231
139.		30kW	65.6A	440V	0.6	6211211
140.	d-c	30kW	54.5A	550V	--	6221231
141.		30kW	120A	250V	--	6221211

B. Galis

		P	I	V	p.f.	Code
142.	Single Boom 30hp a-c	10.5kW	18.4A	550V	0.6	6211331
143.		10.5kW	23.0A	440V	0.6	6211321

Table 1. Continued

B. Galis (continued)

			P	I	V	p.f.	Code
144.		d-c	10.5kW	19.1A	550V	--	6221331
145.			10.5kW	42A	250V	--	6221311

VI. SECTION FANS (All a-c)

146.	50hp		22.4kW	39.2A	550V	0.6	7011131
147.			22.4kW	49.0A	440V	0.6	7011121
148.	40hp		18kW	31.5A	550V	0.6	7011231
149.			18kW	39.4A	440V	0.6	7011221
150.	25hp		11.2kW	19.6A	550V	0.6	7011331
151.			11.2kW	24.5A	440V	0.6	7011321

VII. SHUTTLE CARS (Ave. Parameters)

A. Joy

152.	10SC	95hp a-c	13kW	19.5A	550V	0.70	4411131
153.			13kW	24.4A	440V	0.70	4411121
154.		60hp d-c	13kW	23.6A	550V	--	4421131
155.			13kW	52A	250V	--	4421111
156.	10SC	135hp a-c	15kW	26.2A	550V	0.60	4411231
157.			15kW	32.8A	440V	0.60	4411221
158.		105hp d-c	15kW	27.3A	550V	--	4421231
159.			15kW	60A	250V	--	4421211
160.	15SC	160hp a-c	20kW	35.0A	550V	0.60	4415131
161.			20kW	43.7A	440V	0.60	4415121
162.	16SC	90hp a-c	10kW	17.5A	550V	0.60	4412131
163.			10kW	21.9A	440V	0.60	4412121
164.		55hp d-c	10kW	18.2A	550V	--	4422131
165.			10kW	40A	250V	--	4422111
166.	18SC	57-1/2hp a-c	9kW	13.5A	550V	0.70	4413131
167.			9kW	16.9A	440V	0.70	4413121
168.		45hp a-c	9kW	16.4A	550V	--	4423131
169.			9kW	36A	250V	--	4423111

B. Torkar

170.	40	40hp a-c	15kW	22.5A	550V	0.70	4311131
171			15kW	28.1A	440V	0.70	4311121
172			15kW	27.3A	550V	--	4321131
173.			15kW	60A	250V	--	4321111

Table 1.   Continued

B.   Torkar (continued)

			P	I	V	p.f.	Code
174.	48	60hp a-c	18kW	37.8A	550V	0.50	4312131
175.			18kW	47.2A	440V	0.50	4312121
176.		60hp d-c	18kW	32.7A	550V	--	4322131
177.			18kW	72A	250V	--	4322111

DYNAMIC MOTOR MODELING

The objective of this task segment was to develop a dynamic model for interdependent continuous miner induction motors as a step towards improved load modeling for the mine power system simulation. The second ingredient required for this improved load model, the actual motor load-torque characteristics, will be discussed in the next report section.

The basic assumptions for the dynamic motor model were as follows.

1. Electrical transients are short compared with mechanical response times. Thus, dynamic representation of the induction machines is based upon steady-state theory.

2. The mine power system can be represented by its Thévenin equivalent circuit. This equivalent circuit will be replaced by the actual mine power system simulation when the load simulations are integrated into the overall model.

3. For the purpose of demonstration, a continuous miner having four motors was considered. However, the simulation was written such that more motors or equipment may be added with minor revisions.

The main program and subroutine listings, program description, and a sample execution sequence are given in Appendix B. A flow chart depicting simulation logic is also included.

Motor Representation

The system to be simulated can be represented as shown in Figure 1. The motors can be switched in or out and loads applied or removed at various times. The available voltage at the motor terminals thus depends on how many motors are on line, and on how the motors are loaded.

Point of assumed constant
input voltage.

Variable voltage Bus
due to drop in feeder
caused by current drawn
by motors operating at
various speeds under
various loads.
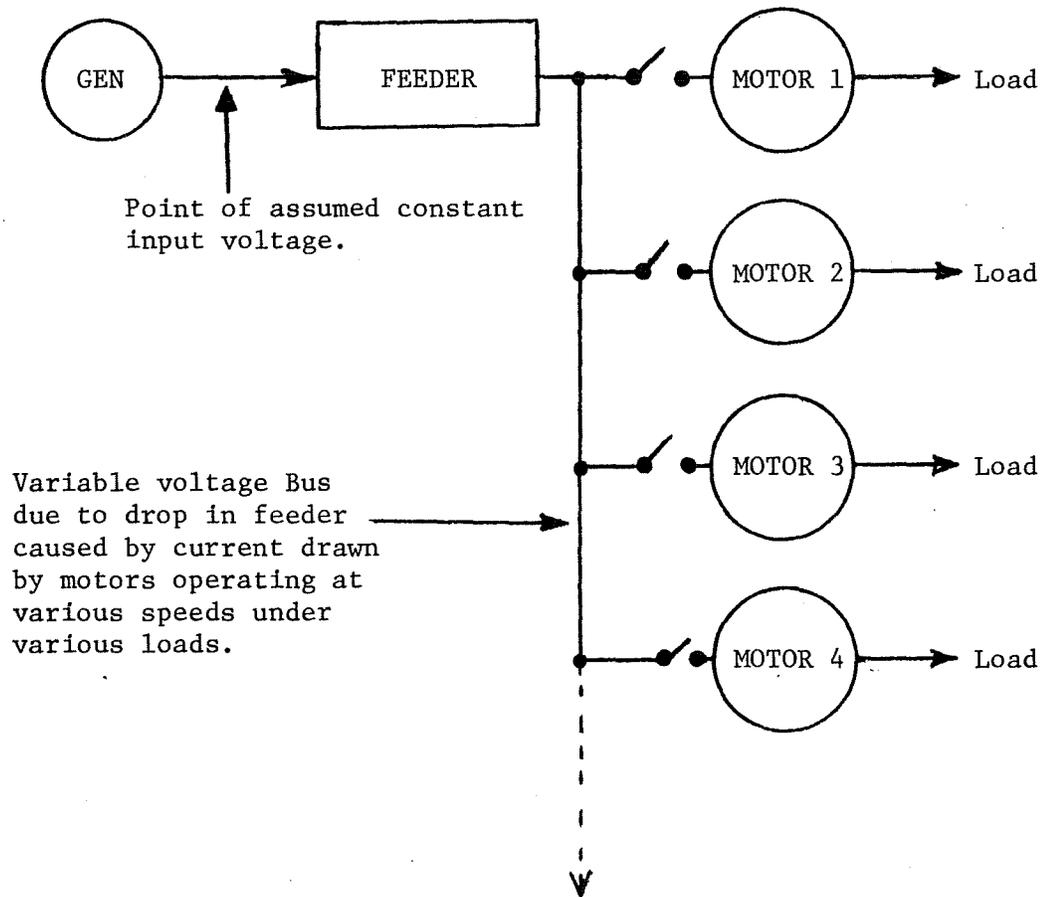
Figure 1. Continuous Miner Motors

The equivalent circuit of one motor is illustrated in Figure 2. The variables shown are as follows:
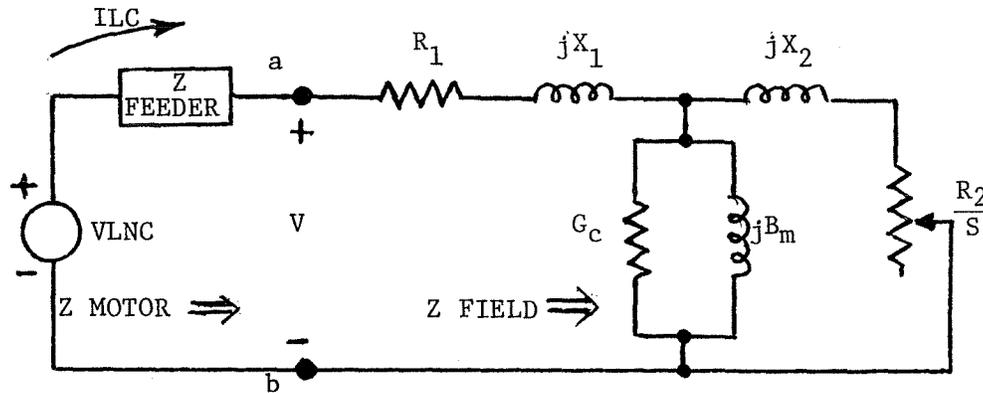
Figure 2. Equivalent Circuit for One Motor

R_1 = stator resistance, ohms

X_1 = stator reactance, ohms

R_2 = rotor resistance, ohms

X_2 = rotor resistance, ohms

G_c = core loss conductance, mhos

B_m = magnetizing susceptance, mhos

s = slip = $(\omega_s - \omega_o)/\omega_s$,

ω_s = synchronous angular velocity of the rotor (in mechanical radians per second), and

ω_o = angular velocity of the rotor (in mechanical radians per second).

The equivalent impedance, Z_{motor}, can be represented as:

$$Z_{rotor} = R_2/s + jX_2 \qquad (1)$$

$$Z_{shunt} = (G_c + jB_m)^{-1} \qquad (2)$$

$$Z_{field} = (Z_{shunt} \ Z_{rotor})/(Z_{shunt} + Z_{rotor}) \qquad (3)$$

$$Z_{stator} = R_1 + jX_1 \tag{4}$$

$$Z_{motor} = Z_{field} + Z_{stator} \tag{5}$$

For a particular slip, s, the impedance at motor terminals a, b (see Figure 2) is thus determined. For a specified voltage applied to the motor terminals, an input current can be computed by:

$$ILC = VLNC/ZTOT \tag{6}$$

where:

ILC = complex line current,

VLNC = complex line-to-neutral voltage,

ZTOT = complex feeder + motor impedance.

From this input current, the voltage drop across the trailing cable impedance is calculated; then the voltage available at the motor terminals (MTVOLT) can be found. The input power and power-factor can also be computed from VLNC and ILC. The voltage drop in the stator is calculated from ILC, Z_{STATOR}, and MTVOLT giving the voltage across both the magnetizing branch and the rotor equivalent circuit. Knowing this voltage and the rotor impedance, the rotor current is computed. The previous operations are handled in the subroutine VOLTAG. The multi-motor interaction will be discussed after the explanation of the torque and power computations.

The power transferred across the air gap between the stator and rotor is given by:

$$Pg_1 = q_1 I_2^2 \frac{R_2}{s} \tag{7}$$

where:

q_1 = number of phases,

I_2 = magnitude of the rotor current, amperes

R_2 = rotor resistance, ohms.

The rotor copper loss is

$$\text{Loss}_{\text{Rotor cu}} = q_1 I_2^2 R_2 \tag{8}$$

The internal mechanical power is then:

$$P_{g1} - \text{Loss}_{\text{Rotor cu}} = q_1 I_2^2 R_2 \frac{1-s}{s} \tag{9}$$

The mechanical power is:

$$P = T\omega_o \tag{10}$$

or

$$P = (1-s)\,\omega_s T$$

Thus, the internal torque developed is:

$$T = \frac{1}{\omega_s} q_1 I_2^2 \frac{R_2}{s} \tag{11}$$

This equation will fail for s = 0 but, because of the losses explained later, the rotor cannot turn at synchronous speed (i.e., s = 0). If the value of s was varied from 1 to 0^+ and I_2 calculated from the equivalent circuit, the internal torque - versus - slip curve would be produced. As explained in the following section, the accelerating torque is the internal torque minus the loss or load torque.

Integration

Torque
(NM)

MOTOR

LOAD

ΔT

Δt

A   B   C   D   E   F

SLIP
or
SPEED
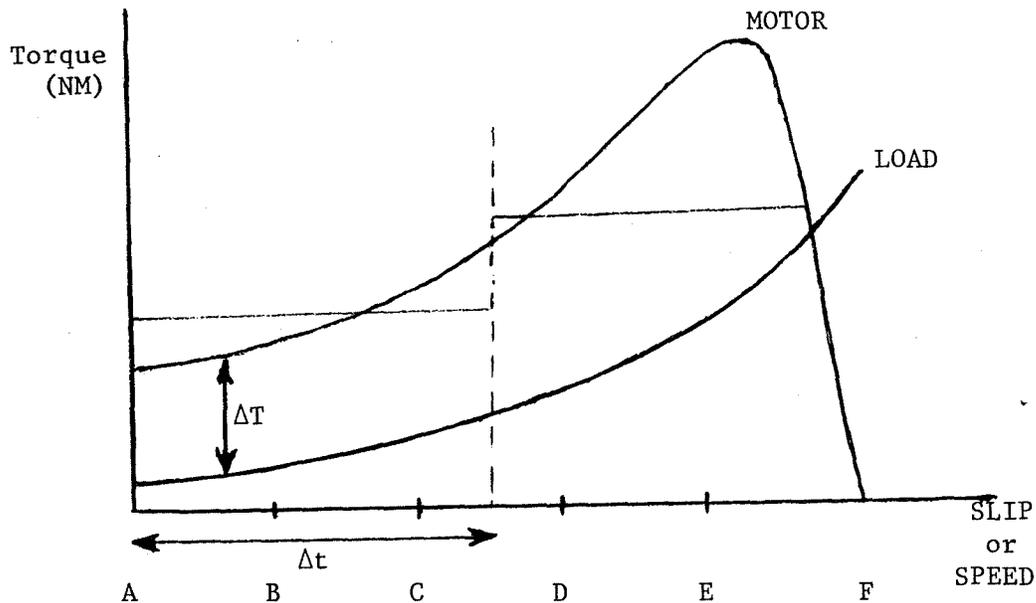
Figure 3. Motor Torque-Speed and Load Curves

For starting, the motor is connected across the feeder with no load
except its losses. When the load changes, the load is applied while the
motor is connected to the feeder and running. Assume, as an example,
that a motor is to be started. Figure 3 shows the motor and load
torques and is exaggerated for the purpose of explanation. There are
actually on the order of 10^3 integration steps. The starting load is
also shown much greater than its actual value.

The torque-slip curve is as given only if no other motors are
connected to the system. If other motors are connected, the interaction
will alter the available voltage and thus the output torque.

Assume for the moment that there is only one motor connected. At
the instant the motor is connected across the trailing cable, it is at
point "A" on the motor curve, loaded by the indicated torque. The

motor cannot turn instantly, so the terminal voltage at time $t = 0^+$ (starting time for Motor 1) can be calculated according to the trailing cable and motor parameters. From this, the rotor current and thus the output torque are computed. Power output (in this case, zero) can be calculated. Motor voltage is then assumed constant for some Δt, which means that the output torque is also constant. (This isn't acutally the case, but for small increments it approximates a continuous curve.) The difference in the motor output torque and the load torque is the torque available to accelerate the load.

Acceleration of a rotating mass is governed by the following relationship:

$$J \frac{d\omega_o}{dt} = \Delta T \qquad (12)$$

where:

ΔT = the available accelerating torque, Newton-meters

J = the rotational inertia of rotor and load, Newton-meter-sec^2

$\frac{d\omega_o}{dt}$ = the change in speed with respect to time, rad/sec^2

Rearranging and integrating:

$$\omega_o = \frac{\Delta T}{J} \int_o^t dt \qquad (13)$$

To perform the integration on a digital computer, time is broken into small increments, and the speed change is computed and summed to the previous speed.

Thus,

$$\Delta\omega_o = \frac{\Delta T}{J} \Delta t \quad \text{and} \quad \omega_o^1 = \omega_o + \Delta\omega_o \qquad (14)$$

where:

ω_o^1 = the new angular speed, rad/sec^2

From this new speed, $\omega_o + \Delta\omega_o$, a new slip is calculated. Then a voltage, torque, and power output can be computed for the next time increment.

This procedure continues until either of the following things happen.

1. ΔT falls to zero when the motor and load torques match. When this occurs, the integration is not performed ($\Delta T \rightarrow 0 \Rightarrow \Delta\omega_o \rightarrow 0$) and the motor runs with constant velocity at the operating point determined by the intersection of the load and motor torque curves.

2. An operation shift requiring a load change on this motor occurs. When this happens, a new load torque is applied which indicates a new ΔT. This ΔT is calculated, and a test is performed to determine whether it is positive or negative. If positive, acceleration is indicated, if negative, deceleration.

At the end of one time increment, the new slip may not be exactly on one of the slip increment points. A simple equation is used to compute the load torque at this point by regarding the load-torque curve to be composed of line segments. For instance, the load-torque curve is composed of straight lines between A and B, B and C, and soforth. (There are actually 2×10^2 points describing this curve.) Therefore, after one Δt, the motor is operating between C and D. The new load torque is computed by assuming a straight-line approximation and calculating the intermediate load-torque value.

Motor Interaction

Now that the operation of the individual motor has been covered,

motor interaction can be discussed.

It has been shown that for any particular motor speed (slip), the motor can be represented as a complex impedance. Because the motors are to be connected in parallel, this impedance will be regarded as some equivalent admittance, Y_{MOTOR}. Because the motors can have different parameters and can operate at various speeds, the admittances of the motors can be different so a subscript will be used to denote a particular motor, as Y_{MOTOR_1}, and so on. Instead of only one motor connected to the trailing cable, there can be any number of motors. Further, the load on the trailing cable is composed of the sum of the individual motors. The first calculation determines the equivalent impedance from which the input current is calculated. The interaction will be demonstrated in Appendix B by running through the actual program procedure. Before this is done, however, the command structure will be described.

Command Philosophy

Up to four motors (more with minor changes) can be connected to the trailing cable. The motors are started and stopped by means of neumonic commands. A load change is also accomplished in this manner. The command sequence is general so any or all motors can be started, loaded, unloaded, and stopped in any sequence, at any particular time.

A load change on one or more motors would occur upon maneuvering, changing from one operation to another, and so forth. To build the command list, it is necessary to know the loads that are applied to each motor, and how these loads change, for the above operations.

Table 2. Assumed Sequence of Operations

Starting Sequence →
- Start hydraulic motor
- Start 1st cutting motor
- Start 2nd cutting motor
- Start conveyor motor

Load Changes →
- Maneuver to face
- Sump
- Shear

Stop Motors →
- Stop cutting motors
- Stop remaining motors
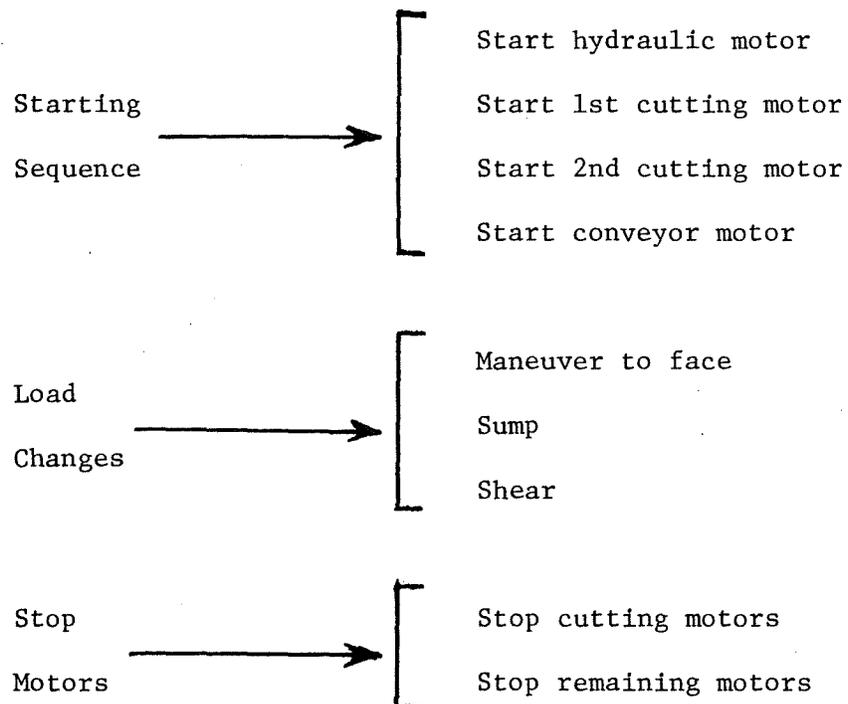
Table 3. Sample Command List

(Time)	Pump (Motor 1)	Hydraulic (Motor 2)	Cutting #4 (Motor 3)	Cutting #4 (Motor 4)
0	STRT			
5			STRT	
10				STRT
15		STRT		
20	CHL1			
25	CHL2	CHL1	CHL1	CHL1
30	CHL3		CHL2	CHL2
35			STOP	STOP
40	STOP	STOP		

Assume the sequence of operations provided in Table 2 is to be simulated. The starting loads must be known for the starting sequence simulation. This load consists of friction and windage of the rotor and other moving parts. The loading of each motor for each operation must also be known. As an example, assume the loading is as follows.

1. There is a starting load particular to each motor.

2. Maneuvering changes the load on the pump motor only.

3. The sumping operation changes the loading of all motors.

4. The shearing operations changes the loading of the pump and cutting motors.

The command list would be constructed as shown in Table 3, assuming for simplicity that the operation changes occur every five seconds. This is how the data is actually entered in the program. In other words, each line is a data card representing a specific operation, while each column is the command string for an individual motor.

The command "STRT" tells the program to turn the particular motor on with its starting load applied. The commands "CHL1", "CHL2", and so on, apply a load to the motor representing some operation. For instance, the command "CHL1", in the column representing Motor 1, tells the program to apply the first load-torque entered after the starting load-torque curve to Motor 1. "CHL2" applies the second load-torque curve and so forth. The "STOP" command removes the motor from the trailing cable. Results for this example operation sequence are given in Appendix B.

Summary

Based upon specified simplifying assumptions, the theory for dynamic modeling of in-mine induction motors has been developed and implemented. Results of the load modeling for a continuous miner example show expected variations due to motor interaction and loading. Planned future work on this area includes integration of motor models with simulations of the mine power system and motor mechanical loading.

MOTOR SHAFT LOADING

The dynamic continuous miner motor model discussed previously requires specification of the shaft load torque on each motor at a particular time for typical mining operations. This torque will, of course, not remain constant but will vary in time according to changes in the mine floor, seam characteristics, conveyor loading, and so on, in addition to changes which occur when changing operations such as from sump to shear.

The scope of work proposed to obtain these load-torque characteristics was to define models of selected continuous miner motors utilizing data obtained from the manufacturers. These models were then to be used in conjunction with in-mine test data to determine actual shaft torque loading. This procedure has been followed, and the theoretical development will be given in the following. A discussion of the computer programs utilized, sample output, and program listings are in Appendix C.

Theoretical Development

The equivalent circuit for an induction motor, with a trailing cable line impedance included, is shown in Figure 4. Torque (T) and slip (s) can be computed given the input voltage (V_1), the line current (I_1) and the power-factor (pf) or power (P). Either power or power-factor may be used, depending on which is more accurate for a given set of input data. For present data, power-factor is more accurate and will be used in the equations.
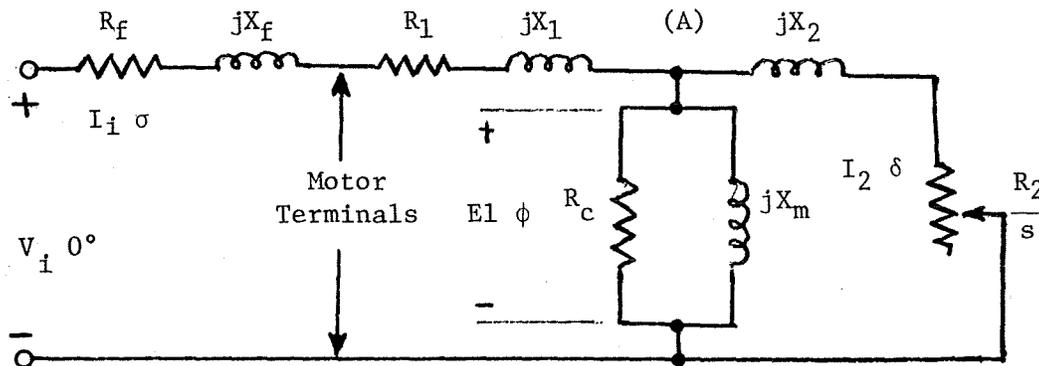
Figure 4. Induction Motor Equivalent Circuit

This circuit will be solved from left to right using Kirchhoff's Current and Voltage Laws, with the input values being the magnitude of the voltage (V_i) and of the line current (I_i). Using the current magnitude and power-factor, the complex line current $I_i \underline{/\theta}$ is

$$I_i \underline{/\theta} = (I_i) (pf) - j (I_i) (\sin (\cos^{-1} (pf))) \qquad (15)$$

where the minus sign is due to the zero reference assumed for the voltage. This sign indicates that the current lags input voltage for an inductive circuit. Applying Kirchhoff's voltage law around the input loop will give $E1 \underline{/\phi}$:

$$E1 \underline{/\phi} = V_i \underline{/0°} - ((R_f + j X_f) + (R_1 + j X_1)) (I_i \underline{/\theta}) \qquad (16)$$

Kirchhoff's current law at node (A) gives the current I_2:

$$I_2 \underline{/\delta} = I_i \underline{/\theta} - (E1 \underline{/\phi}) \left(\frac{1}{R_c + jX_m}\right) \qquad (17)$$

Kirchhoff's voltage law around the output loop gives for the slip (s):

$$E1 \underline{/\phi} = \left(\frac{R_2}{s} + jX_2\right) (I_2 \underline{/\delta}) \qquad (18)$$

or

$$s = R_2/(\frac{E1\angle\phi}{I_2\angle\delta} - jX_2) \qquad (18)$$

Torque (T) can then be found from:

$$T = \frac{(3)\ I_2^{\ 2}\ (R_2)\ \frac{(1-s)}{s} - (power\ loss\ term)}{\omega_s} \qquad (19)$$

where

ω_s = the synchronous speed of the motor given by

$$\omega_s = \frac{4\pi f}{P}, \ rad/sec^2$$

f = the frequency (60 HZ)

P = the number of motor poles.

In the equation 19, the first numerator term is the power transferred

across the air gap and, after subtracting the power loss term (which

includes friction, windage, and stray load losses), this torque becomes

the output torque available at the shaft. All of the preceeding

equations are used in a computer program to solve for torque and slip

as described later.

One difficulty is the equation for slip. This equation involves

phasors, and slip is real number. Therefore, if input voltage and

current are not exact values, the angles in the denominator will not

cancel to give a real slip value. Since input voltage, current, and

power-factor are measured values, computed slip may be complex. This

is utilized as a check as to the consistency of input measurements.

At the present time, a 10% complex slip is allowed where the

percentage is defined as

$$\% \text{ complex} = \frac{\text{Im (complex slip)}}{\text{Re (complex slip)}} \times 100 \qquad (20)$$

If slip is more than 10% complex, the input point is considered invalid and is not used. This 10% limit may be changed after many more input points are checked for data accuracy. The slip value, used in the torque equation, is its magnitude. From previous work, it is known that voltage and current measurements are fairly precise, but that power-factor values were sometimes subject to experimental error. Therefore, if measured power of an invalid point can be utilized to validate measurements, more points will be available for representing load torque.

The torque discussed thus far is not the load-torque value desired, but is the value produced by the motor as it tries to accelerate or decelerate to reach the applied load. To find the actual load torque, the following equation is used:

$$J \frac{d\omega_o}{dt} = \Delta T \qquad (20)$$

This is the dynamic load equation for an induction motor where J is rotating moment of inertia. Figure 5 shows a typical torque-slip characteristic for a motor and a load-torque curve.
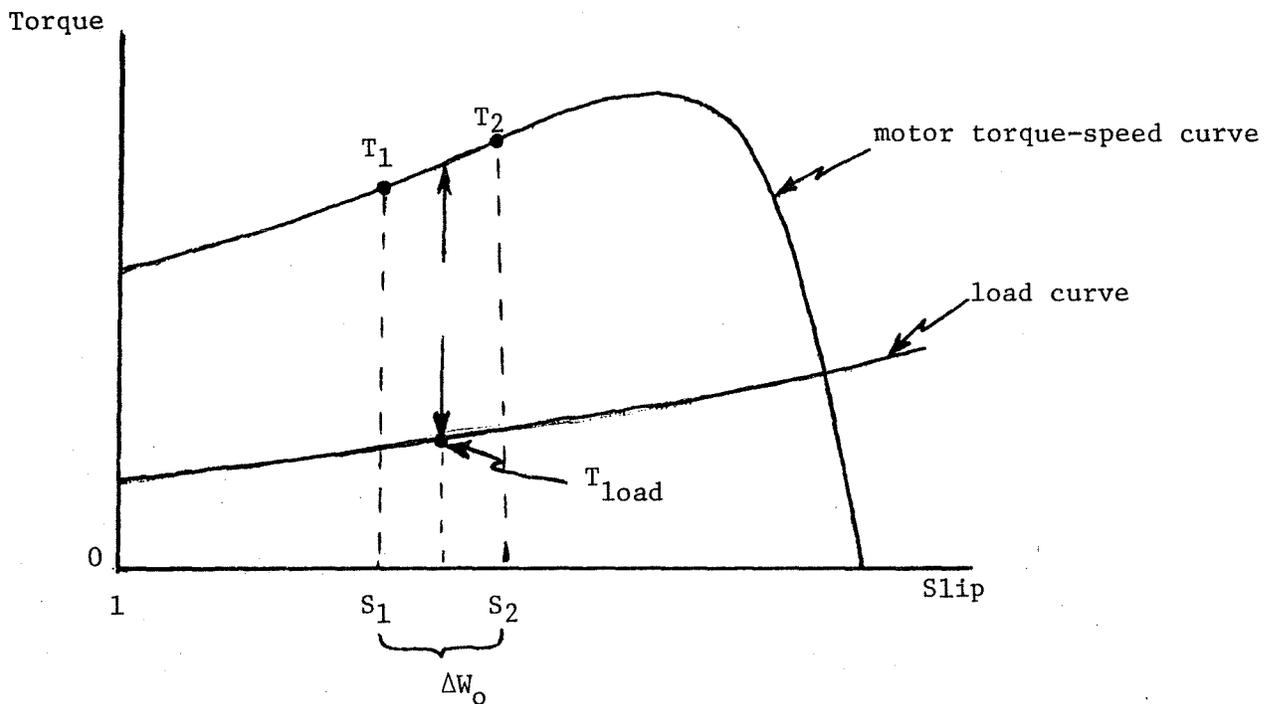
Torque

Figure 5. Motor and Load Torque-Speed Curves

In finite difference form,

$$J \frac{\Delta \omega_o}{\Delta t} = \Delta T, \qquad (21)$$

and ΔT can be evaluated from the time increment between points and the speed at consecutive points. Expressing $\Delta \omega_o = \omega_{o2} - \omega_{o1}$, and letting $\omega_{o2} = \omega_s (1-s_2)$ and $\omega_{o1} = \omega_s (1-s_1)$, this becomes:

$$\Delta T = \frac{J\omega_s ((1-s_2) - (1-s_1))}{\Delta t}$$

or

$$\Delta T = J \frac{\omega_s (s_1-s_2)}{\Delta t} \qquad (22)$$

ΔT is the torque required to accelerate the motor from s_1 to s_2 in Δt seconds. Load torque can now be found by subtracting ΔT from the motor torque. The actual value of torque, that ΔT is subtracted from,

is the average of the motor torque at points 1 and 2, and the load

torque is assigned a slip value which is the average of the slips at

1 and 2.

Thus:

$$T_{Load} = \frac{T_2 + T_1}{2} - \Delta T \qquad (23)$$

or

$$s_{Load} = \frac{s_2 + s_1}{2} \qquad (24)$$

This torque and slip are the desired load values.

Summary

The proposed approach to motor mechanical load modeling has been

investigated and appears to be yielding useful results. A sample run

of this procedure for a maneuver operation is given in Appendix C and

shows the variability of these mechanical load torques. Planned

future work will include the application to this method to a wide

variety of operations in an attempt to better classify and separate

this loading. Upon achievement of this goal, the mechanical loads will

be integrated with the motor and mine power system models.

APPENDIX A

INTERACTIVE MINE POWER SYSTEM SIMULATION

APL VERSION: MINE ELECTRICAL SIMULATOR

(LOAD FLOW)

(THIS VERSION OF THE M.P.S.S. *ALLOWS A*
CONVERSATIONAL MODE OF COMMUNICATION
BETWEEN THE USER AND THE PROGRAM INPUT)

CONCLUSIONS AND RECOMMENDATIONS

The research performed during the current project year has resulted in significant progress towards the removal of the limitations associated with the mine power system simulation. This model is now completely interactive, and the default data developed have provided a practical means for interim load modeling.

Significant progress towards the achievement of improved load models which include dynamic motor and motor shaft loading characteristics has also been achieved. The motor models are presently in useable form, and incorporation of these models into MPSS is planned during the upcoming project year. The motor shaft loading has proved somewhat more elusive, but it now appears that the proper methods have been developed to achieve useable values. A few difficulties still remain relating to the classifications of shaft load-torque characteristics and to the separation of individual motor loads using cable measurements. It is expected that these will be resolved using present methods. Further in-mine measurements may be required to achieve this goal however.

Recommended work for the future includes continued work on the interactive and interative approach to MPSS (progress in this area will be detailed in a subsequent self-contained report) in order to remove the voltage matching limitation and add additional simulation versatility. Upon achievement of this objective, the mine power system simulation and improved load models will be combined to achieve a dynamic balanced model of mine power systems.

TO EXECUTE THE MINE ELECTRICAL SIMULATOR:

COPY WORKSPACE **MPSS** FROM USER LIBRARY RAR01 AND

EXECUTE MAIN PROGRAM MESS.EXPIRATION DATE:SAME AS P0245

FUNCTIONS IN WORKSPACE MESS INCLUDE:

FUNCTIONS WRITTEN BY R.A.RIVELL 3/376

ACLOADS FINDTL LADDER LODFLO INIT   **MPSS**
PFCC   PRINT   RDDLF   RRLS   STOFF XFMR
ZEQUIV

FUNCTIONS WRITTEN BY E.E. DEPT., UNIV. OF ALBERTA

AES CADD CDIV CMUL IM RE PJ MST RNK

STORAGE CONSIDERATIONS:

SPACE REMAINING IN WORKSPACE: 17004 BYTES.

THE ARRAY EQUIP CONTAINING THE EQUIPMENT CATALOG
ENTRIES PRESENTLY HOUSES DATA IN COLUMN 4 WHICH IS
NOT USED. APPROXIMATELY 2K BYTES CAN BE RECOVERED
BY REMOVING THIS DATA.

THE ARRAY DATA WHICH CONTAINS THE INPUT DATA FOR
DYNAMIC RUNS IS CURRENTLY OF LENGTH 400 AND IS
EXPANDED DYNAMICALLY BY 100 INCREMENTS WHEN EXCEEDED.
BOTH THE INITIAL SIZE AND INCREMENTAL INCREASE MAY BE
REDUCED.

THE OUTPUT MESSAGES MAY BE REDUCED BY USING A VARIABLE
FILLED WITH BLANKS AND ANOTHER FILLED WITH ASTERISKS.

INPUT FROM BAT FILES TO FILL THE EQUIP ARRAY WILL
REDUCE STORAGE WHEN THE BFIO OPTION IS OPERATIONAL.

AN INCREASED USE OF LOCAL VARIABLES AND REDUCTION OF

INTERMEDIATE VARIABLES WILL ALSO INCREASE AVAILABLE
STORAGE. TO RETAIN CLARITY FOR SUBSEQUENT MODIFICATIONS
THESE TECHNIQUES WERE KEPT TO A MINIMUM.

SIGNIFICANT DIFFERENCES FROM FORTRAN VERSION:

DC LOAD INPUT HAS BEEN ALTERED TO COMPLY WITH THE
DEFAULT STRUCTURE OF THE EQUIPMENT CATALOG. THE
INFORMATION IN THE CATALOG IS STRUCTURED AS:
          POWER VOLTAGE POWER-FACTOR
THE FORTRAN VERSION; HOWEVER, CALLS FOR DC LOADS AS:
          VOLTAGE POWER
THUS, THE SELECTION OF A CATALOG ENTRY WOULD HAVE
INPUT POWER FOR VOLTAGE AND VOLTAGE FOR POWER
THEREFORE, DC LOAD INPUT IN THE APL VERSION IS:
          POWER VOLTAGE

THE EQUIPMENT CATALOG NUMBERS HAVE BEEN
TEMPORARILY REPLACED WITH SEQUENTIAL NUMBERS
FROM 20 THRU 175. THIS ELIMINATES THE USE OF ABOUT
2K BYTES TO STORE THE CODE NUMBERS

INPUT/OUTPUT:

TERMINAL INPUT/OUTPUT IS THE ONLY FORM PRESENTLY USED
THE EQUIPMENT CATALOG PRESENTLY CONTAINS 4 VALUES PER
ENTRY: POWRE VOLTAGE POWER-FACTOR HORSE-POWER
HORSEPOWER IS NOT USED. DURING DEFAULT SELECTION
IT MUST BE KEPT IN MIND THAT THE PHASE ANGLE IS NOT
IN THE CATALOG. THUS, TO OVERRIDE THE POWER-FACTOR
THE NEW VALUE MUST BE THE THIRD VALUE IN THE LIST.
(I.E. THE INPUT LIST: 82 0 0 .65 OVERRIDES ONLY THE
POWER-FACTOR

OPTIMIZATION

NO ATTEMPT HAS BEEN MADE TO IMPROVE THE FORTRAN VERSION.
THE APL CODE IS ESSENTIALLY A ONE-TO-ONE MAPPING OF THE
FORTRAN INTO APL. THIS WILL ALLOW ANYONE TO ADD THE
FAULT CALCULATIONS IF AND WHEN DESIRED, WITHOUT A TEDIOUS
ANALYSIS OF THE APL CODE

EXAMPLE EXECUTION SEQUENCES:

THE FOUR EXECUTION SEQUENCES DEPICT VARIOUS OPTIONS
AVAILABLE FOR PROGRAM EXECUTION, INPUT, AND DATA CHECKING
THE CASE STUDY CONTAINS: THREE PANELS ON FEEDER LINE ONE,
AND FIVE PANELS ON FEEDER LINE TWO. THE FOLLOWING LOAD TYPES
AND TRANSFORMER CONNECTIONS ARE USED:

FEEDER LINE ONE:

PANEL	LOAD	TRANSFORMER CONNECTIONS
1	1 AC	Δ Y Δ
2	3 AC	NONE
3	1 DC	Δ Y Δ

FEEDER LINE TWO:

1	1 AC 1 DC	Δ Y Δ
2	1 AC	Δ Y Δ
3	1 AC	Y Y Δ
4	1 AC	Y Δ Δ
5	1 AC	Δ Δ Δ

THE LINES CONNECTING PANELS TO FEEDER LINES AND FEEDER
TO MAIN TRANSFORMER ARE SHORT AND THEREFORE ARE CONSIDERED
AS NON-EXISTANT. CALCULATIONS DO NOT INCLUDE MAIN MINE
TRANSFORMER.

FEEDER LOAD 1

XMSN LINE   XMSN LINE

d

PANEL n   PANEL 2   PANEL 1

FEEDER LOAD 2

c

PANEL n   PANEL 2   PANEL 1

FEEDER LOAD n

b

PANEL n   PANEL 2   PANEL 1

a

MAIN MINE
TRANSFORMER
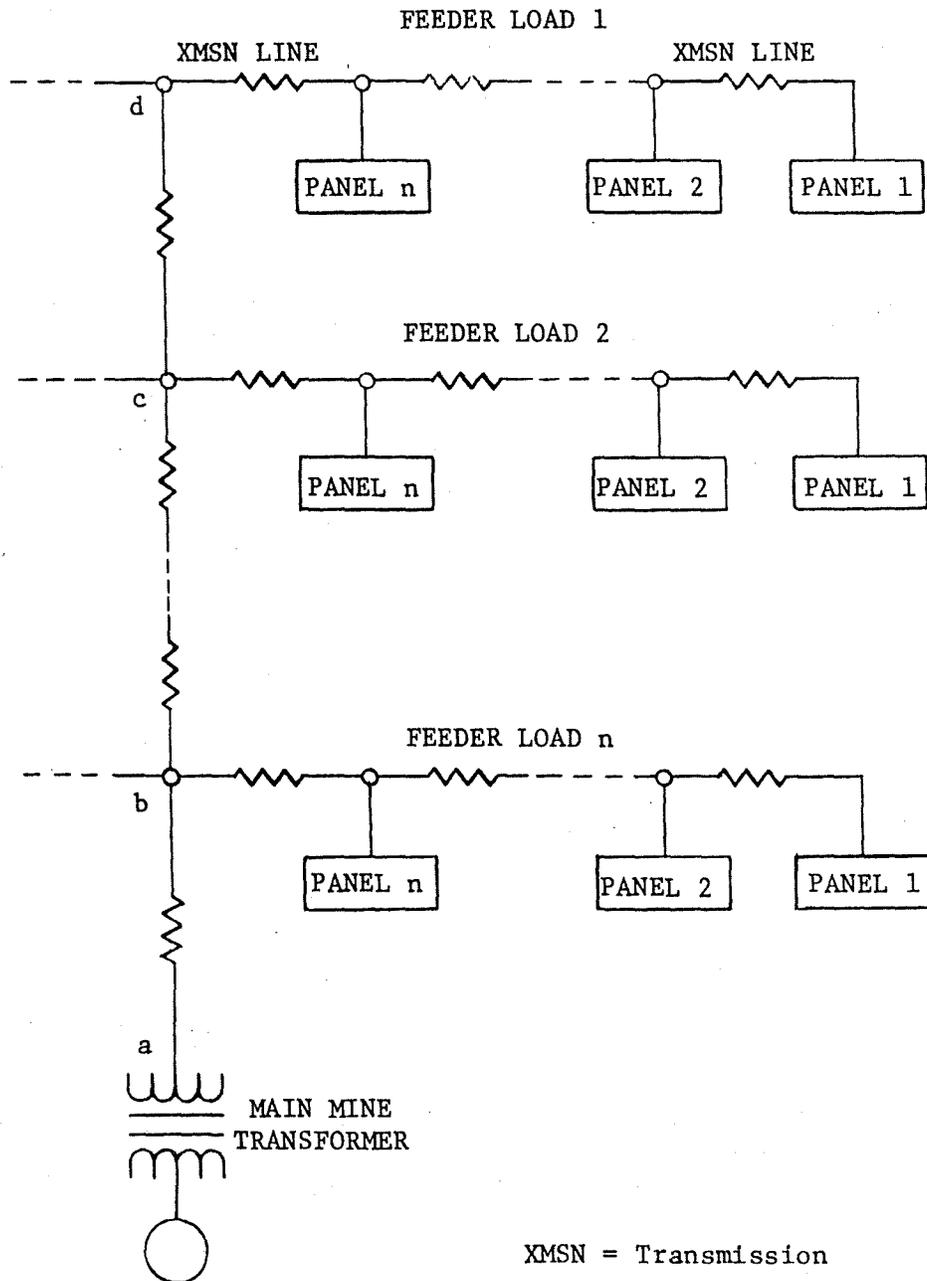
XMSN = Transmission

Figure 6.   Overall Mine Power System Schematic
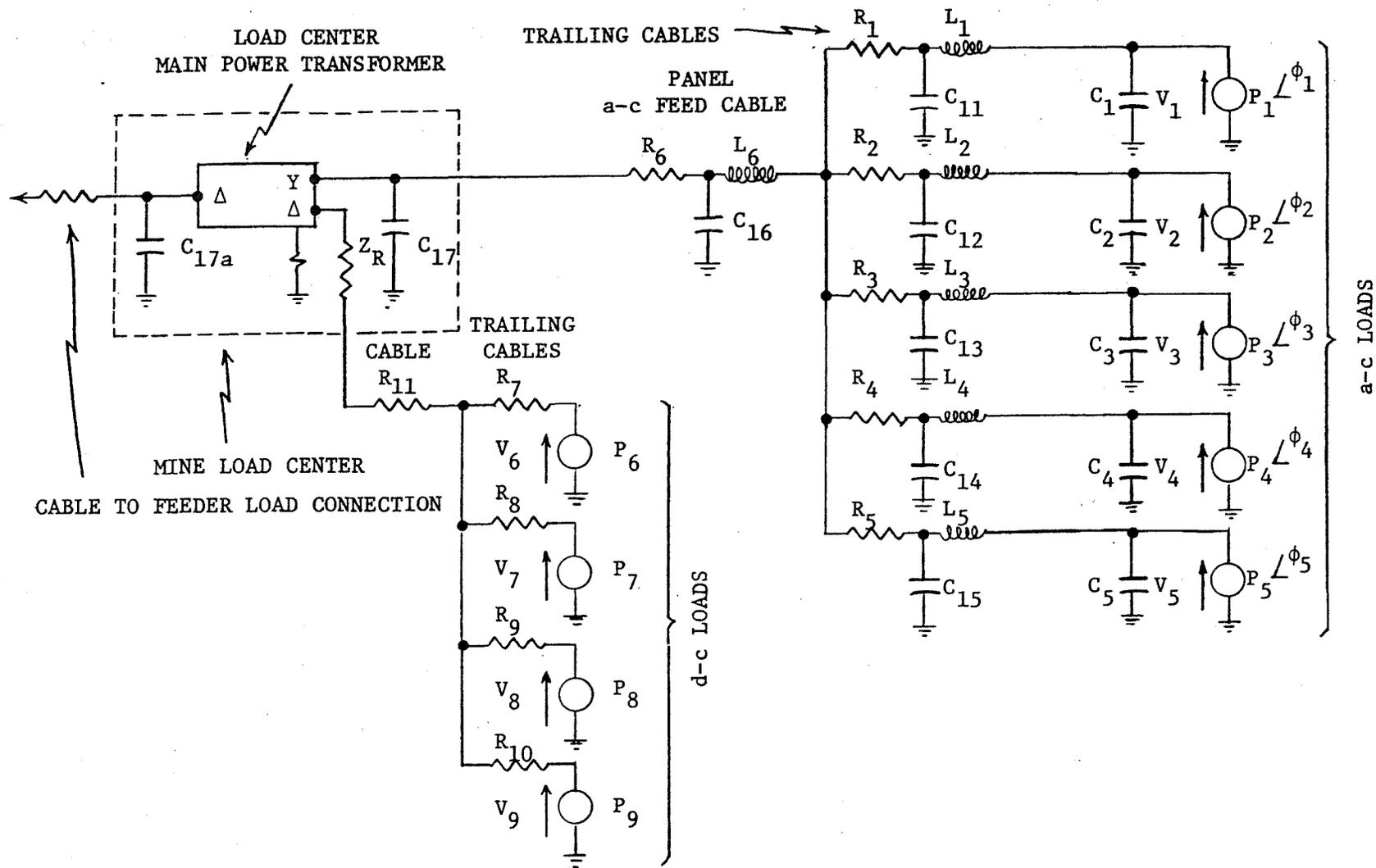
Figure 7. Simplified a-c/d-c Panel Load Center

Table 4. Type Specifications for Transmission Line Input

Type	Size
1	No Cable
2	# 8
3	# 6
4	# 4
5	# 2
6	# 1
7	1/0
8	2/0
9	3/0
10	4/0
11	250 MCM
12	300 MCM
13	350 MCM
14	400 MCM
15	500 MCM

PROGRAM   LISTINGS

(PROGRAMS WRITTEN BY: R.A.RIVELL)

```
        ∇ MPSS[⎕]∇
      ∇  MPSS
[1]     INIT
[2]     IN←NDYN←0
[3]     QT←'123456789'
[4]     LOOP1:' '
[5]     '*****RUN DESCRIPTION*****'
[6]     ' '
[7]     '                    INPUT TITLE FOR THIS RUN'
[8]     MNAME←⎕
[9]     '                    SELECT RUN TYPE AS S-STATIC, D-DYNAMIC, F-FAUL
      T'
[10]    IOPT←⎕
[11]    NDYN←NDYN×(IOPT='D')
[12]    →(IOPT≠'F')/NFLTS
[13]    '                    SELECT FAULT TYPE AS 1-SINGLE LINE TO GROUND,2
      -LINE TO LINE TO GROUND,'
[14]    '                            3-LINE TO LINE,          4
      -THREE PHASE SYMMETRICAL'
[15]    ITYPE←⎕
[16]    '                    SELECT FAULT LOCATION AS 0-AT MACHINE CORRECTI
      ON COMPONENTS'
[17]    '                                1 THRU 8-10 THRU 80 P
      ERCENT OF CABLE LENGTH'
[18]    '                                9-AT DISTRIBUTION BUS
      BAR'
[19]    IPOS←⎕
[20] NFLTS:OPTNS←19ρ0
[21]    '                    DEFAULT CODES USED THIS RUN? YES OR NO'
[22]    CODES←(1=(ECHO←⎕)ι'Y')
[23]    '                    IS DATA ECHO-CHECKING DESIRED? SOME, NONE, ALL'

[24]    ECHO←⎕
[25]    →(1=ECHOι'N')/NECHO
[26]    →(1=ECHOι'A')/ALL
[27]    '                    SELECT ECHO-CHECKS AS (SEPARATE NUMBERS WITH A
       BLANK)'
[28]    '                    1-PANELS        5-XFMROC        9-ACLOAD        13-F
      REQ          17-XFMRPUX'
[29]    '                    2-LINE          6-XFMRSC        10-PFCOMP       14-F
      LTXFMR        18-XFMRKVAR'
[30]    '                    3-NDCLOADS      7-XFMRKVA       11-XFMRPF       15-F
      LTIMPED       19-XFMRWINDG'
[31]    '                    4-XFMRVOLTS     8-NACLOADS      12-RECTIFIER    16-D
      CLOAD          '
[32]    OPTNS[⎕]←1
[33] ALL:OPTNS[ι19]←1
[34] NECHO:→(IOPT≠'D')/FORTY
[35]    NDYN←NDYN+1
[36]    IFLG←(NDYN=1)
[37] FORTY:' '
[38]    '                    NO FAULT CALCULATIONS SPECIFIED, NORMAL FLOW'
[39]    ' '
[40]    '*****FREQ OF CURRENT(HZ),NUMBER OF FEEDER LOADS *****',((NDYN
      >1)×22)ρVECTOR
[41]    F1←2 RRLS 13
[42]    F←F1[1]
[43]    NSECTN←F1[2]
[44]    W←2×PI×F
[45]    ' '
```

```
        [□46]
[46]   →(IOPT='F')/SIXT
[47]   NSEC←NSECTN
[48]  LOOP2:→(NSEC=0)/END2
[49]   NSEC←NSEC-1
[50]   ' '
[51]   '****************************'
[52]   'BEGIN LOAD FLOW FOR FEEDER ',QT[NSECTN-NSEC]
[53]   '****************************'
[54]   ' '
[55]   LODFLO
[56]   LADDER 1
[57]   ' '
[58]   '*************************************************************'
[59]   'FEEDER LOAD ',QT[NSECTN-NSEC],' FEEDER LOAD PARAMETERS - THRE
       E PHASE'
[60]   PRINT 1
[61]   →LOOP2
[62]  END2:LADDER 2
[63]   NDCJ←0
[64]   LIST←ZMINE,IMINE,NSECTN,NDCJ, 0 0 0
[65]   F2←XFMR LIST
[66]   RPWR←F2[1 2]
[67]   Z1PHS←F2[3 4]
[68]   I1PHS←F2[5 6]
[69]   ' '
[70]   '*********************************************************'
[71]   'MINE INPUT PARAMETERS-THREE PHASE'
[72]   PRINT 2
[73]   IPTR←0
[74]   '                    RUN COMPLETED? YES OR NO'
[75]   RUNCK←□
[76]   →(1=RUNCKι'N')/LOOP1
[77]   →0
[78]  SIXT:'FAULTING OPTION NOT IN YET-STOP'
[79]   ∇
```

```
        VINIT
[49]    [□]
     ∇ INIT
[1]     IPTR←0
[2]     HIVAL←1E35
[3]     PI←3.141593
[4]     ROOT3←3*0.5
[5]     VECTOR←'PANELS      LINE       NDCLOADS  XFMRVOLTS XFMROC    XFMRSC
           XFMRKVA   NACLOADS '
[6]     VECTOR←VECTOR,'ACLOAD    PFCOMP    XFMRPF    RECTIFIER FREQ
          FLTXFMR   FLTIMPED '
[7]     VECTOR←VECTOR,'DCLOAD    XFMRPUX   XFMRKVAR  XFMRWINDG '
[8]     NAMES← 19 10 ρVECTOR
[9]     NDEF←175
[10]   ⋀FILL NEQUIP W DEFAULT
[11]    VECTOR← 1 0 0 0 0 1 0 0 0 0 0 0 550 550 550 0 550 100000
        2000 0
[12]    VECTOR←VECTOR, 5 1000 20000 0 0.0042 100000
        550 0 0 0 0 0 100000 550 0.7 0 0 0 0 0 0
        0 0 0 0 0 0 0 60 1 0 0
[13]    VECTOR←VECTOR, 550 100000 0 0 1 1 1 1 250
        100000 0 0 0.03 0.03 0.03 0 100 100 100 0
        0 0 0 0
[14]    VECTOR←VECTOR, 181000 550 0.45 525 181000
        440 0.45 525 130000 550 0.45 400 130000 440
        0.45 400 90000 550 0.6 200
[15]    VECTOR←VECTOR, 90000 440 0.6 200 120000 550
        0.7 225 120000 440 0.7 225 175000 550 0.5
        500 175000 440 0.5 500
[16]    VECTOR←VECTOR, 175000 550 0.5 500 175000
        440 0.5 500 181000 550 0.45 525 181000 440
        0.45 525 151000 550 0.7 290
[17]    VECTOR←VECTOR, 151000 440 0.7 290 150000
        550 0.45 450 150000 440 0.45 450 150000 550
        0.45 450 150000 440 0.45 450
[18]    VECTOR←VECTOR, 157000 550 0.7 300 157000
        440 0.7 300 150000 550 0.45 450 150000 440
        0.45 450 150000 550 0.45 450
[19]    VECTOR←VECTOR, 150000 440 0.45 450 181000
        550 0.6 405 181000 440 0.6 405 181000 550
        0 405 181000 250 0 405
[20]    VECTOR←VECTOR, 177000 550 0.5 475 177000
        440 0.5 475 177000 550 0 475 177000 250 0
        475 147000 550 0.45 350
[21]    VECTOR←VECTOR, 147000 440 0.45 350 120000
        550 0.6 395 120000 440 0.6 395 181000 950
        0.45 535 181000 550 0.45 535
[22]    VECTOR←VECTOR, 181000 440 0.45 535 172000
        950 0.6 385 172000 550 0.6 385 172000 440
        0.6 385 214000 950 0.6 530
[23]    VECTOR←VECTOR, 214000 550 0.6 530 214000
        440 0.6 530 170000 950 0.6 350 170000 550
        0.6 350 170000 440 0.6 350
[24]    VECTOR←VECTOR, 39000 550 0.7 75 39000 440
        0.7 75 39000 550 0 75 39000 250 0 75 52000
        550 0.7 100 52000 440 0.7 100
[25]    VECTOR←VECTOR, 52000 550 0 100 52000 250
        0 100 65000 550 0.7 125 65000 440 0.7 125
        65000 550 0 125 65000 250 0 125
```

```
      [U26]
[26]  VECTOR←VECTOR, 78000 550 0.7 150 78000 440
      0.7 150 78000 550 0 150 78000 250 0 150 91000
      550 0.7 175 91000 440 0.7 175
[27]  VECTOR←VECTOR, 91000 550 0 175 91000 250
      0 175 104000 550 0.7 200 104000 440 0.7 200
      104000 550 0 200
[28]  VECTOR←VECTOR, 104000 250 0 200 117000 550
      0.7 225 117000 440 0.7 225 117000 550 0 225
      117000 250 0 225
[29]  VECTOR←VECTOR, 130000 550 0.7 250 130000
      440 0.7 250 130000 550 0 250 130000 250 0
      250 143000 550 0.7 275
[30]  VECTOR←VECTOR, 143000 440 0.7 275 143000
      550 0 275 143000 250 0 275 156000 550 0.7
      300 156000 440 0.7 300
[31]  VECTOR←VECTOR, 156000 550 0 300 156000 250
      0 300 60000 550 0.8 100 60000 440 0.8 100
      65000 550 0.7 125 65000 440 0.7 125
[32]  VECTOR←VECTOR, 75000 550 0.7 150 75000 440
      0.7 150 81200 550 0.6 200 81200 440 0.6 200
      83900 550 0.5 225 83900 440 0.5 225
[33]  VECTOR←VECTOR, 26000 550 0.7 50 26000 440
      0.7 50 26000 550 0 50 26000 250 0 50 33600
      550 0.6 75 33600 440 0.6 75
[34]  VECTOR←VECTOR, 33600 550 0 75 33600 250 0
      75 37300 550 0.5 100 37300 440 0.5 100 37300
      550 0 100 37300 250 0 100
[35]  VECTOR←VECTOR, 15000 550 0.6 40 15000 440
      0.6 40 15000 550 0 40 15000 250 0 40 30000
      550 0.6 80 30000 440 0.6 80
[36]  VECTOR←VECTOR, 30000 550 0 80 30000 250 0
      80 10500 550 0.6 30 10500 440 0.6 30 10550
      0 30 10500 250 0 30
[37]  VECTOR←VECTOR, 22400 550 0.6 50 22400 440
      0.6 50 18000 550 0.6 40 18000 440 0.6 40
      11200 550 0.6 25 11200 440 0.6 25
[38]  VECTOR←VECTOR, 13000 550 0.7 95 13000 440
      0.7 95 13000 550 0 95 13000 250 0 95 15000
      250 0.6 135 15000 440 0.6 135
[39]  VECTOR←VECTOR, 15000 550 0 135 15000 250
      0 135 20000 550 0.6 160 20000 440 0.6 160
      10000 550 0.6 90 10000 440 0.6 90
[40]  VECTOR←VECTOR, 10000 550 0 90 10000 250 0
      90 9000 550 0.7 57.5 9000 440 0.7 57.5 9000
      550 0 57.5 9000 250 0 57.5
[41]  VECTOR←VECTOR, 15000 550 0.7 40 15000 440
      0.7 40 15000 550 0 40 15000 250 0 40 18000
      550 0.5 60 18000 440 0.5 60
[42]  VECTOR←VECTOR, 18000 550 0 60 18000 250 0 60
[43]  EQUIP← 175 4 ρVECTOR
[44]  REACT← 0 0.034 0.034 0.034 0.04 0.039 0.037
      0.036 0.035 0.034 0.033 0.032 0.032 0.031
      0.03
[45]  REACT←REACT, 0.03 0.029 0.029 0.028 0.028
      0 0 0 0 0 0 0 0 0 0
[46]  RES← 0 0.878 0.552 0.347 0.218 0.173 0.134
      0.107 0.0850000000000001 0.068 0.057 0.048
      0.041 0.036 0.029 0.024 0.021 0.019 0.017
      0.015 0 0 0 0 0 0 0 0 0 0
[47]  ZBE←IFE←ISECTN←ZSECTN← 10 2 ρ0
[48]  VECTOR←'- PREVIOUS VALUES USED'
```

```
      ∇RRLS⌊⎕]∇
   ∇ REALS←NREAL RRLS ICODE
⌊1]   NAMNDX←⌊×ICODE)×ICODE
⌊2]   REALS←4ρ0
⌊3]   →⌊NDYN>1)∧⌊ICODE>0))/THRTY
⌊4]   NUM←0
⌊5]   →⌊0=CODES)/COD
⌊6]   ' '
⌊7]   'TO SELECT DEFAULT ⌊CATALOG) VALUES  : INPUT CATALOG NUMBER FOLL
      OWED BY ZERO'
⌊8]   'TO OVERRIDE DEFAULT ⌊CATALOG) VALUES: INPUT CATALOG NUMBER FOLL
      OWED BY-'
⌊9]   '                                       ZEROES TO SELECT DEFAULT
      ENTRIES'
⌊10]  '                                       NON-ZEROES TO OVERRIDE AN
       ENTRY'
⌊11]  'TO INPUT ALL VALUES FROM KEYBOARD   : INPUT ZERO FOLLOWED BY VA
      LUES'
⌊12]  F2←⎕
⌊13]  NUM←F2⌊1]
⌊14]  REALS⌊ι⌊ρF2)-1]←F2⌊1+ι⌊ρF2)-1]
⌊15]  →OK
⌊16] COD:' '
⌊17]  REALS⌊ι⌊ρZER)-1]←ZER⌊1+ι⌊ρZER←0,ZER←⎕)-1]
⌊18] OK:→⌊⌊∨/⌊REALS=0))∧⌊CODES=1))/FRTY
⌊19] FTY:→⌊OPTNS⌊NAMNDX]=0)/NPRT
⌊20]  '*****ECHO-CHECK OF ',NAMES⌊NAMNDX;],'*****'
⌊21]  REALS
⌊22]  'VALUES OK? YES OR NO'
⌊23]  →⌊1=⌊ECHO←⎕)ι'N')/1
⌊24] NPRT:→⌊⌊IFLG=0)∨⌊ICODE≤0))/0
⌊25]  STORE
⌊26]  →0
⌊27] THRTY:REALS⌊ιNREAL]←DATA⌊IPTR+ιNREAL]
⌊28]  IPTR←IPTR+NREAL
⌊29]  →0
⌊30] FRTY:REALS←RDDEF REALS
⌊31]  →⌊~⌊ICODE=¯9)∨⌊ICODE=¯16))/FTY
⌊32]  REALS←REALS⌊1,2],⌊⌊180÷○1)×¯2○REALS⌊3]),REALS⌊3]
⌊33]  →FTY
   ∇

      ∇RDDEF⌊⎕]∇
   ∇ REAL1←RDDEF REALS
⌊1]   REAL1←REALS
⌊2]   →⌊NUM=0)/TWTY
⌊3]   IEQUIP←NUM
⌊4] CK:→⌊NUM≤175)/THTY
⌊5]   '    ERROR DEFAULT NUMBER NOT IN TABLE,MAKE ANOTHER SELECTION'
⌊6]   NUM←⎕
⌊7]   →CK
⌊8] TWTY:NUM←⌊×ICODE)×ICODE
⌊9] THTY:REAL1←REAL1+EQUIP⌊NUM;]×REAL1=0
   ∇
```

```
      ∇STORE[□]∇
    ∇ STORE
[1]    →(IN=1)/BYPS
[2]    DATA←400ρ0
[3]    NDATA←400
[4]    IN←1
[5]  BYPS:→((IPTR+NREAL)>NDATA)/EXT
[6]  INSRT:DATA[IPTR+ιNREAL]←REALS[ιNREAL]
[7]    IPTR←IPTR+NREAL
[8]    →0
[9]  EXT:NDATA←NDATA+100
[10]   DATA←NDATAρDATA
[11]   →INSRT
    ∇
```

```
      ∇LADDER[□]∇
    ∇ LADDER FROM;J
[1]    →(FROM=2)/TWO
[2]    NBET←NBE
[3]  HR1:J←NBE-NBET-1
[4]    'PANEL ';J;' TO FEEDER TRANSMISSION LINE',((NDYN>1)×22)ρVECTOR
[5]    VEC←FINDTL 2
[6]    ZBE[J;]←ZBE[J;]+(VEC[1]×VEC[3]),(VEC[1]×VEC[4])
[7]    →(J=NBE)/TN
[8]    ZBE[J+1;]←(ZBE[J+1;] CMUL ZBE[J;]) CDIV (ZBE[J;]+ZBE[J+1;])
[9]    IBE[J+1;]←IBE[J;]+IBE[J+1;]
[10] TN:→(0≠NBET←NBET-1)/HR1
[11]   ZSECTN[NSECTN-NSEC;]←ZBE[NBE;]
[12]   ISECTN[NSECTN-NSEC;]←IBE[NBE;]
[13]   →0
[14] TWO:NSECTNT←NSECTN
[15] HR2:J←NSECTN-NSECTNT-1
[16]   'FEEDER CABLE ';J;' TO MAIN MINE TRANSFORMER',((NDYN>1)×
       22)ρVECTOR
[17]   VEC←FINDTL 2
[18]   ZSECTN[J;]←ZSECTN[J;]+(VEC[1]×VEC[3]),(VEC[1]×VEC[4])
[19]   →(J=NSECTN)/TN1
[20]   ZSECTN[J+1;]←(ZSECTN[J+1;] CMUL ZSECTN[J;]) CDIV (ZSECTN[J;]+
       ZSECTN[J+1;])
[21]   ISECTN[J+1;]←ISECTN[J;]+ISECTN[J+1;]
[22] TN1:→(0≠NSECTNT←NSECTNT-1)/HR2
[23]   ZMINE←ZSECTN[NSECTN;]
[24]   IMINE←ISECTN[NSECTN;]
    ∇
```

```
      ∇LODFLO[□]∇
  ∇ LODFLO;J
[1]    '*****NUMBER OF PANELS*****',((NDYN>1)×22)ρVECTOR
[2]    F2←1 RRLS 1
[3]    NBET←NBE←F2[1]
[4]    IDC←10ρ0
[5]    ZPWR←IPWR←RPWR←IBE←ZBE← 10 2 ρ0
[6]  LP1:J←NBE-NBET-1
[7]    ' '
[8]    '***************************'
[9]    'BEGIN LOAD FLOW FOR PANEL ',QT[J]
[10]   '***************************'
[11]   ' '
[12]   IPWR[J;]← 0 0
[13]   →(0≠IRET←ACLOADS 0)/TEN
[14]   ZPWR[J;]←1 CDIV YPWR
[15]   IPWR[J;]←IP
[16]   '*****PANEL AC FEED CABLE VALUES*****',((NDYN>1)×22)ρVECTOR
[17]   VEC←FINDTL 2
[18]   TYPE←VEC[2]
[19]   ZPWR[J;]←ZPWR[J;] CADD(VEC[1]×VEC[3]),(VEC[1]×VEC[4])
[20] TEN:'*****NUMBER OF DC LOADS*****',((NDYN>1)×22)ρVECTOR
[21]   ((NDYN≤1)×(ρOUT))ρOUT←' '
[22]   IDC[J]←0
[23]   F2←1 RRLS 3
[24]   NDCJ←F2[1]
[25]   →(0=NDCJT←NDCJ)/THR
[26]   DCC←DCI←0
[27] LP2:'*****DC LOAD VALUES*****'
[28]   'POWER(WATTS), VOLTAGE(VOLTS)'
[29]   DC←2 RRLS ¯16
[30]   DCI←DCI+DC[1]÷DC[2]
[31]   DCR←DC[1]÷(DCI*2)
[32]   '*****DC TRAILING CABLE VALUES*****',((NDYN>1)×22)ρVECTOR
[33]   VEC←FINDTL 2
[34]   DCC←DCC+1÷(DCR+VEC[1]×VEC[3])
[35]   →(0≠NDCJT←NDCJT-1)/LP2
[36]   IDC[J]←DCI
[37]   RPWR[J;]←1 CDIV DCC
[38]   '*****PANEL DC FEED CABLE VALUES*****',((NDYN>1)×22)ρVECTOR
[39]   VEC←FINDTL 2
[40]   RPWR[J;]←RPWR[J;] CADD(VEC[1]×VEC[3])
[41] THR:LIST←ZPWR[J;],IPWR[J;],NACJ,NDCJ,IDC[J],RPWR[J;]
[42]   F1←XFMR LIST
[43]   RPWR[J;]←F1[1 2]
[44]   ZBE[J;]←F1[3 4]
[45]   IBE[J;]←F1[5 6]
[46]   '*****CABLE TO FEEDER LOAD CONNECTION*****',((NDYN>1)×
       22)ρVECTOR
[47]   VEC←FINDTL 2
[48]   ZBE[J;]←ZBE[J;] CADD(VEC[1]×VEC[3]),(VEC[1]×VEC[4])
[49]   ' '
[50]   '*********************************************************************'
[51]   'PANEL ',QT[NBE-NBET-1],' PANEL LOAD PARAMETERS - THREE PHASE'
[52]   J1←J
[53]   PRINT 3
[54]   →(0≠NBET←NBET-1)/LP1
[55]   →0
  ∇
```

```
      ∇PRINT[□]∇
   ∇ PRINT FROM
[1]    →(FROM=2)/PTWO
[2]    →(FROM=3)/PTW
[3]    I1PHS←ISECTN[NSECTN-NSEC;]
[4]    Z1PHS←ZSECTN[NSECTN-NSEC;]
[5]    →PTWO
[6]  PTW:I1PHS←IBE[J1;]
[7]    Z1PHS←ZBE[J1;]
[8]  PTWO:V1PHS←I1PHS CMUL Z1PHS
[9]    PF←2OTHETA←¯30(Z1PHS[2]÷Z1PHS[1])
[10]   CMAG←ABS I1PHS
[11]   VMAG←ABS(V1PHS CMUL(1.5 PJ ROOT3÷2))
[12]   PMAG←ABS POWER←0.003 CMUL((CMAG[1]*2)×Z1PHS[1]) PJ((CMAG[1]*
       2)×Z1PHS[2])
[13]   ANGL←THETA×180÷PI
[14]   →((Z1PHS[1]≥0)∧(Z1PHS[2]≥0))/PTN
[15]   ANGL←ANGL+((Z1PHS[1]≥0)∧(Z1PHS[2]<0))×360
[16]   ANGL←ANGL+(Z1PHS[1]<0)×180
[17] PTN:'P(KW)      Q(KVAR)        S(KVA)AT DEGREES        V(VOLTS)
       '
[18]   ' '
[19]   POWER,PMAG[1],ANGL,VMAG[1]
[20]   ' '
[21]   'I(AMPS)      PF'
[22]   CMAG[1],PF
[23]   '**********************************************************'
[24]   ' '
[25]   ' '
   ∇


      ∇PFCC[□]∇
   ∇ RT←PFCC
[1]    '*****POWER FACTOR CORRECTION*****',((NDYN>1)×22)ρVECTOR
[2]    RT←0
[3]    ((NDYN≤1)×(ρOUT))ρOUT←'PARALLEL CORRECTION CAPACITOR (FARADS)'
[4]    F2←1 RRLS 10
[5]    CC2←F2[1]
[6]    →(0≠RT←(0≥CC2)×(-HIVAL))/0
[7]    RT←¯1÷(W×CC2)
   ∇


      ∇ZEQUIV[□]∇
   ∇ RT←ZEQUIV LIST
[1]    RT← 0 0
[2]    →(LIST[1]≤1E¯6)/0
[3]    RT←REQ PJ(((LIST[1]÷LIST[3])*2)-REQ×REQ←LIST[2]÷LIST[
       3]*2)*÷2
   ∇
```

```
      ∇ACLOADS⌊⌋∇
    ∇ IRETN←ACLOADS IMODE
[1]    IRETN←1
[2]    '*****NUMBER OF AC LOADS*****',(NDYN>1)×22)ρVECTOR
[3]    F2←1 RRLS 8
[4]    →(0=NACJ←F2⌊1])/0
[5]    YPWR←IP← 0 0
[6]    NACJT←NACJ←NACJ-1×(IMODE=1)
[7]    →((IMODE=1)∧(NACJ<1))/TWNT
[8] LP10:'*****AC LOAD VALUES*****'
[9]    'POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTO
       R'
[10]   F2←4 RRLS ¯9
[11]   ACP←F2⌊1]
[12]   ACV←F2⌊2]
[13]   THETA←F2⌊3]
[14]   ACPF←F2⌊4]
[15]   ACPF←ACPF+(2○○THETA÷180)×(ACPF=0)
[16]   CX2←PFCC
[17]   ACV1←ACV÷ROOT3
[18]   ACP1←ACP÷3
[19]   ZL1←(ACPF*2)×R←(ACV1*2)÷ACP1
[20]   ZL1←ZL1,R×ACPF×10(¯2○ACPF)
[21]   ZL1←1 CDIV(1 CDIV ZL1) CADD(0 PJ 1÷CX2)
[22]   IP←IP CADD(ACV1 CDIV ZL1)
[23]   '*****AC TRAILING CABLE VALUES*****',(NDYN>1)×22)ρVECTOR
[24]   F2←FINDTL 2
[25]   ZL2←ZL1 CADD(F2⌊1]×F2⌊3]) PJ(F2⌊1]×F2⌊4])
[26]   YPWR←YPWR CADD(1 CDIV ZL2)
[27]   →(0≠NACJT←NACJT-1)/LP10
[28]   IRETN←0
[29]   →0
[30] TWNT:YPWR←(2E¯21) PJ 2E¯21
[31]   IRETN←0
[32]   →0
    ∇

      ∇FINDTL⌊⌋∇
    ∇ RET←FINDTL ICODE
[1]    ICODE←(×ICODE)×ICODE
[2]    ((NDYN≤1)×(ρOUT))ρOUT←'LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT
       ), UNIT REACTANCE(OHMS/FT)'
[3]    RET←4 RRLS ICODE
[4]    I←(×RET⌊2])×RET⌊2]
[5]    I←I+1×(I=0)
[6] AG:→((I>0)∧(I≤30))/TENN
[7]    I←1
[8]    'INCORRECT CABLE TYPE, SELECT ANOTHER CABLE'
[9]    RET⌊1]←I←⌑
[10]   →AG
[11] TENN:RET⌊3]←RET⌊3]+(0.001×RES⌊I])×(RET⌊3]=0)
[12]   RET⌊4]←RET⌊4]+(0.001×REACT⌊I])×(RET⌊4]=0)
    ∇
```

```
       ∇XFMR[⎕]∇
    ∇ RT←XFMR LIST;J
[1]    XZPWR←LIST[1 2]
[2]    XIPWR←LIST[3 4]
[3]    XNACJ←LIST[5]
[4]    XNDCJ←LIST[6]
[5]    XIDC←LIST[7]
[6]    XRPWR←LIST[8 9]
[7]    J←1
[8]    '*****TRANSFORMER CONNECTIONS*****',((NDYN>1)×22)ρVECTOR
[9]    TIN:((NDYN≤1)×(ρOUT))ρOUT←'PRIMARY, SECONDARY, TERTIARY (WYE=1,
       DELTA=2), OPTION'
[10]   F2←4 RRLS 19
[11]   PRMRY←F2[1]
[12]   SCNDRY←F2[2]
[13]   TRTARY←F2[3]
[14]   RMETH←F2[4]
[15]   →(PRMRY≠0)/TY
[16]   →(XNDCJ=0)/TTY
[17]   'ERROR NO TRANSFORMER-RECTIFIER FOR DC'
[18]   →TIN
[19]   TTY:XZBUTT←XZPWR
[20]   XIBUTT←XIPWR
[21]   RT←XRPWR,XZBUTT,XIBUTT
[22]   →0
[23]   TY:'*****POWER FACTOR CORRECTION CAPACITOR*****',((NDYN>1)×
       22)ρVECTOR
[24]   ((NDYN≤1)×(ρOUT))ρOUT←'PRIMARY(FARADS), SECONDARY(FARADS)'
[25]   F2←2 RRLS 11
[26]   CC4←F2[1]
[27]   CC3←F2[2]
[28]   '*****FORWARD RECTIFIER RESISTANCE(OHMS)*****',((NDYN>1)×
       22)ρVECTOR
[29]   ((NDYN≤1)×(ρOUT))ρOUT←' '
[30]   F2←1 RRLS 12
[31]   RFW←F2[1]
[32]   →(0≠CX3←-HIVAL×(CC3≤0))/NFIF
[33]   CX3←‾1÷(W×CC3)
[34]   NFIF:→(0≠CX4←HIVAL×(CC4≤0))/NSIX
[35]   CX4←‾1÷(W×CC4)
[36]   NSIX:'*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****',((
       NDYN>1)×22)ρVECTOR
[37]   ((NDYN≤1)×(ρOUT))ρOUT←' '
[38]   F2←3 RRLS 4
[39]   RATEP←F2[1]
[40]   A1←RATEP÷RATEAC←F2[2]
[41]   A2←RATEP÷RATEDC←F2[3]
[42]   '*****OPEN CIRCUIT TEST DATA*****',((NDYN>1)×22)ρVECTOR
[43]   ((NDYN≤1)×(ρOUT))ρOUT←'VOLTAGE(VOLTS), POWER(WATTS), CURRENT(A
       MPS)'
[44]   F2←3 RRLS 5
[45]   PEOC←F2[2]
[46]   IEOC←F2[3]
[47]   WLE←RA←0
[48]   RA←RA+((RPVOC*2)÷PEOC)×(0≠RPVOC←F2[1])
[49]   WLE←RA←RA+HIVAL×(RA=0)
[50]   →(0=RPVOC)/NINE
[51]   WLE←1÷((((IEOC÷RPVOC)*2)-1÷(RA*2))*0.5
[52]   →NINI
[53]   NINE:WLE←HIVAL
[54]   NINI:→(RMETH≥2)/ONH
```

```
      [☐55]
[55]  '*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****',((NDYN>1)×
      22)ρVECTOR
[56]  ((NDYN≤1)×(ρOUT))ρOUT←'VOLTAGE(VOLTS), POWER(WATTS), CURRENT(A
      MPS)'
[57]  F2←3 RRLS 6
[58]  ZAB←ZEQUIV F2
[59]  '*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****',((NDYN>1)×
      22)ρVECTOR
[60]  ((NDYN≤1)×(ρOUT))ρOUT
[61]  F2←3 RRLS 6
[62]  ZCA←ZEQUIV F2
[63]  '*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****',((NDYN>1)×
      22)ρVECTOR
[64]  ((NDYN≤1)×(ρOUT))ρOUT
[65]  F2←3 RRLS 6
[66]  ZBC←ZEQUIV F2
[67]  →ONF
[68]  ONH:'*****RESISTANCE PERCENT TRANSFORMER DATA*****',((NDYN>1)×
      22)ρVECTOR
[69]  ONHI:((NDYN≤1)×(ρOUT))ρOUT←'PERCENT RESISTANCE, KVA, VOLTAGE FO
      R WINDING-';LETTER[J]
[70]  F2←3 RRLS 7
[71]  VOLTLL←RKVA←PCR← 0 0 0
[72]  PCR[J]←F2[1]
[73]  RKVA[J]←F2[2]
[74]  VOLTLL[J]←F2[3]
[75]  J←J+1
[76]  →(J≠4)/ONHI
[77]  '*****REACTANCE PERCENT TRANSFORMER DATA*****',((NDYN>1)×
      22)ρVECTOR
[78]  ((NDYN≤1)×(ρOUT))ρOUT←'PERCENT REACTANCE A-B, B-C, A-C'
[79]  F2←3 RRLS 17
[80]  PCX12←F2[1]
[81]  PCX23←F2[2]
[82]  PCX13←F2[3]
[83]  ((NDYN≤1)×(ρOUT))ρOUT←'KVA A-B, B-C, A-C'
[84]  F2←3 RRLS 18
[85]  XKVA12←F2[1]
[86]  XKVA23←F2[2]
[87]  XKVA13←F2[3]
[88]  →(RMETH=2)/ONTH
[89]  PCR[ι3]←0.0042
[90]  PCX13←PCX23←PCX12←0.03
[91]  ONTH:KVARF←RKVA[1]
[92]  PV←VOLTLL[1]÷ROOT3
[93]  PC←(KVARF×1000)÷(3×PV)
[94]  R←PCR×(KVARF÷RKVA)×PV÷PC
[95]  ZAB←(R[1]+R[2]) PJ PCX12×(KVARF÷XKVA12)×PV÷PC
[96]  ZBC←(R[2]+R[3]) PJ PCX23×(KVARF÷XKVA23)×PV÷PC
[97]  ZCA←(R[1]+R[3]) PJ PCX13×(KVARF÷XKVA13)×PV÷PC
[98]  ONF:ZA←(ZAB CADD ZCA CADD-ZBC) CDIV 2
[99]  ZB←(ZAB CADD ZBC CADD-ZCA) CDIV 2
[100] ZC←(ZCA CADD ZBC CADD-ZAB) CDIV 2
[101] ZCC3←0,CX3
[102] →(XNACJ>0)/ONS
[103] AZACEQ←HIVAL,HIVAL
[104] IACEQ←0,0
[105] →ONSEV
[106] ONS:AZACEQ←(A1*2) CDIV((1 CDIV ZCC3)+1 CDIV XZPWR)
[107] IACEQ←(XIPWR CADD XIPWR CMUL XZPWR CDIV ZCC3) CDIV A1
```

```
        [□108]
[108] →(SCNDRY=1)/ONSEV
[109] IACEQ←IACEQ CMUL 0.5 0.288675
[110] AZACEQ←AZACEQ CMUL 3
[111]ONSEV:AZACEQ←AZACEQ CADD ZB
[112] →(TRTARY=2)/ONET
[113] 'ERROR- DC TERTIARY IS NOT GIVEN AS DELTA CONNECTION'
[114] 'CONTINUE WITH DELTA ASSUMED--- YES OR NO'
[115] F2←□
[116] →(1=F2ι'N')/0
[117] TRTARY←2
[118]ONET:→(XNDCJ≤0)/TH
[119] IDCEQ←(XIDC÷A2) CMUL 0.5 0.288675
[120] XRPWR←((XRPWR CADD RFW) CMUL(A2*2)×3) CADD ZC
[121] →THI
[122]TH:XRPWR←HIVAL,HIVAL
[123] IDCEQ← 0 0
[124]THI:Z←ZA CADD 1 CDIV((1 CDIV XRPWR) CADD 1 CDIV AZACEQ)
[125] ZE←1 CDIV((1 CDIV RA,0) CADD 1 CDIV 0,WLE)
[126] ZINT←1 CDIV((1 CDIV Z) CADD 1 CDIV ZE)
[127] IIN←IIN CADD(Z CMUL IIN←IACEQ CADD IDCEQ) CDIV ZE
[128] →(PRMRY=1)/TTE
[129] IIN←IIN CMUL 1.5 ⁻0.866025
[130] ZINT←ZINT CDIV 3
[131]TTE:IPRMRY←IIN
[132] XZBUTT←1 CDIV((1 CDIV ZINT) CADD 1 CDIV 0,CX4)
[133] XIBUTT←IPRMRY CADD(ZINT CMUL IPRMRY) CDIV 0,CX4
[134] RT←XRPWR,XZBUTT,XIBUTT
[135] ∇
```

PROGRAM   LISTINGS

(PROGRAMS WRITTEN BY UNIV. OF ALBERTA)

```
        ∇ABS
[3]     [⎕]
    ∇   R←ABS X
[1]     →MST
[2]     R← 1 0 ↑(1,1↓ρX)ρ(+/X×X)*0.5
    ∇
[3]     ∇


        ∇CADD
[3]     [⎕]
    ∇   R←X CADD Y
[1]     →RNK
[2]     R←X+Y
    ∇
[3]     ∇


        ∇CDIV
[5]     [⎕]
    ∇   R←X CDIV Y
[1]     →RNK
[2]     →(∧/,(∨/0≠Y)∨∧/0=X)ρ4
[3]     →0,ρ⎕←'COMPLEX DOMAIN ERROR'
[4]     R←(ρX)ρ(,(+/X×Y)÷R),,(-/Y×⊖X)÷R+0=R←+/Y×Y
    ∇
[5]     ∇


        ∇CMUL
[3]     [⎕]
    ∇   R←X CMUL Y
[1]     →RNK
[2]     R←(ρX)ρ(,-/X×Y),,+/X×⊖Y
    ∇
[3]     ∇


        ∇IM
[3]     [⎕]
    ∇   R←IM X
[1]     →MST
[2]     R← 1 0 ↑ 0 1 /X
    ∇
[3]     ∇


        ∇PJ
[11]    [⎕]
    ∇   R←X PJ Y;RX;RY;L
[1]     →(L←(ρRX←ρX)≠ρRY←ρY)ρ3
[2]     →(∧/RX=RY)ρ10
[3]     →(1=(×/RX,1),(×/RY,1))/ 7 9
[4]     →Lρ6
[5]     →0,ρ⎕←'COMPLEX LENGTH ERROR'
[6]     →0,ρ⎕←'COMPLEX RANK ERROR'
[7]     X←(RY)ρX
[8]     →10
[9]     Y←(RX)ρY
[10]    R←(2,ρX)ρ(,X),,Y
    ∇
[11]    ∇
```

```
      ∇RE
[3]   ⎣⎵⎦
    ∇ R←RE  X
[1]   →MST
[2]   R← 1  0 ⍕ 1 0 ≠X
    ∇
[3]   ∇


      ∇MST
[4]   ⎣⎵⎦
    ∇ R←MST;RX
[1]   →((2=1ρRX),1=×/RX←(ρX),1)/ 0  3 ,R←''
[2]   →R←0,ρ⎵←'COMPLEX STRUCTURE ERROR'
[3]   X←(,X),0
    ∇
[4]   ∇


      ∇RNK
[16]  ⎣⎵⎦
    ∇ R←RNK;RX;RY;L
[1]   →((2=1ρRX),1=×/RX←(ρY),1)/ 4  3
[2]   →R←0,ρ⎵←'COMPLEX STRUCTURE ERROR-2ND ARGUMENT'
[3]   Y←(,Y),0
[4]   →((2=1ρRX),1=×/RX←(ρX),1)/ 7  6
[5]   →R←0,ρ⎵←'COMPLEX STRUCTURE ERROR-1ST ARGUMENT'
[6]   X←(,X),0
[7]   →(L←(ρRX←ρX)≠ρRY←ρY)ρ9,R←''
[8]   →(∧/(RX)=RY)ρ0
[9]   →(2=(×/RX),×/RY)/ 13 15
[10]  →Lρ12
[11]  →R←0,ρ⎵←'COMPLEX LENGTH ERROR'
[12]  →R←0,ρ⎵←'COMPLEX RANK ERROR'
[13]  X←(1⌽⍳ρRY)⍉(1⊖RY)ρX
[14]  →0
[15]  Y←(1⌽⍳ρRX)⍉(1⌽RX)ρY
    ∇
[16]  ∇
```

DATA STRUCTURES

EQUIP[ι50;]

1.000000000E0	0.000000000E0	0.000000000E0	0.000000000E0
0.000000000E0	1.000000000E0	0.000000000E0	0.000000000E0
0.000000000E0	0.000000000E0	0.000000000E0	0.000000000E0
5.500000000E2	5.500000000E2	5.500000000E2	0.000000000E0
5.500000000E2	1.000000000E5	2.000000000E3	0.000000000E0
5.000000000E0	1.000000000E3	2.000000000E4	0.000000000E0
4.200000000E3	1.000000000E5	5.500000000E2	0.000000000E0
0.000000000E0	0.000000000E0	0.000000000E0	0.000000000E0
1.000000000E5	5.500000000E2	7.000000000E1	0.000000000E0
0.000000000E0	0.000000000E0	0.000000000E0	0.000000000E0
0.000000000E0	0.000000000E0	0.000000000E0	0.000000000E0
0.000000000E0	0.000000000E0	0.000000000E0	0.000000000E0
6.000000000E1	1.000000000E0	0.000000000E0	0.000000000E0
5.500000000E2	1.000000000E5	0.000000000E0	0.000000000E0
1.000000000E0	1.000000000E0	1.000000000E0	1.000000000E0
2.500000000E2	1.000000000E5	0.000000000E0	0.000000000E0
3.000000000E2	3.000000000E2	3.000000000E2	0.000000000E0
1.000000000E2	1.000000000E2	1.000000000E2	0.000000000E0
0.000000000E0	0.000000000E0	0.000000000E0	0.000000000E0
1.810000000E5	5.500000000E2	4.500000000E1	5.250000000E2
1.810000000E5	4.400000000E2	4.500000000E1	5.250000000E2
1.300000000E5	5.500000000E2	4.500000000E1	4.000000000E2
1.300000000E5	4.400000000E2	4.500000000E1	4.000000000E2
9.000000000E4	5.500000000E2	6.000000000E1	2.000000000E2
9.000000000E4	4.400000000E2	6.000000000E1	2.000000000E2
1.200000000E5	5.500000000E2	7.000000000E1	2.250000000E2
1.200000000E5	4.400000000E2	7.000000000E1	2.250000000E2
1.750000000E5	5.500000000E2	5.000000000E1	5.000000000E2
1.750000000E5	4.400000000E2	5.000000000E1	5.000000000E2
1.750000000E5	5.500000000E2	5.000000000E1	5.000000000E2
1.750000000E5	4.400000000E2	5.000000000E1	5.000000000E2
1.810000000E5	5.500000000E2	4.500000000E1	5.250000000E2
1.810000000E5	4.400000000E2	4.500000000E1	5.250000000E2
1.510000000E5	5.500000000E2	7.000000000E1	2.900000000E2
1.510000000E5	4.400000000E2	7.000000000E1	2.900000000E2
1.500000000E5	5.500000000E2	4.500000000E1	4.500000000E2
1.500000000E5	4.400000000E2	4.500000000E1	4.500000000E2
1.500000000E5	5.500000000E2	4.500000000E1	4.500000000E2
1.500000000E5	4.400000000E2	4.500000000E1	4.500000000E2
1.570000000E5	5.500000000E2	7.000000000E1	3.000000000E2
1.570000000E5	4.400000000E2	7.000000000E1	3.000000000E2
1.500000000E5	5.500000000E2	4.500000000E1	4.500000000E2
1.500000000E5	4.400000000E2	4.500000000E1	4.500000000E2
1.500000000E5	5.500000000E2	4.500000000E1	4.500000000E2
1.500000000E5	4.400000000E2	4.500000000E1	4.500000000E2
1.810000000E5	5.500000000E2	6.000000000E1	4.050000000E2
1.810000000E5	4.400000000E2	6.000000000E1	4.050000000E2
1.810000000E5	5.500000000E2	0.000000000E0	4.050000000E2
1.810000000E5	2.500000000E2	0.000000000E0	4.050000000E2
1.770000000E5	5.500000000E2	5.000000000E1	4.750000000E2

```
      EQUIP[50+ι50;]
1.770000000E5        4.400000000E2        5.000000000E 1       4.750000000E2
1.770000000E5        5.500000000E2        0.000000000E0        4.750000000E2
1.770000000E5        2.500000000E2        0.000000000E0        4.750000000E2
1.470000000E5        5.500000000E2        4.500000000E 1       3.500000000E2
1.470000000E5        4.400000000E2        4.500000000E 1       3.500000000E2
1.200000000E5        5.500000000E2        6.000000000E 1       3.950000000E2
1.200000000E5        4.400000000E2        6.000000000E 1       3.950000000E2
1.810000000E5        9.500000000E2        4.500000000E 1       5.350000000E2
1.810000000E5        5.500000000E2        4.500000000E 1       5.350000000E2
1.810000000E5        4.400000000E2        4.500000000E 1       5.350000000E2
1.720000000E5        9.500000000E2        6.000000000E 1       3.850000000E2
1.720000000E5        5.500000000E2        6.000000000E 1       3.850000000E2
1.720000000E5        4.400000000E2        6.000000000E 1       3.850000000E2
2.140000000E5        9.500000000E2        6.000000000E 1       5.300000000E2
2.140000000E5        5.500000000E2        6.000000000E 1       5.300000000E2
2.140000000E5        4.400000000E2        6.000000000E 1       5.300000000E2
1.700000000E5        9.500000000E2        6.000000000E 1       3.500000000E2
1.700000000E5        5.500000000E2        6.000000000E 1       3.500000000E2
1.700000000E5        4.400000000E2        6.000000000E 1       3.500000000E2
3.900000000E4        5.500000000E2        7.000000000E 1       7.500000000E1
3.900000000E4        4.400000000E2        7.000000000E 1       7.500000000E1
3.900000000E4        5.500000000E2        0.000000000E0        7.500000000E1
3.900000000E4        2.500000000E2        0.000000000E0        7.500000000E1
5.200000000E4        5.500000000E2        7.000000000E 1       1.000000000E2
5.200000000E4        4.400000000E2        7.000000000E 1       1.000000000E2
5.200000000E4        5.500000000E2        0.000000000E0        1.000000000E2
5.200000000E4        2.500000000E2        0.000000000E0        1.000000000E2
6.500000000E4        5.500000000E2        7.000000000E 1       1.250000000E2
6.500000000E4        4.400000000E2        7.000000000E 1       1.250000000E2
6.500000000E4        5.500000000E2        0.000000000E0        1.250000000E2
6.500000000E4        2.500000000E2        0.000000000E0        1.250000000E2
7.800000000E4        5.500000000E2        7.000000000E 1       1.500000000E2
7.800000000E4        4.400000000E2        7.000000000E 1       1.500000000E2
7.800000000E4        5.500000000E2        0.000000000E0        1.500000000E2
7.800000000E4        2.500000000E2        0.000000000E0        1.500000000E2
9.100000000E4        5.500000000E2        7.000000000E 1       1.750000000E2
9.100000000E4        4.400000000E2        7.000000000E 1       1.750000000E2
9.100000000E4        5.500000000E2        0.000000000E0        1.750000000E2
9.100000000E4        2.500000000E2        0.000000000E0        1.750000000E2
1.040000000E5        5.500000000E2        7.000000000E 1       2.000000000E2
1.040000000E5        4.400000000E2        7.000000000E 1       2.000000000E2
1.040000000E5        5.500000000E2        0.000000000E0        2.000000000E2
1.040000000E5        2.500000000E2        0.000000000E0        2.000000000E2
1.170000000E5        5.500000000E2        7.000000000E 1       2.250000000E2
1.170000000E5        4.400000000E2        7.000000000E 1       2.250000000E2
1.170000000E5        5.500000000E2        0.000000000E0        2.250000000E2
1.170000000E5        2.500000000E2        0.000000000E0        2.250000000E2
1.300000000E5        5.500000000E2        7.000000000E 1       2.500000000E2
1.300000000E5        4.400000000E2        7.000000000E 1       2.500000000E2
1.300000000E5        5.500000000E2        0.000000000E0        2.500000000E2
```

```
      EQUIP[100+ι50;]
1.300000000E5      2.500000000E2      0.000000000E0      2.500000000E2
1.430000000E5      5.500000000E2      7.000000000E 1      2.750000000E2
1.430000000E5      4.400000000E2      7.000000000E 1      2.750000000E2
1.430000000E5      5.500000000E2      0.000000000E0      2.750000000E2
1.430000000E5      2.500000000E2      0.000000000E0      2.750000000E2
1.560000000E5      5.500000000E2      7.000000000E 1      3.000000000E2
1.560000000E5      4.400000000E2      7.000000000E 1      3.000000000E2
1.560000000E5      5.500000000E2      0.000000000E0      3.000000000E2
1.560000000E5      2.500000000E2      0.000000000E0      3.000000000E2
6.000000000E4      5.500000000E2      8.000000000E 1      1.000000000E2
6.000000000E4      4.400000000E2      8.000000000E 1      1.000000000E2
6.500000000E4      5.500000000E2      7.000000000E 1      1.250000000E2
6.500000000E4      4.400000000E2      7.000000000E 1      1.250000000E2
7.500000000E4      5.500000000E2      7.000000000E 1      1.500000000E2
7.500000000E4      4.400000000E2      7.000000000E 1      1.500000000E2
8.120000000E4      5.500000000E2      6.000000000E 1      2.000000000E2
8.120000000E4      4.400000000E2      6.000000000E 1      2.000000000E2
8.390000000E4      5.500000000E2      5.000000000E 1      2.250000000E2
8.390000000E4      4.400000000E2      5.000000000E 1      2.250000000E2
2.600000000E4      5.500000000E2      7.000000000E 1      5.000000000E1
2.600000000E4      4.400000000E2      7.000000000E 1      5.000000000E1
2.600000000E4      5.500000000E2      0.000000000E0      5.000000000E1
2.600000000E4      2.500000000E2      0.000000000E0      5.000000000E1
3.360000000E4      5.500000000E2      6.000000000E 1      7.500000000E1
3.360000000E4      4.400000000E2      6.000000000E 1      7.500000000E1
3.360000000E4      5.500000000E2      0.000000000E0      7.500000000E1
3.360000000E4      2.500000000E2      0.000000000E0      7.500000000E1
3.730000000E4      5.500000000E2      5.000000000E 1      1.000000000E2
3.730000000E4      4.400000000E2      5.000000000E 1      1.000000000E2
3.730000000E4      5.500000000E2      0.000000000E0      1.000000000E2
3.730000000E4      2.500000000E2      0.000000000E0      1.000000000E2
1.500000000E4      5.500000000E2      6.000000000E 1      4.000000000E1
1.500000000E4      4.400000000E2      6.000000000E 1      4.000000000E1
1.500000000E4      5.500000000E2      0.000000000E0      4.000000000E1
1.500000000E4      2.500000000E2      0.000000000E0      4.000000000E1
3.000000000E4      5.500000000E2      6.000000000E 1      8.000000000E1
3.000000000E4      4.400000000E2      6.000000000E 1      8.000000000E1
3.000000000E4      5.500000000E2      0.000000000E0      8.000000000E1
3.000000000E4      2.500000000E2      0.000000000E0      8.000000000E1
1.050000000E4      5.500000000E2      6.000000000E 1      3.000000000E1
1.050000000E4      4.400000000E2      6.000000000E 1      3.000000000E1
1.055000000E4      0.000000000E0      3.000000000E1      1.050000000E4
2.500000000E2      0.000000000E0      3.000000000E1      2.240000000E4
5.500000000E2      6.000000000E 1      5.000000000E1      2.240000000E4
4.400000000E2      6.000000000E 1      5.000000000E1      1.800000000E4
5.500000000E2      6.000000000E 1      4.000000000E1      1.800000000E4
4.400000000E2      6.000000000E 1      4.000000000E1      1.120000000E4
5.500000000E2      6.000000000E 1      2.500000000E1      1.120000000E4
4.400000000E2      6.000000000E 1      2.500000000E1      1.300000000E4
5.500000000E2      7.000000000E 1      9.500000000E1      1.300000000E4
```

```
      EQUIP[150+ʏ25;]
   4.400000000E2      7.000000000E 1      9.500000000E1      1.300000000E4
   5.500000000E2      0.000000000E0      9.500000000E1      1.300000000E4
   2.500000000E2      0.000000000E0      9.500000000E1      1.500000000E4
   2.500000000E2      6.000000000E 1      1.350000000E2      1.500000000E4
   4.400000000E2      6.000000000E 1      1.350000000E2      1.500000000E4
   5.500000000E2      0.000000000E0      1.350000000E2      1.500000000E4
   2.500000000E2      0.000000000E0      1.350000000E2      2.000000000E4
   5.500000000E2      6.000000000E 1      1.600000000E2      2.000000000E4
   4.400000000E2      6.000000000E 1      1.600000000E2      1.000000000E4
   5.500000000E2      6.000000000E 1      9.000000000E1      1.000000000E4
   4.400000000E2      6.000000000E 1      9.000000000E1      1.000000000E4
   5.500000000E2      0.000000000E0      9.000000000E1      1.000000000E4
   2.500000000E2      0.000000000E0      9.000000000E1      9.000000000E3
   5.500000000E2      7.000000000E 1      5.750000000E1      9.000000000E3
   4.400000000E2      7.000000000E 1      5.750000000E1      9.000000000E3
   5.500000000E2      0.000000000E0      5.750000000E1      9.000000000E3
   2.500000000E2      0.000000000E0      5.750000000E1      1.500000000E4
   5.500000000E2      7.000000000E 1      4.000000000E1      1.500000000E4
   4.400000000E2      7.000000000E 1      4.000000000E1      1.500000000E4
   5.500000000E2      0.000000000E0      4.000000000E1      1.500000000E4
   2.500000000E2      0.000000000E0      4.000000000E1      1.800000000E4
   5.500000000E2      5.000000000E 1      6.000000000E1      1.800000000E4
   4.400000000E2      5.000000000E 1      6.000000000E1      1.800000000E4
   5.500000000E2      0.000000000E0      6.000000000E1      1.800000000E4
   2.500000000E2      0.000000000E0      6.000000000E1      1.000000000E0
```

```
      REACT
0  0.034 0.034 0.034 0.04 0.039 0.037 0.036 0.035 0.034 0.033
      0.032 0.032 0.031 0.03 0.03 0.029 0.029 0.028 0.028 0
      0 0 0 0 0 0 0 0 0
```

```
      RES
0  0.878 0.552 0.347 0.218 0.173 0.134 0.107 0.085 0.068 0.057
      0.048 0.041 0.036 0.029 0.024 0.021 0.019 0.017 0.015
      0 0 0 0 0 0 0 0 0
```

```
      NAMES
PANELS
LINE
NDCLOADS
XFMRVOLTS
XFMROC
XFMRSC
XFMRKVA
NACLOADS
ACLOAD
PFCOMP
XFMRPF
RECTIFIER
FREQ
FLTXFMR
FLTIMPED
DCLOAD
XFMRPUX
XFMRKVAR
XFMRPUIMP
```

DATA

```
60 2 3 1 0 1000 10 0 0 0 1 0 0 0 2 1 2 1 0 0 0 7200 550 550
    7200 34560 8.8957727 70.5902452 2478.843 90.9 5 1000 20000
    5 1000 20000 400 1 0.000115 0.000103 3 0 1000 10 0 0 0
    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
    0 0
```

EXECUTION SEQUENCE

DYNAMIC, NO DEFAULTS, NO ECHO-CHECK

MPSS

*****RUN DESCRIPTION*****

INPUT TITLE FOR THIS RUN
TEST OF APL LOAD FLOW - USER: R.A. RIVELL   DATE: 12/2/76
                    SELECT RUN TYPE AS S-STATIC, D-DYNAMIC, F-FAULT
D

                    DEFAULT CODES USED THIS RUN? YES OR NO
NO

                    IS DATA ECHO-CHECKING DESIRED? SOME, NONE, ALL
NONE

                    NO FAULT CALCULATIONS SPECIFIED, NORMAL FLOW

*****FREQ OF CURRENT(HZ),NUMBER OF FEEDER LOADS *****

□:
        60 2

****
BEGIN LOAD FLOW FOR FEEDER 1
****

*****NUMBER OF PANELS*****

□:
        3

****
BEGIN LOAD FLOW FOR PANEL 1
****

*****NUMBER OF AC LOADS*****

□:
        1
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
        72000 540 0 0.72
*****POWER FACTOR CORRECTION*****
PARALLEL CORRECTION CAPACITOR (FARADS)

□:
        0
*****AC TRAILING CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        1000 10
*****PANEL AC FEED CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:

          0 1

*****NUMBER OF DC LOADS*****

☐:
          0
*****TRANSFORMER CONNECTIONS*****
PRIMARY, SECONDARY, TERTIARY (WYE=1,DELTA=2), OPTION

☐:
       2 1 2 1
*****POWER FACTOR CORRECTION CAPACITOR*****
PRIMARY(FARADS), SECONDARY(FARADS)

☐:
          0
*****FORWARD RECTIFIER RESISTANCE(OHMS)*****

☐:
          0
*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****

☐:
       7200 550 550
*****OPEN CIRCUIT TEST DATA*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

☐:
       7200 34560 8.8957727
*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

☐:
       70.5902452 2478.843 90.9
*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

☐:
          0
*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

☐:
          0
*****CABLE TO FEEDER LOAD CONNECTION*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

☐:

```
      400 0 .000115 .000103
```

```
************************************************************
```
PANEL 1 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

109.5570644 125.5279707 166.6133902 48.88651004 4191.254437

I(AMPS)   PF
22.95119209 0.6575525788
```
************************************************************
```

```
****************************
```
BEGIN LOAD FLOW FOR PANEL 2
```
****************************
```

*****NUMBER OF AC LOADS*****

□:
```
      3
```
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
```
      72000 540 0 0.72
```
*****POWER FACTOR CORRECTION*****
PARALLEL CORRECTION CAPACITOR (FARADS)

□:
```
      0
```
*****AC TRAILING CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
```
      1000 10
```
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
```
      72000 540 0 0.72
```
*****POWER FACTOR CORRECTION*****
PARALLEL CORRECTION CAPACITOR (FARADS)

□:
```
      0
```
*****AC TRAILING CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
```
      1000 10
```
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
```
      72000 540 0 0.72
```

*****POWER FACTOR CORRECTION*****
PARALLEL CORRECTION CAPACITOR (FARADS)

□:
        0
*****AC TRAILING CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        1000 10
*****PANEL AC FEED CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        0 1

*****NUMBER OF DC LOADS*****

□:
        0
*****TRANSFORMER CONNECTIONS*****
PRIMARY, SECONDARY, TERTIARY (WYE=1,DELTA=2), OPTION

□:
        0
*****CABLE TO FEEDER LOAD CONNECTION*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        0 1

****
PANEL 2 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

222.9958848 211.6901613 307.4733956 43.51012857 553.4521121

I(AMPS)   PF
320.7501495 0.7252526169
****

****
BEGIN LOAD FLOW FOR PANEL 3
****

*****NUMBER OF AC LOADS*****

□:
        0

*****NUMBER OF DC LOADS*****

□:
        1

```
*****DC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS)

□:
        100000 200
*****DC TRAILING CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        1000 10
*****PANEL DC FEED CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        0 1
*****TRANSFORMER CONNECTIONS*****
PRIMARY, SECONDARY, TERTIARY (WYE=1,DELTA=2), OPTION

□:
        2 1 2 1
*****POWER FACTOR CORRECTION CAPACITOR*****
PRIMARY(FARADS), SECONDARY(FARADS)

□:
        0
*****FORWARD RECTIFIER RESISTANCE(OHMS)*****

□:
        0
*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****

□:
        7200 550 550
*****OPEN CIRCUIT TEST DATA*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
        7200 34560 8.8957727
*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
        0
*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
        70.5902452 2478.843 90.9
```

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
        0
*****CABLE TO FEEDER LOAD CONNECTION*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        0 1

****
PANEL 3 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

407.8802798 89.11502627 417.5018689 12.3245017 5312.381716

I(AMPS)   PF
45.37415218 0.9769543807
****

PANEL 1 TO FEEDER TRANSMISSION LINE
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        0 1
PANEL 2 TO FEEDER TRANSMISSION LINE
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        0 1
PANEL 3 TO FEEDER TRANSMISSION LINE
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        0 1

****
FEEDER LOAD 1 FEEDER LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

305.2199527 285.9391185 418.2348611 43.13193804 638.4883353

I(AMPS)   PF
378.1870337 0.7297812333
****

****
BEGIN LOAD FLOW FOR FEEDER 2
****

*****NUMBER OF PANELS*****
□:
        5

```
****************************
BEGIN LOAD FLOW FOR PANEL 1
****************************


*****NUMBER OF AC LOADS*****

□:
     1
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
     72000 540 0 0.72
*****POWER FACTOR CORRECTION*****
PARALLEL CORRECTION CAPACITOR (FARADS)

□:
     0
*****AC TRAILING CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
     1000 10
*****PANEL AC FEED CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
     0 1


*****NUMBER OF DC LOADS*****

□:
     1


*****DC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS)

□:
     100000 200
*****DC TRAILING CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
     1000 10
*****PANEL DC FEED CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
     0 1
*****TRANSFORMER CONNECTIONS*****
PRIMARY, SECONDARY, TERTIARY (WYE=1,DELTA=2), OPTION

□:
     2 1 2 1
```

```
*****POWER FACTOR CORRECTION CAPACITOR*****
PRIMARY(FARADS), SECONDARY(FARADS)

[]:
       0
*****FORWARD RECTIFIER RESISTANCE(OHMS)*****

[]:
       0
*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****

[]:
       7200 550 550
*****OPEN CIRCUIT TEST DATA*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

[]:
       7200 34560 8.8957727
*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

[]:
       70.5902452 2478.843 90.9
*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

[]:
       70.5902452 2478.843 90.9
*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

[]:
       70.5902452 2478.843 90.9
*****CABLE TO FEEDER LOAD CONNECTION*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

[]:
       0 1


************************************************************
PANEL 1 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)        Q(KVAR)          S(KVA)AT DEGREES        V(VOLTS)

372.236794 143.4099236 398.9068024 21.06994088 4464.522655

I(AMPS)        PF
51.5864668 0.9331422572
************************************************************



***************************
BEGIN LOAD FLOW FOR PANEL 2
***************************

*****NUMBER OF AC LOADS*****

[]:
       1
```

```
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR


□:
      72000 540 0 0.72
*****POWER FACTOR CORRECTION*****
PARALLEL CORRECTION CAPACITOR (FARADS)


□:
      0
*****AC TRAILING CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)


□:
      1000 10
*****PANEL AC FEED CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)


□:
      0 1


*****NUMBER OF DC LOADS*****


□:
      0
*****TRANSFORMER CONNECTIONS*****
PRIMARY, SECONDARY, TERTIARY (WYE=1,DELTA=2), OPTION


□:
      2  1  2  1
*****POWER FACTOR CORRECTION CAPACITOR*****
PRIMARY(FARADS), SECONDARY(FARADS)


□:
      .43900E⁻04 0
*****FORWARD RECTIFIER RESISTANCE(OHMS)*****


□:
      0
*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****


□:
      7200 550 550
*****OPEN CIRCUIT TEST DATA*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)


□:
      7200 34560 8.8957727


*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
      70.5902452 2478.843 90.9
```

```
*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)


□:
      0
*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)


□:
      0
*****CABLE TO FEEDER LOAD CONNECTION*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)


□:
      400 0 .000115 .000103


*****************************************************************
PANEL 2 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)        Q(KVAR)        S(KVA)AT DEGREES        V(VOLTS)

109.5871068 ⁻164.833137 197.937609 303.6174215 4188.399249

I(AMPS)      PF
27.28472742 0.5536446934
*****************************************************************




****************************
BEGIN LOAD FLOW FOR PANEL 3
****************************

*****NUMBER OF AC LOADS*****

□:
      1
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR


□:
      72000 540 0 0.72
*****POWER FACTOR CORRECTION*****
PARALLEL CORRECTION CAPACITOR (FARADS)


□:
      0
*****AC TRAILING CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)


□:
      1000 10
```

```
*****PANEL AC FEED CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)


□:
       0  1


*****NUMBER OF DC LOADS*****

□:
       0
*****TRANSFORMER CONNECTIONS*****
PRIMARY, SECONDARY, TERTIARY (WYE=1,DELTA=2), OPTION

□:
       1  1  2  1
*****POWER FACTOR CORRECTION CAPACITOR*****
PRIMARY(FARADS), SECONDARY(FARADS)

□:
       0
*****FORWARD RECTIFIER RESISTANCE(OHMS)*****

□:
       0
*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****

□:
       7200 550 550
*****OPEN CIRCUIT TEST DATA*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
       7200 34560 8.8957727
*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
       70.5902452 2478.843 90.9
*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
       0
*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
       0
*****CABLE TO FEEDER LOAD CONNECTION*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
       400 0 .000115 .000103
```

```
*****************************************************************
PANEL 3 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)        Q(KVAR)        S(KVA)AT DEGREES        V(VOLTS)

109.5086282 125.4845952 166.5488615 48.88925204 7256.653227

I(AMPS)       PF
13.25087847 0.6575165223
*****************************************************************
```

```
****************************
BEGIN LOAD FLOW FOR PANEL 4
****************************
```

```
*****NUMBER OF AC LOADS*****
```

☐:
```
       1
```
```
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR
```

☐:
```
       72000 540 0 0.72
```
```
*****POWER FACTOR CORRECTION*****
PARALLEL CORRECTION CAPACITOR (FARADS)
```

☐:
```
       0
```
```
*****AC TRAILING CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)
```

☐:
```
       1000 10
```
```
*****PANEL AC FEED CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)
```

☐:
```
       0 1
```

```
*****NUMBER OF DC LOADS*****
```

☐:
```
       0
```
```
*****TRANSFORMER CONNECTIONS*****
PRIMARY, SECONDARY, TERTIARY (WYE=1,DELTA=2), OPTION
```

☐:
```
       1  2  2  1
```

*****POWER FACTOR CORRECTION CAPACITOR*****
PRIMARY(FARADS), SECONDARY(FARADS)

□:
        0
*****FORWARD RECTIFIER RESISTANCE(OHMS)*****

□:
        0
*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****

□:
        7200 550 550
*****OPEN CIRCUIT TEST DATA*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
        7200 34560 8.8957727
*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
        70.5902452 2478.843 90.9
*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
        0
*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
        0
*****CABLE TO FEEDER LOAD CONNECTION*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        400 0 .000115 .000103

****
PANEL 4 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

179.4601298 234.5989885 295.3686232 52.58525299 12556.2701

I(AMPS)   PF
13.5813544 0.6075802088
****

****
BEGIN LOAD FLOW FOR PANEL 5
****

*****NUMBER OF AC LOADS*****

□:
        1

```
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
      72000 540 0 0.72
*****POWER FACTOR CORRECTION*****
PARALLEL CORRECTION CAPACITOR (FARADS)

□:
      0
*****AC TRAILING CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
      1000 10
*****PANEL AC FEED CABLE VALUES*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
      0 1


*****NUMBER OF DC LOADS*****

□:
      0
*****TRANSFORMER CONNECTIONS*****
PRIMARY, SECONDARY, TERTIARY (WYE=1,DELTA=2), OPTION

□:
      2 2 2 1
*****POWER FACTOR CORRECTION CAPACITOR*****
PRIMARY(FARADS), SECONDARY(FARADS)

□:
      0
*****FORWARD RECTIFIER RESISTANCE(OHMS)*****

□:
      0
*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****

□:
      7200 550 550
*****OPEN CIRCUIT TEST DATA*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
      7200 34560 8.8957727
*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
      70.5902452 2478.843 90.9
```

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
        0
*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****
VOLTAGE(VOLTS), POWER(WATTS), CURRENT(AMPS)

□:
        0
*****CABLE TO FEEDER LOAD CONNECTION*****
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        400 0 .000115 .000103

****
PANEL 5 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

179.510997 234.6445306 295.4357016 52.58278394 7251.013104

I(AMPS)   PF
23.52359311 0.6076144353
****

PANEL 1 TO FEEDER TRANSMISSION LINE
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        0 1
PANEL 2 TO FEEDER TRANSMISSION LINE
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        0 1
PANEL 3 TO FEEDER TRANSMISSION LINE
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        0 1
PANEL 4 TO FEEDER TRANSMISSION LINE
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        0 1
PANEL 5 TO FEEDER TRANSMISSION LINE
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
        0 1

```
**********************************************************
FEEDER LOAD 2 FEEDER LOAD PARAMETERS - THREE PHASE
P(KW)         Q(KVAR)        S(KVA)AT DEGREES        V(VOLTS)

1217.396126 236.6047618 1240.175448 10.99849887 6211.355434

I(AMPS)       PF
115.2752626 0.9816321782
**********************************************************


FEEDER CABLE 1 TO MAIN MINE TRANSFORMER
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
      0 1
FEEDER CABLE 2 TO MAIN MINE TRANSFORMER
LENGTH(FT), TYPE, UNIT RESISTANCE(OHMS/FT), UNIT REACTANCE(OHMS/FT)

□:
      0 1
*****TRANSFORMER CONNECTIONS*****
PRIMARY, SECONDARY, TERTIARY (WYE=1,DELTA=2), OPTION

□:
      0

**********************************************************
MINE INPUT PARAMETERS-THREE PHASE
P(KW)         Q(KVAR)        S(KVA)AT DEGREES        V(VOLTS)

502.8933018 456.0251954 678.8671828 42.20183319 802.8237921

I(AMPS)       PF
488.2069447 0.7407830495
**********************************************************


              RUN COMPLETED? YES OR NO


      NO
```

EXECUTION SEQUENCE

DYNAMIC, NO DEFAULTS, NO ECHO-CHECK

LOADS SAME AS BEFORE

*****RUN DESCRIPTION*****

        INPUT TITLE FOR THIS RUN
DATA SET 2 LOADS ONLY (SAME AS BEFORE)
        SELECT RUN TYPE AS S-STATIC, D-DYNAMIC, F-FAULT
D

        DEFAULT CODES USED THIS RUN? YES OR NO
NO

        IS DATA ECHO-CHECKING DESIRED? SOME, NONE, ALL
NONE

        NO FAULT CALCULATIONS SPECIFIED, NORMAL FLOW

*****FREQ OF CURRENT(HZ),NUMBER OF FEEDER LOADS *****- PREVIOUS VALUES USED

****
BEGIN LOAD FLOW FOR FEEDER 1
****

*****NUMBER OF PANELS*****- PREVIOUS VALUES USED

****
BEGIN LOAD FLOW FOR PANEL 1
****

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
     72000 540 0 0.72

*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED


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**************************************************************
PANEL 1 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)        Q(KVAR)         S(KVA)AT DEGREES        V(VOLTS)

109.5570644 125.5279707 166.6133902 48.88651004 4191.254437

I(AMPS)       PF
22.95119209 0.6575525788
**************************************************************
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****************************
BEGIN LOAD FLOW FOR PANEL 2
****************************
```

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
        72000 540 0 0.72

*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
     72000 540 0 0.72
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
     72000 540 0 0.72
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED

****
PANEL 2 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

222.9958848 211.6901613 307.4733956 43.51012857 553.4521121

I(AMPS)   PF
320.7501495 0.7252526169
****

****
BEGIN LOAD FLOW FOR PANEL 3
****

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****DC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS)

□:
     100000 200

*****DC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL DC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED

****
PANEL 3 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

407.8802798 89.11502627 417.5018689 12.3245017 5312.381716

I(AMPS)   PF
45.37415218 0.9769543807
****

PANEL 1 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 2 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 3 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

****
FEEDER LOAD 1 FEEDER LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

305.2199527 285.9391185 418.2348611 43.13193804 638.4883353

I(AMPS)   PF
378.1870337 0.7297812333
****

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***************************
BEGIN LOAD FLOW FOR FEEDER 2
***************************

*****NUMBER OF PANELS*****- PREVIOUS VALUES USED

***************************
BEGIN LOAD FLOW FOR PANEL 1
***************************

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
      72000 540 0 0.72
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****DC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS)

□:
      100000 200
```

*****DC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL DC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED

****
PANEL 1 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

372.236794 143.4099236 398.9068024 21.06994088 4464.522655

I(AMPS)   PF
51.5864668 0.9331422572
****

****
BEGIN LOAD FLOW FOR PANEL 2
****

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

☐:
      72000 540 0 0.72

*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED


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************************************************************
PANEL 2 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)         Q(KVAR)         S(KVA)AT DEGREES        V(VOLTS)

109.5871068 ¯164.833137 197.937609 303.6174215 4188.399249

I(AMPS)      PF
27.28472742 0.5536446934
************************************************************
```



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****************************
BEGIN LOAD FLOW FOR PANEL 3
****************************
```

```
*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
      72000 540 0 0.72
```

*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED

****
PANEL 3 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

109.5086282 125.4845952 166.5488615 48.88925204 7256.653227

I(AMPS)   PF
13.25087847 0.6575165223
****

****
BEGIN LOAD FLOW FOR PANEL 4
****

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
     72000 540 0 0.72

*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED

****
PANEL 4 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

179.4601298 234.5989885 295.3686232 52.58525299 12556.2701

I(AMPS)   PF
13.5813544 0.6075802088
****

****
BEGIN LOAD FLOW FOR PANEL 5
****

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
      72000 540 0 0.72

*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED

****
PANEL 5 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

179.510997 234.6445306 295.4357016 52.58278394 7251.013104

I(AMPS)   PF
23.52359311 0.6076144353
****

PANEL 1 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 2 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 3 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 4 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 5 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

```
*************************************************************
FEEDER LOAD 2 FEEDER LOAD PARAMETERS - THREE PHASE
P(KW)        Q(KVAR)       S(KVA)AT DEGREES       V(VOLTS)

1217.396126 236.6047618 1240.175448 10.99849887 6211.355434

I(AMPS)      PF
115.2752626 0.9816321782
*************************************************************
```

FEEDER CABLE 1 TO MAIN MINE TRANSFORMER- PREVIOUS VALUES USED

FEEDER CABLE 2 TO MAIN MINE TRANSFORMER- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

```
*************************************************************
MINE INPUT PARAMETERS-THREE PHASE
P(KW)        Q(KVAR)       S(KVA)AT DEGREES       V(VOLTS)

502.8933018 456.0251954 678.8671828 42.20183319 802.8237921

I(AMPS)      PF
488.2069447 0.7407830495
*************************************************************
```

RUN COMPLETED? YES OR NO
NO

EXECUTION SEQUENCE

DYNAMIC, NO DEFAULTS, NO ECHO-CHECK
VARY LOADS

*****RUN DESCRIPTION*****

             INPUT TITLE FOR THIS RUN
VARY LOADS IN THIS RUN
             SELECT RUN TYPE AS S-STATIC, D-DYNAMIC, F-FAULT
D
             DEFAULT CODES USED THIS RUN? YES OR NO
NO
             IS DATA ECHO-CHECKING DESIRED? SOME, NONE, ALL
NONE

             NO FAULT CALCULATIONS SPECIFIED, NORMAL FLOW

*****FREQ OF CURRENT(HZ),NUMBER OF FEEDER LOADS *****- PREVIOUS VALUES USED

****
BEGIN LOAD FLOW FOR FEEDER 1
****

*****NUMBER OF PANELS*****- PREVIOUS VALUES USED

****
BEGIN LOAD FLOW FOR PANEL 1
****

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
       72000 540 0 0.72

*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED

****
PANEL 1 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

109.5570644 125.5279707 166.6133902 48.88651004 4191.254437

I(AMPS)   PF
22.95119209 0.6575525788
****

****
BEGIN LOAD FLOW FOR PANEL 2
****

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

☐:
      72000 540 0 0.72

*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

☐:
        36000 540 0 0.65
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

☐:
        95000 540 0 0.70
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED

****
PANEL 2 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

210.2734667 212.1499486 298.7014086 45.25451165 554.4195012

I(AMPS)   PF
311.0556867 0.7039587382
****

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****************************
BEGIN LOAD FLOW FOR PANEL 3
****************************

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****DC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS)

[]:
     10000 200
*****DC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL DC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED


************************************************************
PANEL 3 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)          Q(KVAR)          S(KVA)AT DEGREES          V(VOLTS)

73.06608951 66.40572055 98.73385011 42.26595652 4612.576682

I(AMPS)        PF
12.35838857 0.7400307941
************************************************************
```

PANEL 1 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 2 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 3 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED


```
***********************************************************
FEEDER LOAD 1 FEEDER LOAD PARAMETERS - THREE PHASE
P(KW)        Q(KVAR)        S(KVA)AT DEGREES        V(VOLTS)

251.5319931 253.9615076 357.4420105 45.27536918 602.1359418

I(AMPS)        PF
342.7286542 0.7037001408
***********************************************************
```


```
****************************
BEGIN LOAD FLOW FOR FEEDER 2
****************************
```

*****NUMBER OF PANELS*****- PREVIOUS VALUES USED

```
****************************
BEGIN LOAD FLOW FOR PANEL 1
****************************
```

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

☐:
    72000 540 0 0.72
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****DC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS)

☐:
    15000 200

*****DC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL DC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED

****
PANEL 1 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

122.7143125 104.8666894 161.4181682 40.51585676 3828.955377

I(AMPS)   PF
24.33949046 0.7602261494
****

```
*****************************
BEGIN LOAD FLOW FOR PANEL 2
*****************************

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
     95000 540 0 0.70
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED


********************************************************************
PANEL 2 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)       Q(KVAR)        S(KVA)AT DEGREES       V(VOLTS)

135.2234374 ‾140.4268412 194.9489054 313.9185708 4226.206195

I(AMPS)      PF
26.63235011 0.6936352736
********************************************************************
```

```
****************************
BEGIN LOAD FLOW FOR PANEL 3
****************************


*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
      72000 540 0 0.72
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED


****************************************************************
PANEL 3 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)        Q(KVAR)        S(KVA)AT DEGREES        V(VOLTS)

109.5086282 125.4845952 166.5488615 48.88925204 7256.653227

I(AMPS)     PF
13.25087847 0.6575165223
****************************************************************
```

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**************************
BEGIN LOAD FLOW FOR PANEL 4
**************************


*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

▯:
      72000 540 0 0.72
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED


**********************************************************
PANEL 4 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)        Q(KVAR)        S(KVA)AT DEGREES        V(VOLTS)

179.4601298 234.5989885 295.3686232 52.58525299 12556.2701

I(AMPS)     PF
13.5813544 0.6075802088
**********************************************************
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* * * * * * * * * * * * * * * * * * * * * * * * * * * *
BEGIN LOAD FLOW FOR PANEL 5
* * * * * * * * * * * * * * * * * * * * * * * * * * * *

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

□:
      72000 540 0 0.72
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED


* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
PANEL 5 PANEL LOAD PARAMETERS  - THREE PHASE
P(KW)        Q(KVAR)          S(KVA)AT DEGREES        V(VOLTS)

179.510997 234.6445306 295.4357016 52.58278394 7251.013104

I(AMPS)       PF
23.52359311 0.6076144353
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

PANEL 1 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 2 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 3 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 4 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 5 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

****
FEEDER LOAD 2 FEEDER LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

902.1507645 304.7115603 952.2211596 18.66297295 6321.829731

I(AMPS)   PF
86.96297848 0.9474172626
****

FEEDER CABLE 1 TO MAIN MINE TRANSFORMER- PREVIOUS VALUES USED

FEEDER CABLE 2 TO MAIN MINE TRANSFORMER- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

****
MINE INPUT PARAMETERS-THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

387.5068475 383.044965 544.8715464 44.6682274 735.5033019

I(AMPS)   PF
427.7094789 0.7111893621
****

           RUN COMPLETED? YES OR NO
NO

EXECUTION SEQUENCE

DYNAMIC, DEFAULTS, ECHO-CHECK
SELECT EQUIPMENT FROM CATALOG

EQUIPMENT SELECTION NUMBER	PREVIOUS EQUIPMENT CODE	OVERRIDE
82	2011431	NONE USED,ALL DEFAULTS RETAINED
89	2021511	NONE USED,ALL DEFAULTS RETAINED
24	1111331	NONE USED,ALL DEFAULTS RETAINED
29	1111521	POWER 170000,OVERRIDES 175000

*****RUN DESCRIPTION*****

        INPUT TITLE FOR THIS RUN
TEST DEFAULTS IN EQUIPMENT CATALOG AND ECHO-CHECK INPUT
        SELECT RUN TYPE AS S-STATIC, D-DYNAMIC, F-FAULT
D

        DEFAULT CODES USED THIS RUN? YES OR NO
YES

        IS DATA ECHO-CHECKING DESIRED? SOME, NONE, ALL
ALL

        NO FAULT CALCULATIONS SPECIFIED, NORMAL FLOW

*****FREQ OF CURRENT(HZ),NUMBER OF FEEDER LOADS *****- PREVIOUS VALUES USED

****
BEGIN LOAD FLOW FOR FEEDER 1
****

*****NUMBER OF PANELS*****- PREVIOUS VALUES USED

****
BEGIN LOAD FLOW FOR PANEL 1
****

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

TO SELECT DEFAULT (CATALOG) VALUES : INPUT CATALOG NUMBER FOLLOWED BY ZERO
TO OVERRIDE DEFAULT (CATALOG) VALUES: INPUT CATALOG NUMBER FOLLOWED BY-
                             ZEROES TO SELECT DEFAULT ENTRIES
                             NON-ZEROES TO OVERRIDE AN ENTRY
TO INPUT ALL VALUES FROM KEYBOARD : INPUT ZERO FOLLOWED BY VALUES
□:
    82 0
*****ECHO-CHECK OF ACLOAD   *****
78000 550 0.7953988302 0.7
VALUES OK? YES OR NO
YES

*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED

****
PANEL 1 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

117.4727095 138.2117711 181.3899974 49.63721391 4276.176737

I(AMPS)   PF
24.49046666 0.6476250685
****

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****************************
BEGIN LOAD FLOW FOR PANEL 2
****************************

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

TO SELECT DEFAULT (CATALOG) VALUES  : INPUT CATALOG NUMBER FOLLOWED BY ZERO
TO OVERRIDE DEFAULT (CATALOG) VALUES: INPUT CATALOG NUMBER FOLLOWED BY-
                                      ZEROES TO SELECT DEFAULT ENTRIES
                                      NON-ZEROES TO OVERRIDE AN ENTRY
TO INPUT ALL VALUES FROM KEYBOARD   : INPUT ZERO FOLLOWED BY VALUES
[]:
      82 0
*****ECHO-CHECK OF ACLOAD    *****
78000 550 0.7953988302 0.7
VALUES OK? YES OR NO
YES
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

TO SELECT DEFAULT (CATALOG) VALUES  : INPUT CATALOG NUMBER FOLLOWED BY ZERO
TO OVERRIDE DEFAULT (CATALOG) VALUES: INPUT CATALOG NUMBER FOLLOWED BY-
                                      ZEROES TO SELECT DEFAULT ENTRIES
                                      NON-ZEROES TO OVERRIDE AN ENTRY
TO INPUT ALL VALUES FROM KEYBOARD   : INPUT ZERO FOLLOWED BY VALUES
[]:
      82 .0
*****ECHO-CHECK OF ACLOAD    *****
78000 550 0.7953988302 0.7
VALUES OK? YES OR NO
YES
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

TO SELECT DEFAULT (CATALOG) VALUES  : INPUT CATALOG NUMBER FOLLOWED BY ZERO
TO OVERRIDE DEFAULT (CATALOG) VALUES: INPUT CATALOG NUMBER FOLLOWED BY-
                                      ZEROES TO SELECT DEFAULT ENTRIES
                                      NON-ZEROES TO OVERRIDE AN ENTRY
TO INPUT ALL VALUES FROM KEYBOARD   : INPUT ZERO FOLLOWED BY VALUES
[]:
      82 0 0 .65
```

*****ECHO-CHECK OF ACLOAD   *****
78000 550 0.8632118901 0.65
VALUES OK? YES OR NO
YES
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED

****
PANEL 2 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

242.8103635 254.7245924 351.911197 46.37176704 564.8196286

I(AMPS)   PF
359.7184199 0.689976237
****

****
BEGIN LOAD FLOW FOR PANEL 3
****

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****DC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS)

TO SELECT DEFAULT (CATALOG) VALUES : INPUT CATALOG NUMBER FOLLOWED BY ZERO
TO OVERRIDE DEFAULT (CATALOG) VALUES: INPUT CATALOG NUMBER FOLLOWED BY-
                                      ZEROES TO SELECT DEFAULT ENTRIES
                                      NON-ZEROES TO OVERRIDE AN ENTRY
TO INPUT ALL VALUES FROM KEYBOARD   : INPUT ZERO FOLLOWED BY VALUES
⬚:
     89 0
*****ECHO-CHECK OF DCLOAD   *****
91000 250 1.570796327 0
VALUES OK? YES OR NO
YES

*****DC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL DC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED


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**************************************************************
PANEL 3 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)        Q(KVAR)        S(KVA)AT DEGREES        V(VOLTS)

378.0010874 121.8549784 397.156717 17.8675932 6234.58494

I(AMPS)        PF
36.77847678 0.9517680836
**************************************************************
```


PANEL 1 TO FEEDER TRANSMISSION LINE - PREVIOUS VALUES USED

PANEL 2 TO FEEDER TRANSMISSION LINE - PREVIOUS VALUES USED

PANEL 3 TO FEEDER TRANSMISSION LINE - PREVIOUS VALUES USED


```
**************************************************************
FEEDER LOAD 1 FEEDER LOAD PARAMETERS - THREE PHASE
P(KW)        Q(KVAR)        S(KVA)AT DEGREES        V(VOLTS)

314.9569502 327.8794735 454.6458287 46.15161966 636.5647647

I(AMPS)        PF
412.3537873 0.6927523145
**************************************************************
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***************************
BEGIN LOAD FLOW FOR FEEDER 2
***************************

*****NUMBER OF PANELS*****- PREVIOUS VALUES USED

***************************
BEGIN LOAD FLOW FOR PANEL 1
***************************

*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES******
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

TO SELECT DEFAULT (CATALOG) VALUES  : INPUT CATALOG NUMBER FOLLOWED BY ZERO
TO OVERRIDE DEFAULT (CATALOG) VALUES: INPUT CATALOG NUMBER FOLLOWED BY-
                                      ZEROES TO SELECT DEFAULT ENTRIES
                                      NON-ZEROES TO OVERRIDE AN ENTRY
TO INPUT ALL VALUES FROM KEYBOARD   : INPUT ZERO FOLLOWED BY VALUES
[]:
     82 0
*****ECHO-CHECK OF ACLOAD    *****
78000 550 0.7953988302 0.7
VALUES OK? YES OR NO
YES
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****DC LOAD VALUES******
POWER(WATTS), VOLTAGE(VOLTS)

TO SELECT DEFAULT (CATALOG) VALUES  : INPUT CATALOG NUMBER FOLLOWED BY ZERO
TO OVERRIDE DEFAULT (CATALOG) VALUES: INPUT CATALOG NUMBER FOLLOWED BY-
                                      ZEROES TO SELECT DEFAULT ENTRIES
                                      NON-ZEROES TO OVERRIDE AN ENTRY
TO INPUT ALL VALUES FROM KEYBOARD   : INPUT ZERO FOLLOWED BY VALUES

[]:
     89 100000 0
*****ECHO-CHECK OF DCLOAD    *****
100000 250 1.570796327 0
VALUES OK? YES OR NO
YES
```

*****DC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL DC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED

****
PANEL 1 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)   Q(KVAR)   S(KVA)AT DEGREES   V(VOLTS)

339.6773772 173.7688674 381.5446761 27.09293484 4786.198583

I(AMPS)   PF
46.02502752 0.8902689475
****

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***************************
BEGIN LOAD FLOW FOR PANEL 2
***************************


*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

TO SELECT DEFAULT (CATALOG) VALUES  : INPUT CATALOG NUMBER FOLLOWED BY ZERO
TO OVERRIDE DEFAULT (CATALOG) VALUES: INPUT CATALOG NUMBER FOLLOWED BY-
                                      ZEROES TO SELECT DEFAULT ENTRIES
                                      NON-ZEROES TO OVERRIDE AN ENTRY
TO INPUT ALL VALUES FROM KEYBOARD   : INPUT ZERO FOLLOWED BY VALUES
□:
      82 0
*****ECHO-CHECK OF ACLOAD    *****
78000 550 0.7953988302 0.7
VALUES OK? YES OR NO
YES
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED


**********************************************************************
PANEL 2 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)        Q(KVAR)        S(KVA)AT DEGREES        V(VOLTS)

117.492491 ‾164.0297983 201.7678373 305.6135571 4273.263736

I(AMPS)       PF
27.26036172 0.5823152618
**********************************************************************
```

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* * * * * * * * * * * * * * * * * * * * * * * * * * * *
BEGIN LOAD FLOW FOR PANEL 3
* * * * * * * * * * * * * * * * * * * * * * * * * * * *


* * * * *NUMBER OF AC LOADS* * * * *- PREVIOUS VALUES USED
* * * * *AC LOAD VALUES* * * * *
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

TO SELECT DEFAULT (CATALOG) VALUES  : INPUT CATALOG NUMBER FOLLOWED BY ZERO
TO OVERRIDE DEFAULT (CATALOG) VALUES: INPUT CATALOG NUMBER FOLLOWED BY-
                                      ZEROES TO SELECT DEFAULT ENTRIES
                                      NON-ZEROES TO OVERRIDE AN ENTRY
TO INPUT ALL VALUES FROM KEYBOARD   : INPUT ZERO FOLLOWED BY VALUES
□:
      24 0
* * * * *ECHO-CHECK OF ACLOAD    * * * * *
90000 550 0.927295218 0.6
VALUES OK? YES OR NO
YES
* * * * *POWER FACTOR CORRECTION* * * * *- PREVIOUS VALUES USED

* * * * *AC TRAILING CABLE VALUES* * * * *- PREVIOUS VALUES USED

* * * * *PANEL AC FEED CABLE VALUES* * * * *- PREVIOUS VALUES USED

* * * * *NUMBER OF DC LOADS* * * * *- PREVIOUS VALUES USED

* * * * *TRANSFORMER CONNECTIONS* * * * *- PREVIOUS VALUES USED

* * * * *POWER FACTOR CORRECTION CAPACITOR* * * * *- PREVIOUS VALUES USED

* * * * *FORWARD RECTIFIER RESISTANCE(OHMS)* * * * *- PREVIOUS VALUES USED

* * * * *PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)* * * * *- PREVIOUS VALUES USED

* * * * *OPEN CIRCUIT TEST DATA* * * * *- PREVIOUS VALUES USED

* * * * *TRANSFORMER SHORT CIRCUIT DATA A TO B* * * * *- PREVIOUS VALUES USED

* * * * *TRANSFORMER SHORT CIRCUIT DATA A TO C* * * * *- PREVIOUS VALUES USED

* * * * *TRANSFORMER SHORT CIRCUIT DATA B TO C* * * * *- PREVIOUS VALUES USED

* * * * *CABLE TO FEEDER LOAD CONNECTION* * * * *- PREVIOUS VALUES USED


* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
PANEL 3 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)        Q(KVAR)        S(KVA)AT DEGREES        V(VOLTS)

132.3245193 180.7578489 224.0160225 53.79384917 7461.203298

I(AMPS)      PF
17.33443062 0.5906922097
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
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**************************
BEGIN LOAD FLOW FOR PANEL 4
**************************


*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

TO SELECT DEFAULT (CATALOG) VALUES  : INPUT CATALOG NUMBER FOLLOWED BY ZERO
TO OVERRIDE DEFAULT (CATALOG) VALUES: INPUT CATALOG NUMBER FOLLOWED BY-
                                      ZEROES TO SELECT DEFAULT ENTRIES
                                      NON-ZEROES TO OVERRIDE AN ENTRY
TO INPUT ALL VALUES FROM KEYBOARD   : INPUT ZERO FOLLOWED BY VALUES
☐:
      29 170000
*****ECHO-CHECK OF ACLOAD    *****
170000 440 1.047197551 0.5
VALUES OK? YES OR NO
YES
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED


*****************************************************************
PANEL 4 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)       Q(KVAR)        S(KVA)AT DEGREES       V(VOLTS)

293.7671834 444.7326977 532.9974957 56.55332696 11141.31932

I(AMPS)     PF
27.62026999 0.5511605321
*****************************************************************
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```
****************************
BEGIN LOAD FLOW FOR PANEL 5
****************************


*****NUMBER OF AC LOADS*****- PREVIOUS VALUES USED
*****AC LOAD VALUES*****
POWER(WATTS), VOLTAGE(VOLTS), PHASE ANGLE(DEGREES), POWER FACTOR

TO SELECT DEFAULT (CATALOG) VALUES  : INPUT CATALOG NUMBER FOLLOWED BY ZERO
TO OVERRIDE DEFAULT (CATALOG) VALUES: INPUT CATALOG NUMBER FOLLOWED BY-
                                      ZEROES TO SELECT DEFAULT ENTRIES
                                      NON-ZEROES TO OVERRIDE AN ENTRY
TO INPUT ALL VALUES FROM KEYBOARD   : INPUT ZERO FOLLOWED BY VALUES
☐:
      82 0
*****ECHO-CHECK OF ACLOAD     *****
78000 550 0.7953988302 0.7
VALUES OK? YES OR NO
YES
*****POWER FACTOR CORRECTION*****- PREVIOUS VALUES USED

*****AC TRAILING CABLE VALUES*****- PREVIOUS VALUES USED

*****PANEL AC FEED CABLE VALUES*****- PREVIOUS VALUES USED

*****NUMBER OF DC LOADS*****- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED

*****POWER FACTOR CORRECTION CAPACITOR*****- PREVIOUS VALUES USED

*****FORWARD RECTIFIER RESISTANCE(OHMS)*****- PREVIOUS VALUES USED

*****PRIMARY,SECONDARY, TERTIARY VOLTAGES(VOLTS)*****- PREVIOUS VALUES USED

*****OPEN CIRCUIT TEST DATA*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO B*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA A TO C*****- PREVIOUS VALUES USED

*****TRANSFORMER SHORT CIRCUIT DATA B TO C*****- PREVIOUS VALUES USED

*****CABLE TO FEEDER LOAD CONNECTION*****- PREVIOUS VALUES USED


************************************************************
PANEL 5 PANEL LOAD PARAMETERS - THREE PHASE
P(KW)        Q(KVAR)        S(KVA)AT DEGREES        V(VOLTS)

190.2601413 251.744858 315.5541077 52.91925499 7397.225595

I(AMPS)      PF
24.62886209 0.602939834
************************************************************
```

PANEL 1 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 2 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 3 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 4 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED

PANEL 5 TO FEEDER TRANSMISSION LINE- PREVIOUS VALUES USED


```
****************************************************************
FEEDER LOAD 2 FEEDER LOAD PARAMETERS - THREE PHASE
P(KW)        Q(KVAR)        S(KVA)AT DEGREES        V(VOLTS)

1495.830166 509.0542561 1580.077251 18.79423551 7122.890715

I(AMPS)        PF
128.0741293 0.9466816666
****************************************************************
```


FEEDER CABLE 1 TO MAIN MINE TRANSFORMER- PREVIOUS VALUES USED

FEEDER CABLE 2 TO MAIN MINE TRANSFORMER- PREVIOUS VALUES USED

*****TRANSFORMER CONNECTIONS*****- PREVIOUS VALUES USED


```
****************************************************************
MINE INPUT PARAMETERS-THREE PHASE
P(KW)        Q(KVAR)        S(KVA)AT DEGREES        V(VOLTS)

525.307467 533.4084916 748.6471491 45.43839913 806.9365195

I(AMPS)        PF
535.64515 0.7016756394
****************************************************************
```


                    RUN COMPLETED? YES OR NO
YES

APPENDIX B

DYNAMIC MOTOR MODELS

Program Execution - Commands

The neumonic commands are read by the main program (see Figure 8) under an A4 format. The variables into which the commands are read form an integer array. After one line of commands is read, the program checks each location in the command array (CMD) to see if a "STOP" command has been entered. If so, the location in the array "OFF" corresponding to the stopped motor is set to "1":

If (CMD(X) .EQ. STOP) OFF(X) = 1.

The subroutine "STPMOT", [STP MOTors] is then called. This subroutine checks to see if all motors are stopped, i.e., all locations in the array "OFF" are set to "1".) and if this is the case, signals the end of the program execution by setting STPRN [SToP RuNning] to "1".

The actual operation and load changes are handled by the COMAND [COMmAND] subroutine. The vector containing the commands is passed from MAIN to COMAND. This is one line of the command list, excluding the time entry. For each entry (corresponding to a particular motor), a series of tests is performed. The tests are of the form:

IF (PCMD(X) .EQ. STRT) GO TO 1.

"PCMD" is the command array. "X" is the motor index. STRT is an integer variable which has been initialized to the value 'STRT'. The internal representation for the value of PCMD is compared with the internal representation of the variable STRT. If they agree, some action is taken, in this case, to start the motor. The motor is turned on by setting the entry in the "ON" vector to "1". The entry in the vector MLD [Motor LoaD] is set to the load torque curve

applicable for the particular operation, in the case, number 1.

If they do not agree, the next test is performed, etc. If there is no agreement, the conditions pertaining to that motor are not altered.
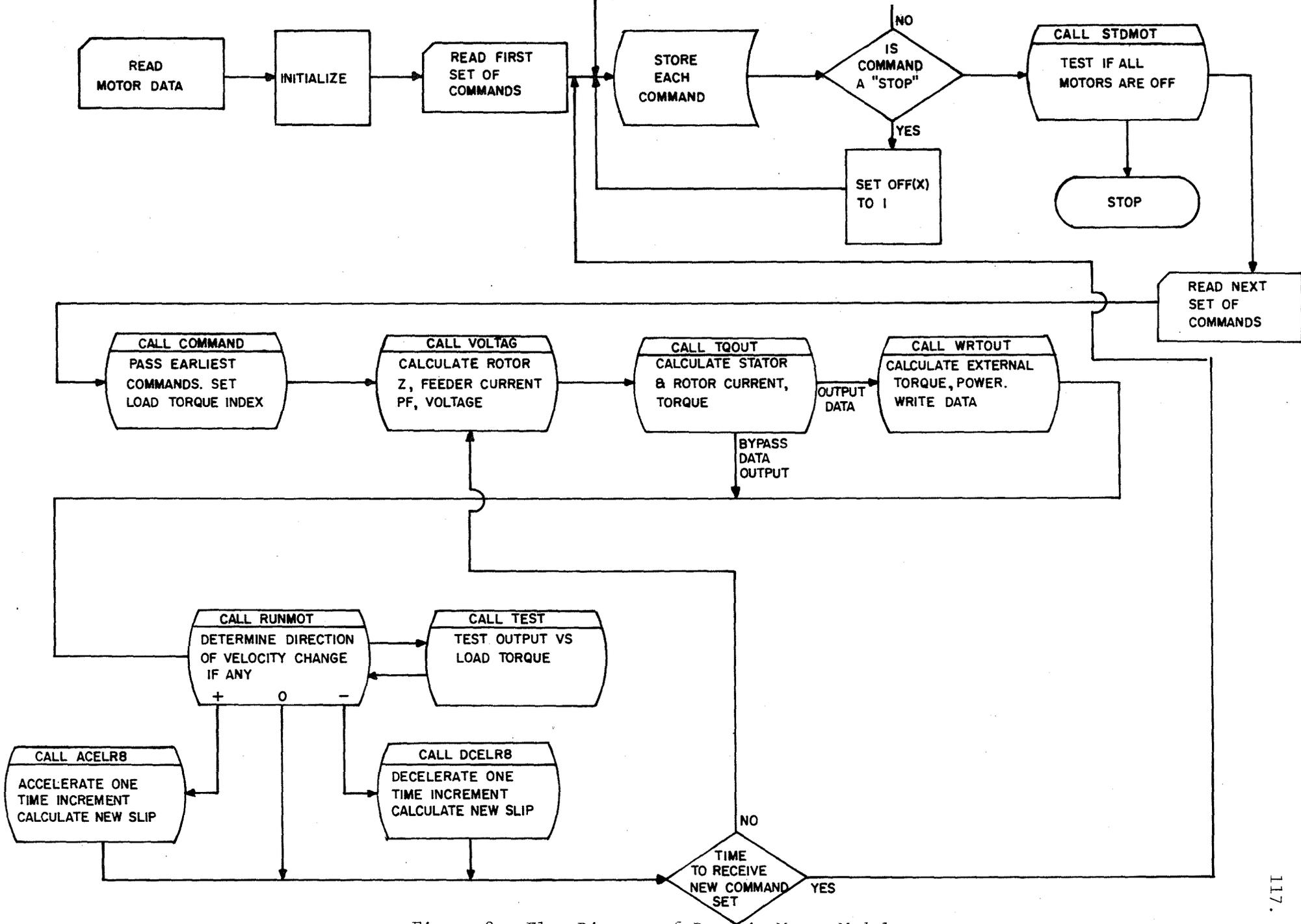
Figure 8. Flow Diagram of Dynamic Motor Models

Program Execution - Motor Interaction

The program sequence handling the motor operations will now be described. Assume the command sequence is at a point where Motor 1 is running under load and Motor 2 is to be started.

The COMAND subroutine has been executed and has assigned a starting load to Motor 2. There was no command in the Motor 1 string so its operation remains unaltered. The next call is to subroutine VOLTAG. Motor parameters are now all subscripted, i.e., $R1(X)$, $X1(X)$, $ZRO(X)$, etc. This subroutine contains a DO loop which sets an index to indicate Motor 1. A test is performed to determine whether the motor is "ON". (If $ON(1) = 1$, Motor 1 has been connected to the feeder.)

In the example case to be described, Motor 1 is on. The impedances of Motor 1 are then computed and stored in the vector YMOT, as an admittance, in position $YMOT(1)$. The DO loop is now executed again, this time for Motor 2. The ON test is performed for Motor 2 and it is found to be ON also. Its slip is 1, because it is just being started. The rotor and then motor impendances of Motor 2 are computed and stored in position 2 of YMOT as an admittance. The DO loop is executed two more times for Motors 3 and 4. They are found to be off, and their admittances are set to zero, i.e., they are not connected to the feeder.

Now the admittances are summed, converted to impedances, and connected to the feeder impedance. The input current and power-factor are calculated as described previously.

The voltage at the motor terminals is then computed with an equivalent impedance representing both motors. This is the end of the VOLTAG subroutine.

The TQOUT [TorQue OUTput] subroutine is the next subroutine called. This routine contains a DO loop and test sequence similar to the VOLTAG subroutine. If a motor is "ON", the following procedure is followed. Knowing the voltage at the motor terminals and the individual admittance of each motor (computed and stored by VOLTAG), the individual input currents for each motor are calculated. The rotor currents and output torques are then computed.

The output subroutine WRTOUT [WRiTe OUT data] is then called to print out computed data. External torque is computed in this subroutine by subtracting friction, windage, and losses from the computed internal torque. From this external torque, power output is determined using the known operating speed. Then, the RUNMOT [RUN MOTors] subroutine is called.

RUNMOT and its associated subroutine TEST are the decision making subroutines which determine if the motors will accelerate, decelerate, or operate at constant velocity. A DO loop and test sequence is used in this subroutine also. If the motor is not on, it is by-passed. If it is found to be on, the TEST subroutine is called by RUNMOT. The Torque Differential DTRQ (ΔT) is computed. A test is then performed to determine whether ΔT is positive, negative or zero. If positive, an acceleration is indicated; if negative, a deceleration; and if zero, the velocity of the motor will not change. Assuming Motor 1 is up to speed, the latter will occur. The DO loop will then execute again, Motor 2 will be found to be on, and TEST is called. This time an acceleration is indicated, and the subroutine ACELR8 [ACcELRate $\rightarrow$ 8] is called.

ACELR8 preforms the integration and speed change. A straight line approximation is used to compute the actual load. Output torque, computed by TQOUT, and load torque are used to compute torque differential. Integration is then performed, and the velocity change required by the accelerating torque acting over Δt is computed. The new angular velocity is then stored, and a new operating point on the torque slip curve is computed. Control then returns to RUNMOT and motors 3 and 4 are bypassed. At this point, the main program regains control and time is checked to determine whether a command change is required.

Program Execution - Load Charges

Data is entered such that a particular command list is associated with the time that a command will go into effect. The first line always starts at 0 seconds. This line is read into CMD, while the time 0 is stored in CHGTME. This value of time is NOT actually used. The program assumes it is zero. Before going through all calculations, the next command line is read. Just before this, the first line is transferred into PCMD. Thus, there are two command lines in memory before the program continues, and the value in CHGTME is the second one in the time column. PCMD and not CMD is passed to COMAND. Therefore, the first line of commands control execution. The second line is held back until needed as described below.

COMAND sets up program execution under control of PCMD commands. These commands remain in effect until the program goes through enough time increments so the sum of these increments equals CHGTME. (Because of numerical error, the program is set up to accept a range of values as "equal".) At this point, control breaks out of the loop, and a third line of commands is read into CMD after the second line is

transferred into PCMD. A new CHGTME now exists, and COMAND sets up the program under control of the new PCMD line.

A load change is accomplished by a command in the motor's command string requiring a new load curve. STRT requires a particular load curve. The motor accelerates under this load until one of the previously described conditions occurs. If a new command string is called before the motor gets up to speed and a load change is indicated, it is handled in the following way.

The new load curve is used. The motor speed is the most recently computed value. Using this speed, output torque is computed. RUNMOT compares this with the new load and determines whether acceleration, deceleration, or no action is required. The procedure then continues as before.

Study of an Example Simulation

A sample of output of the dynamic motor model is shown in Figures 10 and 11. Figure 10 shows motor voltage, current, power and power-factor at the motor end of the trailing cable as a junction of time. Figure 11 shows voltage, current and speed for all motors. In these figures only two sample sets of points are corrected for clarity. Other points may be connected in the same manner. The plotting routine does not plot multiple points if they occur at the same spot on the graph.

Time = 0.0 sec. Input voltage (line to line) = 483.0 volts

MOTOR 1: Started

Voltage drops sharply to 450 volts due to the load applied to the trailing cable.

As the motor accelerates:

1. Input current drops

2. Input power drops

3. Power-factor increases to a maximum value, then drops

    sharply

4. Output torque drops to zero
                                        }   Not Plotted
5. Output power drops to zero

6. Voltage decreases slightly then returns to 481.7 volts

The lower voltage is due to the voltage dropped across the trailing

cable impedance, caused by the no load current drawn by MOTOR 1.

Time = 1.0 sec

MOTOR 3: Started

Conditions as above.

Torque output of MOTOR 1 becomes negative.

Explanations:

Torque output is defined here as the difference between the

torque produced by the motor's internal power, and the loss

due to friction and windage.

Referring to Figure 9, assume MOTOR 1 is operating on curve A at

the point of intersection with L. Suddenly the available voltage

drops due to the start of MOTOR 3. Because of the Rotor's rota-

tional inertia, it cannot change speed instantaneously. However,

the reduced voltage input produces a drop in input current, and

subsequently a drop in output power. The motor now is constrained

(for this instant) to operate on curve B. The torque the motor

can produce is not less than the loss torque and the motor must
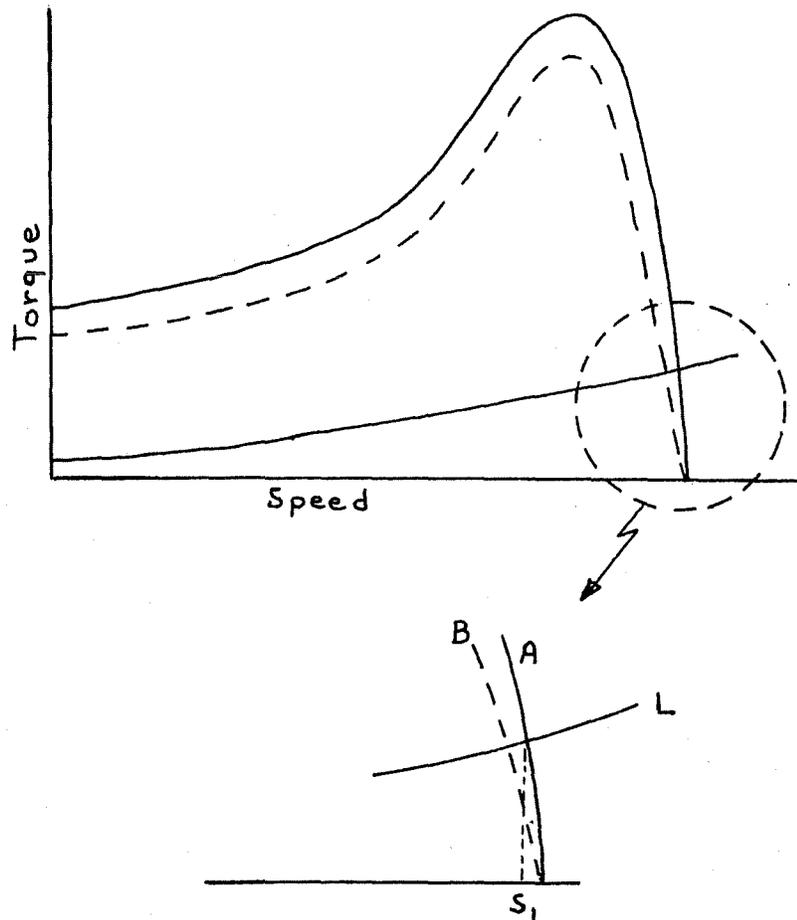
Figure 9. Multiple Motor Torque-Speed
Curves and Load Characteristic.

decelerate. MOTOR 1 does decelerate, and then resumes almost

its previous speed, as MOTOR 3 comes up to speed. This pro-

cedure is essentially repeated until all motors are started.

Time = 4.0 sec

A light load is applied to MOTOR 2, and its speed drops. The

motor input voltage also drops slightly. This, however, is

not enough drop to affect the other motors appreciably. The

power-factor increases, as does the input power.

Time = 5.0 sec

MOTOR 1 is loaded, and the only measurable change is the power-factor, which increases slightly.

Time = 6.0 sec

MOTORS 3 and 4 are loaded. The current drawn increases sharply, as does the power input. The input voltage drops. The power-factor increases sharply.

Time = 7.0 sec

All motors are operating near full load, and the input current and power are very large. The motor voltage is near 420 volts, down 40 volts from NO LOAD. Power-factor is near unity. The loads are now removed, and the motors are disconnected. The voltage rises, while power-factor, power, and current drop to no load conditions

PLOT OF VOLTAGE -V- PF -F- CURRENT -C- POWER -P-

VOLTAGE	400.00	420.00	440.00	460.00	480.00	500.00
PWR. FAC.	0.00	0.20	0.40	0.60	0.80	1.00
CURRENT	0.00	200.00	400.00	600.00	800.00	1000.00
POWER (VA)	0.00	200000.00	400000.00	600000.00	800000.00	1000000.00

Figure 10. Dynamic Response at Motor End of Trailing Cable.

```
            400.00      420.00      440.00      460.00      480.00      500.00
              0.00        0.20        0.40        0.60        0.80        1.00
              0.00      200.00      400.00      600.00      800.00     1000.00
              0.00   200000.00   400000.00   600000.00   800000.001000000.00
              *..........*..........*..........*..........*..........*....
 2.00000 START 4  I                          F      V              P        C
 2.05000          I                          F       V             P  P
 2.10000          I                          F       V             P
 2.15000          I                          F      V              P        C
 2.20000          I                           F     V              P        C
 2.25000          I                           F     V              P        C
 2.30000          I                           F      V             P        C
 2.35000          I                            FV                  P        C
 2.40000          I                          V    F                P        C
 2.45000          I               PCF                                   V
 2.50000          I               PCF                                   V
 2.55000          I               PCF                                   V
 2.60000          I               PCF                              Voltage  V
 2.65000          I               PCF                                   V
 2.70000          I               PCF                                   V
 2.75000          I               PCF      Current                      V
 2.80000          I               PCF                                   V
 2.85000          I               PCF                                   V
 2.90000          I               PCF                                   V
 2.95000          I               PCF                                   V
 3.00000 START 2  I                          F   V                   P      C
 3.05000          I                          F   V                   P
 3.10000          I                           F  V                   P      C
 3.15000          I                           F  V                   P      C
 3.20000          I                            F V                   P      C
 3.25000          I                           FV                     P      C
 3.30000          I                             F                    P      C
 3.35000          I                           V  F                   P      C
 3.40000          I                          V      F                P      C
 3.45000          I               P  C                               V
 3.50000          I               P  C                               V
 3.55000          I               P  C                               V
 3.60000          I               P  C                               V
 3.65000          I               P  C                               V
 3.70000          I               P  C                               V
 3.75000          I               P  C                               V
 3.80000          I               P  C                               V
 3.85000          I               P  C                               V
 3.90000          I               P  C                               V
 3.95000          I               P  C                               V
              *..........*..........*..........*..........*..........*....
```

Figure 10.   Continued.

```
         400.00       420.00       440.00       460.00       480.00       500.00
           0.00         0.20         0.40         0.60         0.80         1.00
           0.00       200.00       400.00       600.00       800.00      1000.00
           0.00   200000.00    400000.00    600000.00    800000.001000000.00
          *..........*..........*..........*..........*..........*..........*....
          ----------------------------------------------------------------------
4.00000  LOAD 2   I         P C                                        V
4.05000           I         P C  F                                     V
4.10000           I         P C  F                                     V
4.15000           I         P C  F                                     V
4.20000           I         P C  F                                     V
4.25000           I         P C  F                                     V
4.30000           I         P C  F                                     V
4.35000           I         P C  F                                     V
4.40000           I         P C  F                                     V
4.45000           I         P C  F                                     V
4.50000           I         P C  F                                     V
4.55000           I         P C  F                                     V
4.60000           I         P C  F                                     V
4.65000           I         P C  F                                     V
4.70000           I         P C  F                                     V
4.75000           I         P C  F                                     V
4.80000           I         P C  F                                     V
4.85000           I         P C  F                                     V
4.90000           I         P C  F                                     V
4.95000           I         P C  F                                     V
5.00000  LOAD 1   I         P C  F                                     V
5.05000           I         P C     F                                  V
5.10000           I         P C     F                                  V
5.15000           I         P C     F                                  V
5.20000           I         P C     F                                  V
5.25000           I         P C     F                                  V
5.30000           I         P C     F                                  V
5.35000           I         P C     F                                  V
5.40000           I         P C     F                                  V
5.45000           I         P C     F                                  V
5.50000           I         P C     F                                  V
5.55000           I         P C     F                                  V
5.60000           I         P C     F                                  V
5.65000           I         P C     F                                  V
5.70000           I         P C     F                                  V
5.75000           I         P C     F                                  V
5.80000           I         P C     F                                  V
5.85000           I         P C     F                                  V
5.90000           I         P C     F                                  V
5.95000           I         P C     F                                  V
          *..........*..........*..........*..........*..........*..........*....
```

Figure 10. Continued.

400.00	420.00	440.00	460.00	480.00	500.00
0.00	0.20	0.40	0.60	0.80	1.00
0.00	200.00	400.00	600.00	800.00	1000.00
0.00	200000.00	400000.00	600000.00	800000.00	1000000.00

```
                 *..........*..........*..........*..........*..........*....
               ------------------------------------------------------------
 6.00000  LOAD 3  I          P C---F        V        ---  ---V
 6.05000       4  I                   VP   C      --- ---             F
 6.10000  INC  2  I                   VP   C                          F
 6.15000          I                   VP   C                          F
 6.20000          I                   VP   C                          F
 6.25000          I                   VP   C                          F
 6.30000          I                   VP   C                          F
 6.35000          I                   VP   C                          F
 6.40000          I                   VP   C                          F
 6.45000          I                   VP   C                          F
 6.50000          I                   VP   C                          F
 6.55000          I                   VP   C                          F
 6.60000          I                   VP   C                          F
 6.65000          I                   VP   C                          F
 6.70000          I                   VP   C                          F
 6.75000          I                   VP   C                          F
 6.80000          I                   VP   C                          F
 6.85000          I                   VP   C                          F
 6.90000          I                   VP   C                          F
 6.95000          I                   VP   C                          F
 7.00000  INC  1  I                  --VP   C                         F
 7.05000       3  I            V --- ---       P     C                F
 7.10000       4  I            V                P    C               F
 7.15000          I            V                P    C               F
 7.20000          I            V                P    C               F
 7.25000          I            V                P    C               F
 7.30000          I            V                P    C               F
 7.35000          I            V                P    C               F
 7.40000          I            V                P    C               F
 7.45000          I            V                P    C               F
 7.50000          I            V                P    C               F
 7.55000          I            V                P    C               F
 7.60000          I            V                P    C               F
 7.65000          I            V                P    C               F
 7.70000          I            V                P    C               F
 7.75000          I            V                P    C               F
 7.80000          I            V                P    C               F
 7.85000          I            V                P    C               F
 7.90000          I            V                P    C               F
 7.95000          I            V                P    C               F
                  *..........*..........*..........*..........*..........*....
```

Figure 10.   Continued.

```
         400.00      420.00      440.00      460.00      480.00      500.00
           0.00        0.20        0.40        0.60        0.80        1.00
           0.00      200.00      400.00      600.00      800.00     1000.00
           0.00   200000.00   400000.00   600000.00   800000.00  1000000.00
          *..........*..........*..........*..........*..........*..........*....
       ------------------------------------------------------------------------
8.00000  IDLE 1    I             V — — — —         P    C              F
8.05000            I      P  C   F                               V
8.10000       3    I      P  C   F                               V
8.15000  DEC  4    I      P  C   F                               V
8.20000       2    I      P  C   F                               V
8.25000            I      P  C   F                               V
8.30000            I      P  C   F                               V
8.35000            I      P  C   F                               V
8.40000            I      P  C   F                               V
8.45000            I      P  C   F                               V
8.50000            I      P  C   F                               V
8.55000            I      P  C   F                               V
8.60000            I      P  C   F                               V
8.65000            I      P  C   F                               V
8.70000            I      P  C   F                               V
8.75000            I      P  C   F                               V
8.80000            I      P  C   F                               V
8.85000            I      P  C   F                               V
8.90000            I      P  C   F                               V
8.95000            I      P  C   F                               V
9.00000  IDLE 2    I      P  C   F                               V
9.05000            I      P  C                                   V
9.10000            I      P  C                                   V
9.15000            I      P  C                                   V
9.20000            I      P  C                                   V
9.25000            I      P  C                                   V
9.30000            I      P  C                                   V
9.35000            I      P  C                                   V
9.40000            I      P  C                                   V
9.45000            I      P  C                                   V
9.50000            I      P  C                                   V
9.55000            I      P  C                                   V
9.60000            I      P  C                                   V
9.65000            I      P  C                                   V
9.70000            I      P  C                                   V
9.75000            I      P  C                                   V
9.80000            I      P  C                                   V
9.85000            I      P  C                                   V
9.90000            I      P  C                                   V
9.95000            I      P  C                                   V
          *..........*..........*..........*..........*..........*..........*....
```

Figure 10. Continued.

```
                   400.00       420.00       440.00       460.00       480.00       500.00
                     0.00         0.20         0.40         0.60         0.80         1.00
                     0.00       200.00       400.00       600.00       800.00      1000.00
                     0.00     200000.00    400000.00    600000.00    800000.00   1000000.00
                   *..........*..........*..........*..........*..........*..........*....
                   ---------------------------------------------------------------------
10.00000  STOP 3     I     PC   F                                            V
10.05000       4     I     PC   F                                            V
10.10000             I     PC   F                                            V
10.15000             I     PC   F                                            V
10.20000             I     PC   F                                            V
10.25000             I     PC   F                                            V
10.30000             I     PC   F                                            V
10.35000             I     PC   F                                            V
10.40000             I     PC   F                                            V
10.45000             I     PC   P                                            V
10.50000             I     PC   F                                            V
10.55000             I     PC   F                                            V
10.60000             T     PC   F                                            V
10.65000             I     PC   F                                            V
10.70000             I     PC   F                                            V
10.75000             I     PC   F                                            V
10.80000             I     PC   F                                            V
10.85000             I     PC   F                                            V
10.90000             I     PC   F                                            V
10.95000             I     PC   F                                            V
11.00000  STOP 1     I     PC   F                                            V
11.05000             I     PC   F                                            V
11.10000             I     PC   F                                            V
11.15000             I     PC   F                                            V
11.20000             I     PC   F                                            V
11.25000             I     PC   F                                            V
11.30000             I     PC   F                                            V
11.35000             I     PC   F                                            V
11.40000             I     PC   F                                            V
11.45000             I     PC   F                                            V
11.50000             I     PC   P                                            V
11.55000             I     PC   F                                            V
11.60000             I     PC   F                                            V
11.65000             I     PC   F                                            V
11.70000             I     PC   F                                            V
11.75000             I     PC   P                                            V
11.80000             I     PC   F                                            V
11.85000             I     PC   F                                            V
11.90000             I     PC   F                                            V
11.95000             I     PC   F                                            V
          STOP 2     *..........*..........*..........*..........*..........*....
```

Figure 10. Continued.

PLOT OF VOLTAGE -V- CURRENT -1,2,3,4- SPEED -A,B,C,D-

VOLTAGE	400.00	420.00	440.00	460.00	480.00	500.00
CURRENT	0.00	60.00	120.00	180.00	240.00	300.00
SPEED	1750.00	1760.00	1770.00	1780.00	1790.00	1800.00

```
                    *..........*..........*..........*..........*..........*....
                    ---------------------------------------------------------
0.00000 START 1 DI4                                  /V
0.05000         DI4                                   V
0.10000         DI4                                   V
0.15000         DI4                                   V--    ---    ---
0.20000         DI4              1               ----------------V-   --...
0.25000         DI4           1                                      V       A
0.30000         DI4         1                                        V       A
0.35000         DI4         1                                        V       A
0.40000         DI4         1                                        V       A
0.45000         DI4         1                                        V       A
0.50000         DI4         1                        Voltage         V       A
0.55000         DI4         1                                        V       A
0.60000         DI4         1       Current                          V       A
0.65000         DI4         1       of motor 1                       V       A
0.70000         DI4         1                                        V       A
0.75000         DI4         1                                        V       A
0.80000         DI4         1                                        V       A
0.85000         DI4         1                                        V       A
0.90000         DI4         1                                        V       A
0.95000         DI4         1                              ---    -- V       A
1.00000 START 3 DI4         1               V--  --  --                      A
1.05000         DI4         1               V                                A
1.10000         DI4         1               V                                A
1.15000         DI4         1               V                                A
1.20000         DI4         1               V                                A
1.25000         DI4         1               V         Speed                  A
1.30000         DI4         1              V          of motor 1             A
1.35000         DI4         1              V                                 A
1.40000         DI4         1           V--.   ---  ---  ---  ---            A
1.45000         DI4         1    3                          --  -- V         C
1.50000         DI4         1    3                                 V         C
1.55000         DI4         1    3                                 V         C
1.60000         DI4         1    3                                 V         C
1.65000         DI4         1    3                                 V         C
1.70000         DI4         1    3                                 V         C
1.75000         DI4         1    3                                 V         C
1.80000         DI4         1    3  \                              V         C
1.85000         DI4         1    3                                 V         C
1.90000         DI4         1    3                                 V         C
1.95000         DI4         1    3                                 V         C
                    *..........*..........*..........*..........*..........*...
```

Figure 11. Dynamic Voltage, Current, and
Speed of all Motors.

```
            400.00      420.00      440.00      460.00      480.00      500.00
              0.00       60.00      120.00      180.00      240.00      300.00
           1750.00     1760.00     1770.00     1780.00     1790.00     1800.00     1
               *..........*..........*..........*..........*..........*....
           ----------------------------------------------------------------
2.00000 START 4 DI2  1    3         V                                    C
2.05000         DI2  1    3         V                                    C
2.10000         DI2  1    3          V                                   C
2.15000         DI2  1    3          V                                   C
2.20000         DI2  1    3          V                                   C
2.25000         DI2  1    3          V                                   C
2.30000         DI2  1    3          V                                   C
2.35000         DI2  1    3           V                                  C
2.40000         DI2  1    3         V — — — — — — — — — — — —V           C
2.45000         BI2  1    4                                      V       D
2.50000         BI2  1    4                                       V      D
2.55000         BI2  1    4                                       V      D
2.60000         BI2  1    4                                       V      D
2.65000         BI2  1    4                                       V      D
2.70000         BI2  1    4                                       V      D
2.75000         BI2  1    4                                       V      D
2.80000         BI2  1    4                                       V      D
2.85000         BI2  1    4                                       V      D
2.90000         BI2  1    4                                       V      D
2.95000         BI2  1    4                                      —V      D
3.00000 START 2 BI   1    4         V — — — — — — — —                    D
3.05000         BI   1    4          V                                   D
3.10000         BI   1    4          V                                   D
3.15000         BI   1    4          V                                   D
3.20000         BI   1    4          V                                   D
3.25000         BI   1    4         V                                    D
3.30000         BI   1    4         V                                    D
3.35000         BI   1    4        V                                     D
3.40000         BI   1    4        V — — — — — — — —                     D
3.45000         I    1   24                                    — V       DB
3.50000         I    1   24                                      V       DB
3.55000         I    1   24                                      V       DB
3.60000         I    1   24                                      V       DB
3.65000         I    1   24                                      V       DB
3.70000         I    1   24                                      V       DB
3.75000         I    1   24                                      V       DB
3.80000         I    1   24                                      V       DB
3.85000         I    1   24                                      V       DB
3.90000         I    1   24                                      V       DB
3.95000         I    1   24                                      V       DB
               *..........*..........*..........*..........*..........*....
```

Figure 11.   Continued.

```
           400.00      420.00      440.00      460.00      480.00      500.00
             0.00       60.00      120.00      180.00      240.00      300.00
          1750.00     1760.00     1770.00     1780.00     1790.00     1800.00
              *..........*..........*..........*..........*..........*....
          ------------------------------------------------------------------
4.00000 LOAD 2   I    1   24                                V            DB
4.05000          I    1   4 2                               V            B D
4.10000          I    1   4 2                               V            B D
4.15000          I    1   4 2                               V            B D
4.20000          I    1   4 2                               V            B D
4.25000          I    1   4 2                               V            B D
4.30000          I    1   4 2                               V            B D
4.35000          I    1   4 2                               V            B D
4.40000          I    1   4 2                               V            B D
4.45000          I    1   4 2                               V            B D
4.50000          I    1   4 2                               V            B D
4.55000          I    1   4 2                               V            B D
4.60000          I    1   4 2                               V            B D
4.65000          I    1   4 2                               V            B D
4.70000          I    1   4 2                               V            B D
4.75000          I    1   4 2                               V            B D
4.80000          I    1   4 2                               V            B D
4.85000          I    1   4 2                               V            B D
4.90000          I    1   4 2                               V            B D
4.95000          I    1   4 2                               V            B D
5.00000 LOAD 1   I    1   4 2                               V            B D
5.05000          I    1   4 2                               V        A   B D
5.10000          I    1   4 2                               V        A   B D
5.15000          I    1   4 2                               V        A   B D
5.20000          I    1   4 2                               V        A   B D
5.25000          I    1   4 2                               V        A   B D
5.30000          I    1   4 2                               V        A   B D
5.35000          I    1   4 2                               V        A   B D
5.40000          I    1   4 2                               V        A   B D
5.45000          I    1   4 2                               V        A   B D
5.50000          I    1   4 2                               V        A   B D
5.55000          I    1   4 2                               V        A   B D
5.60000          I    1   4 2                               V        A   B D
5.65000          I    1   4 2                               V        A   B D
5.70000          I    1   4 2                               V        A   B D
5.75000          I    1   4 2                               V        A   B D
5.80000          I    1   4 2                               V        A   B D
5.85000          I    1   4 2                               V        A   B D
5.90000          I    1   4 2                               V        A   B D
5.95000          I    1   4 2                               V        A   B D
              *..........*..........*..........*..........*..........*....
```

Figure 11. Continued
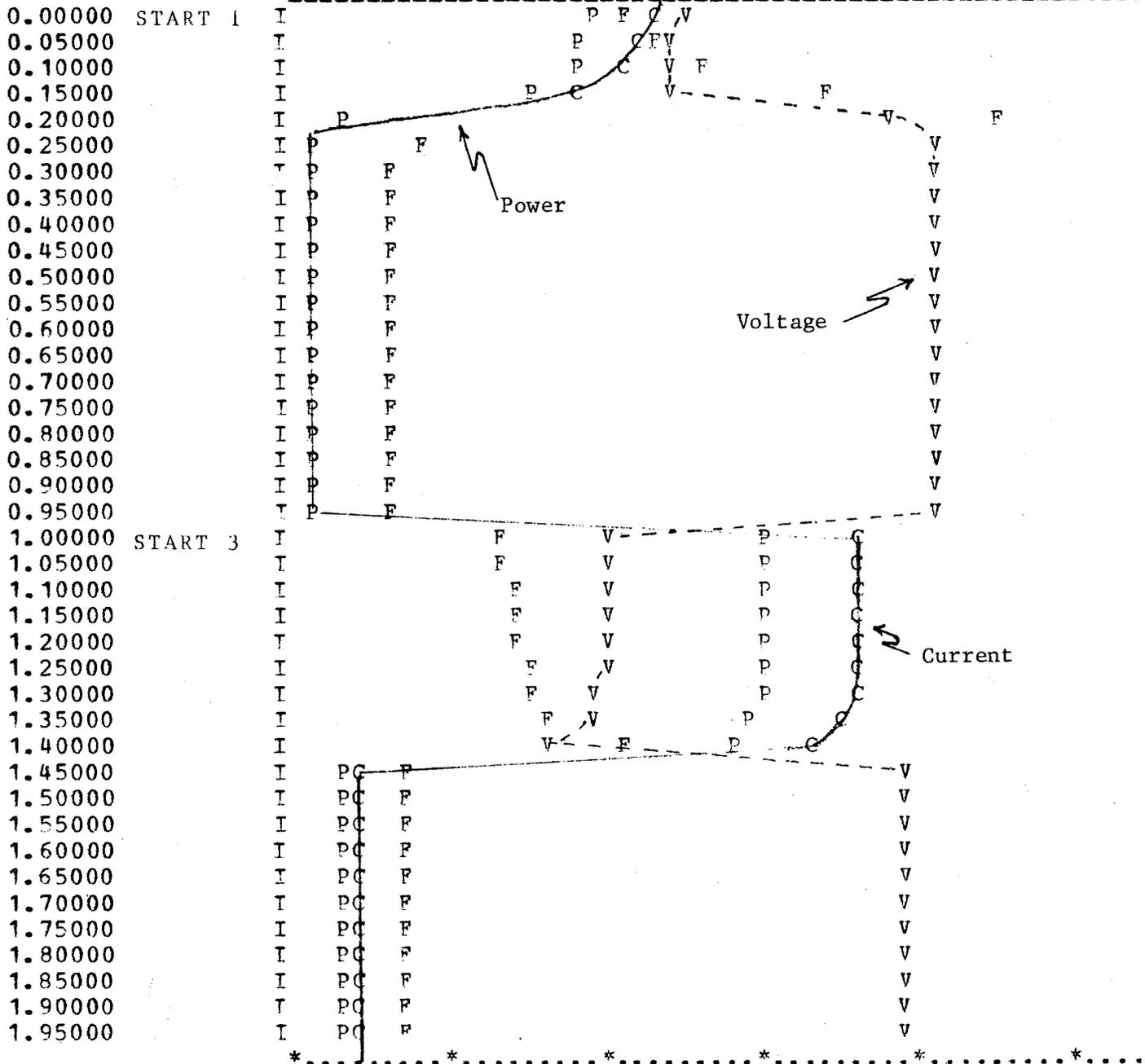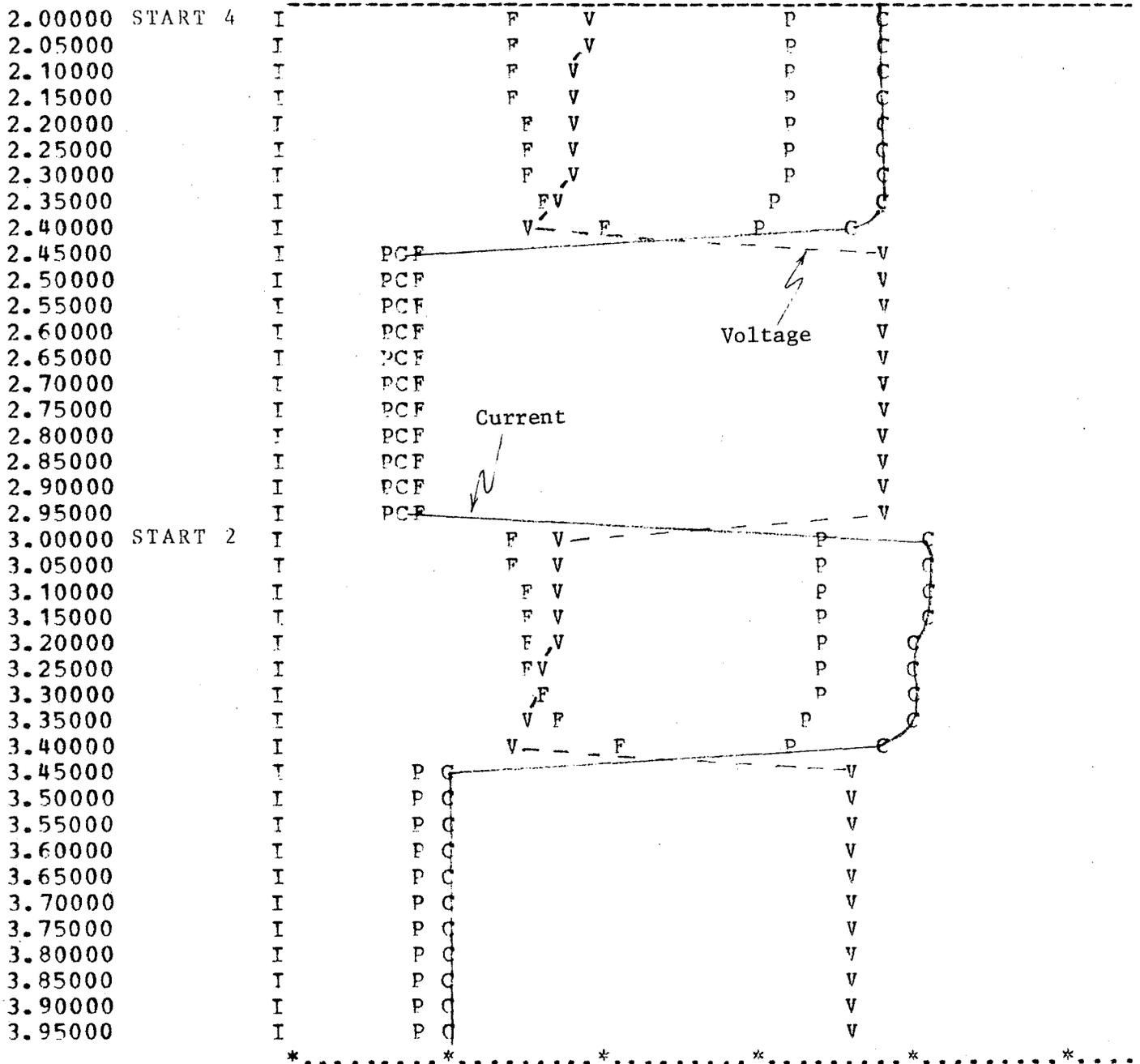
```
                400.00       420.00       440.00       460.00       480.00       500.00
                  0.00        60.00       120.00       180.00       240.00       300.00
               1750.00      1760.00      1770.00      1780.00      1790.00      1800.00
                *..........*..........*..........*..........*..........*.....
 ------------------------------------------------------------------------------------
6.00000 LOAD 3  I     1     4 2                          V          A   B D
6.05000      4  I     1              V    24         D          A
6.10000 INC  2  I     1              V    24         D          A
6.15000         I     1              V    24         D          A
6.20000         I     1              V    24         D          A
6.25000         I     1              V    24         D          A
6.30000         I     1              V    24         D          A
6.35000         I     1              V    24         D          A
6.40000         I     1              V    24         D          A
6.45000         I     1              V    24         D          A
6.50000         I     1              V    24         D          A
6.55000         I     1              V    24         D          A
6.60000         I     1              V    24         D          A
6.65000         I     1              V    24         D          A
6.70000         T     1              V    24         D          A
6.75000         I     1              V    24         D          A
6.80000         I     1              V    24         D          A
6.85000         T     1              V    24         D          A
6.90000         I     1              V    24         D          A
6.95000         I     1              V    24         D          A
7.00000 INC  1  I     1              V    24         D          A
7.05000      3  I        1  A V                D 2       B 4
7.10000      4  I        A  V                  D 2       B 4
7.15000         I        A  V                  D 2       B 4
7.20000         I        A  V                  D 2       B 4
7.25000         I        A  V                  D 2       B 4
7.30000         I        A  V                  D 2       B 4
7.35000         I        A  V                  D 2       B 4
7.40000         I        A  V                  D 2       B 4
7.45000         I        A  V                  D 2       B 4
7.50000         I        A  V                  D 2       B 4
7.55000         I        A  V                  D 2       B 4
7.60000         I        A  V                  D 2       B 4
7.65000         I        A  V                  D 2       B 4
7.70000         I        A  V                  D 2       B 4
7.75000         I        A  V                  D 2       B 4
7.80000         I        A  V                  D 2       B 4
7.85000         I        A  V                  D 2       B 4
7.90000         I        A  V                  D 2       B 4
7.95000         T        A  V                  D 2       B 4
                *..........*..........*..........*..........*..........*.....
```

Figure 11. Continued.

		400.00	420.00	440.00	460.00	480.00	500.00
		0.00	60.00	120.00	180.00	240.00	300.00
		1750.00	1760.00	1770.00	1780.00	1790.00	1800.00
		*	*	*	*	*	* . . . .

8.00000	IDLE 1	I		A V — — — —	D 2	B 4		
8.05000	3	I	1	4 2		— — — V		BAD
8.10000	4	I	1	4 2		V		B D
8.15000	DEC 2	I	1	4 2		V		B D
8.20000		I	1	4 2		V		B D
8.25000		I	1	4 2		V		B D
8.30000		I	1	4 2		V		B D
8.35000		I	1	4 2		V		B D
8.40000		I	1	4 2		V		B D
8.45000		I	1	4 2		V		B D
8.50000		I	1	4 2		V		B D
8.55000		I	1	4 2		V		B D
8.60000		I	1	4 2		V		B D
8.65000		I	1	4 2		V		B D
8.70000		I	1	4 2		V		B D
8.75000		I	1	4 2		V		B D
8.80000		I	1	4 2		V		B D
8.85000		I	1	4 2		V		B D
8.90000		I	1	4 2		V		B D
8.95000		I	1	4 2		V		B D
9.00000	IDLE 2	I	1	4 2		V		B D
9.05000		I	1	24			V	DB
9.10000		I	1	24			V	DB
9.15000		I	1	24			V	DB
9.20000		I	1	24			V	DB
9.25000		I	1	24			V	DB
9.30000		I	1	24			V	DB
9.35000		I	1	24			V	DB
9.40000		I	1	24			V	DB
9.45000		I	1	24			V	DB
9.50000		I	1	24			V	DB
9.55000		I	1	24			V	DB
9.60000		I	1	24			V	DB
9.65000		I	1	24			V	DB
9.70000		I	1	24			V	DB
9.75000		I	1	24			V	DB
9.80000		I	1	24			V	DB
9.85000		I	1	24			V	DB
9.90000		I	1	24			V	DB
9.95000		I	1	24			V	DB

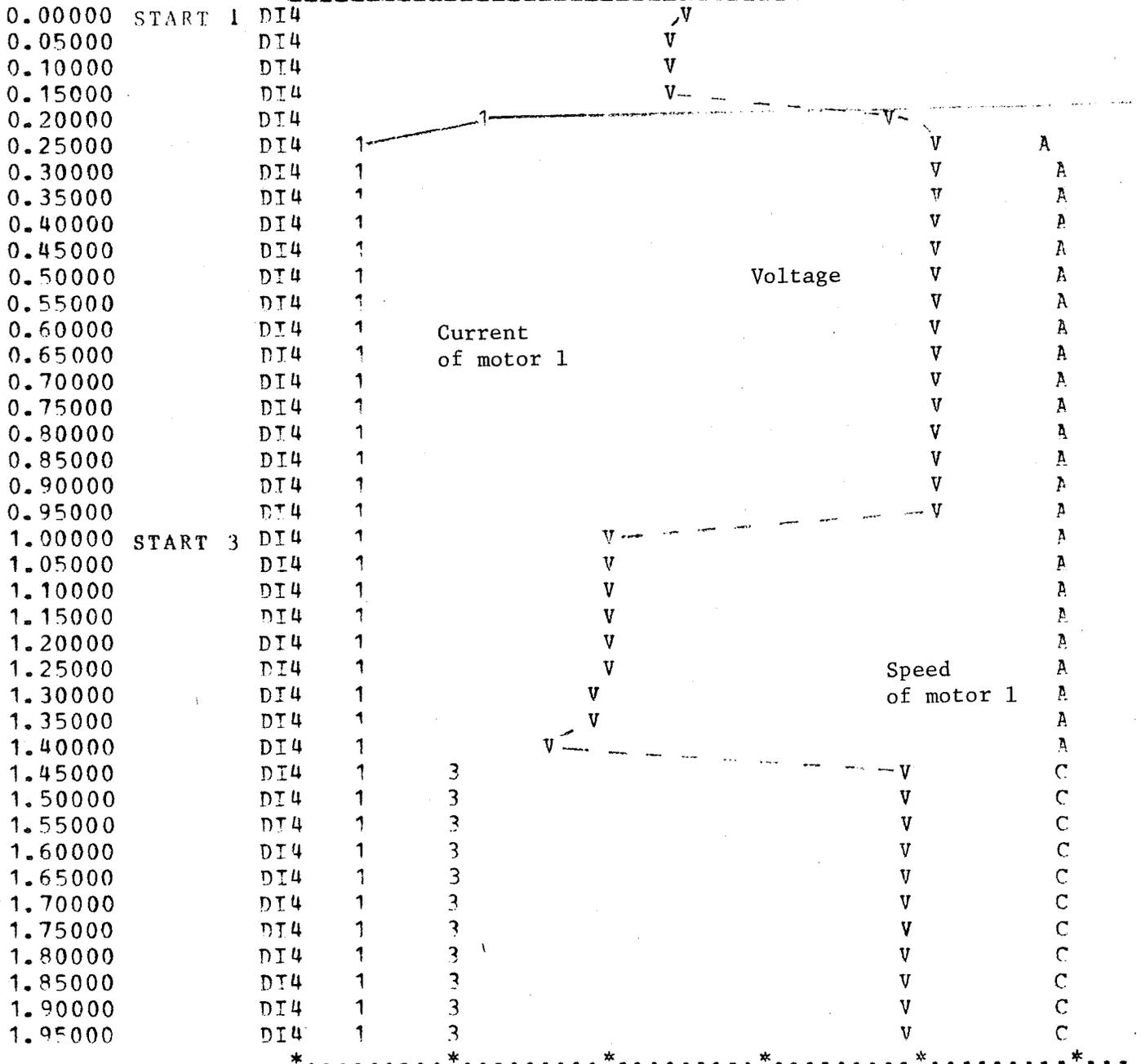| | | * . . . . | * . . . . | * . . . . | * . . . . | * . . . . | * . . . . |

Figure 11. Continued.

```
                    400.00        420.00        440.00        460.00        480.00        500.00
                      0.00         60.00        120.00        180.00        240.00        300.00
                   1750.00       1760.00       1770.00       1780.00       1790.00       1800.00
                      *.........*.........*.........*.........*.........*....
 10.00000 STOP  3  DT4    1       2                                           V          A B
 10.05000       4  DI4    1       2                                           V          A B
 10.10000          DI4    1       2                                           V          A B
 10.15000          DI4    1       2                                           V          A B
 10.20000          DI4    1       2                                           V          A B
 10.25000          DI4    1       2                                           V          A B
 10.30000          DI4    1       2                                           V          A B
 10.35000          DI4    1       2                                           V          A B
 10.40000          DI4    1       2                                           V          A B
 10.45000          DI4    1       2                                           V          A B
 10.50000          DI4    1       2                                           V          A B
 10.55000          DI4    1       2                                           V          A B
 10.60000          DI4    1       2                                           V          A B
 10.65000          DI4    1       2                                           V          A B
 10.70000          DI4    1       2                                           V          A B
 10.75000          DI4    1       2                                           V          A B
 10.80000          DI4    1       2                                           V          A B
 10.85000          DI4    1       2                                           V          A B
 10.90000          DI4    1       2                                           V          A B
 10.95000          DI4    1       2                                           V          A B
 11.00000 STOP  1  DI4            2                                        V             B
 11.05000          DI4            2                                        V             B
 11.10000          DI4            2                                        V             B
 11.15000          DI4            2                                        V             B
 11.20000          DI4            2                                        V             B
 11.25000          DI4            2                                        V             B
 11.30000          DI4            2                                        V             B
 11.35000          DI4            2                                        V             B
 11.40000          DI4            2                                        V             B
 11.45000          DI4            2                                        V             B
 11.50000          DI4            2                                        V             B
 11.55000          DI4            2                                        V             B
 11.60000          DI4            2                                        V             B
 11.65000          DI4            2                                        V             B
 11.70000          DI4            2                                        V             B
 11.75000          DI4            2                                        V             B
 11.80000          DI4            2                                        V             B
 11.85000          DI4            2                                        V             B
 11.90000          DI4            2                                        V             B
 11.95000          DI4            2                                        V             B
         STOP  2     *.........*.........*.........*.........*.........*....
```
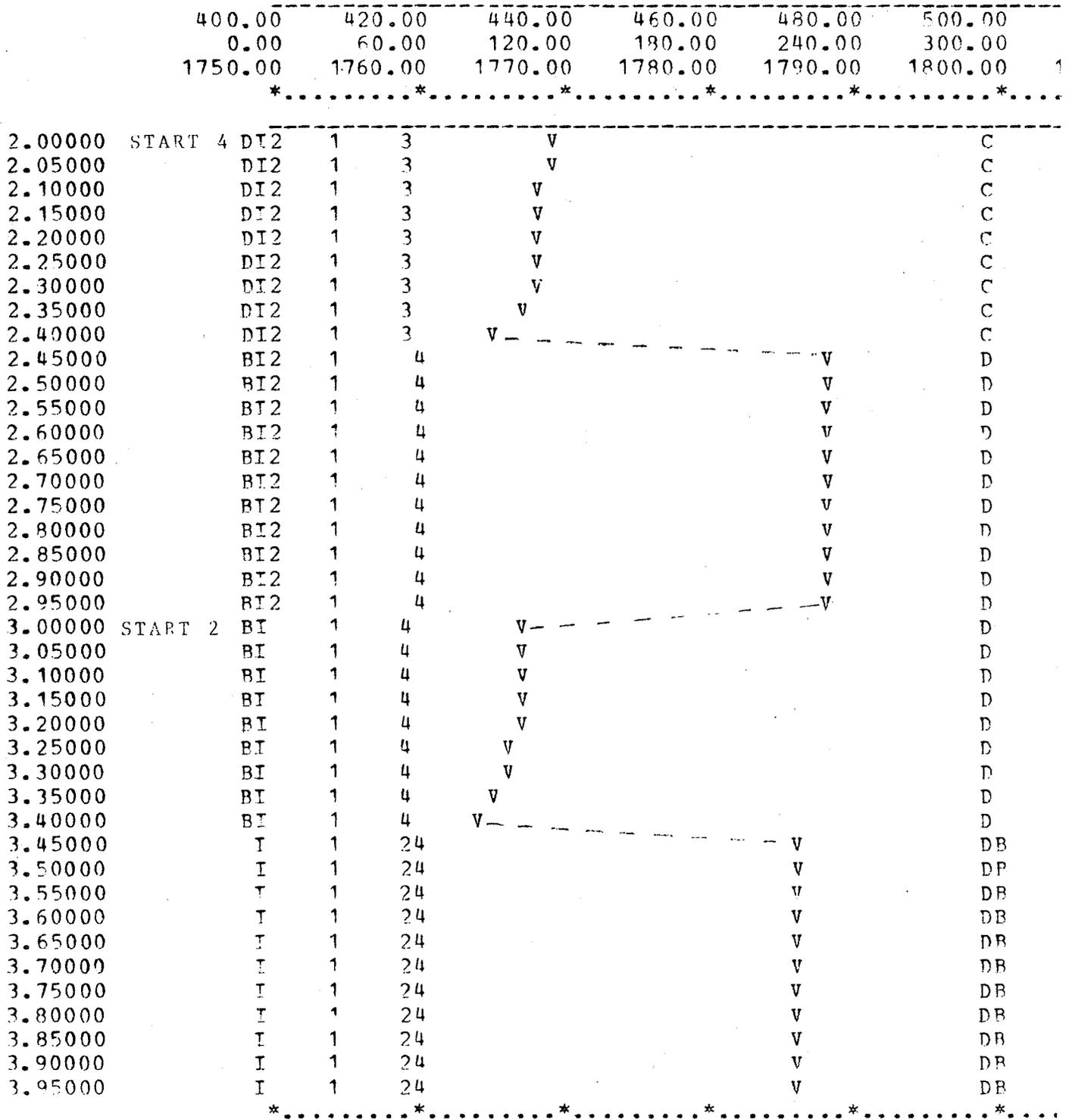
Figure 11. Continued.

```
      COMPLEX VLNC,ZST(4)
      REAL SLIP(4),AVEL(4),R2(4),TOUT(4),I1(4),PF(4)
      REAL TQLD(4,5,201)
      INTEGER TNMOT,CHGTME,CMD(4),PCMD(4),X,ITINDX(4),ACCEL,DECEL,NVELCG
     $,MLD(4),ENDEX,ON(4),OFF(4),OUT6,PROCED
      INTEGER STOP/'STOP'/
      COMMON /INDEX/ITINDX
      COMMON /STATE/ON
      COMMON /DYNMIC/ACCEL,DECEL,NVELCG
      IN5=5
      OUT6=6
      L=0
      CALL READIN(TNMOT,VLNC,ZST,R2,TQLD,TMRES,OUTINC)
      TMRES=.001
      DO 3 X=1,4
      SLIP(X)=1
      ON(X)=0
      OFF(X)=0
      ITINDX(X)=1
      AVEL(X)=0
      I1(X)=0
      TOUT(X)=0
3     CONTINUE
      ISTPRN=0
      ACCEL=3
      DECEL=1
      NVELCG=2
      I=1
      READ(IN5,1000)CHGTME,CMD(1),CMD(2),CMD(3),CMD(4)
1000  FORMAT(10X,I10,10X,A4,1X,A4,1X,A4,1X,A4)
5     DO 1 X=1,TNMOT
      PCMD(X)=CMD(X)
      IF(CMD(X).EQ.STOP)OFF(X)=1
1     CONTINUE
      CALL STPMOT(AVEL,TNMOT,OFF,ISTPRN,TOUT,I1)
      IF(ISTPRN.EQ.1)GO TO 10
      READ(IN5,1000)CHGTME,CMD(1),CMD(2),CMD(3),CMD(4)
      CALL COMAND(PCMD,MLD,TNMOT)
2     CALL VOLTAG(VLNC,ZST,R2,SLIP,TNMOT,I)
      CALL TQOUT(ZST,R2,TOUT,SLIP,TNMOT,I1)
      IF(L.EQ.0)GO TO 13
      IF(L.EQ.IFIX((OUTINC/TMRES)+TMRES))GO TO 13
      L=L+1
      GO TO 6
13    CALL WRTOUT(VLNC,TOUT,AVEL,I1,I,TMRES,TQLD,SLIP,PROCED)
      L=1
6     CALL RUNMOT(TNMOT,SLIP,CHGTME,TMRES,AVEL,I,MLD,TQLD,TOUT,PROCED)
      IF(I*TMRES+TMRES.GT.CHGTME)GO TO 15
      I=I+1
      GO TO 2
15    IF(ISTPRN.EQ.1)GO TO 10
      I=I+1
      GO TO 5
10    STOP
      END
18350
```

```
      SUBROUTINE READIN(TNMOT,VLNC,ZST,R2,TQLD,TMRES,OUTINC)
      COMPLEX VLNC,ZSH(4),ZST(4),ZFEED,YCF
      REAL R1(4),X1(4),GC(4),BM(4),POLES(4),TQLD(4,5,201),SYNAV(4)
     $,SYNSPD(4),R2(4),X2(4),JW(4)
      INTEGER TNLTC(4),X,TNMOT,OUT6
      COMMON /R8/RES,SYNAV
      COMMON /VOLT/YCF,RF,XF,X2,ZSH,ZFEED
      COMMON /INERT/JW
      IN5=5
      OUT6=6
      READ(IN5,100)OUTINC
      READ,TNMOT
      READ(IN5,100)FREQ,VLL
      READ(IN5,100)FDLGTH,OPTF,ROPTF
100   FORMAT(8F10.5)
      PI=3.14159
      RES=.005
      N=IFIX(1./RES)
      NP1=N+1
      RF=OPTF*FDLGTH
      XF=ROPTF*FDLGTH
      ZFEED=CMPLX(RF,XF)
      VLNC=CMPLX(VLL/SQRT(3.),0.)
      VLN=CABS(VLNC)
      YCF=(0.,0.)
      WRITE(OUT6,1000)VLL
      WRITE(OUT6,1001)TNMOT
      WRITE(OUT6,1002)
      WRITE(OUT6,1003)
      DO 10 X=1,TNMOT
      READ(IN5,100) R1(X),X1(X),R2(X),X2(X),GC(X),BM(X),POLES(X),JW(X)
      SYNSPD(X)=120.*FREQ/POLES(X)
      SYNAV(X)=2.*PI*SYNSPD(X)/60.
      ZSH(X)=1/CMPLX(GC(X),-BM(X))
      ZST(X)=CMPLX(R1(X),X1(X))
      WRITE(OUT6,1004)X,R1(X),X1(X),R2(X),X2(X),GC(X),BM(X),SYNSPD(X)
      READ,TNLTC(X)
      CALL REDLTC(TQLD,NP1,TNLTC,X)
10    CONTINUE
1000  FORMAT(10X,'LINE TO LINE VOLTAGE',5X,F10.5/)
1001  FORMAT(10X,'NUMBER OF MOTORS IN SIMULATION',3X,I2/)
1002  FORMAT(20X,'R1- STATOR',5X,'X1- STATOR',5X,'R2-  ROTOR',5X,'X2-  R
     $OTOR',5X,'GC-   CORE',5X,'BM-MAGNET.',5X,'SYNCHRONOUS')
1003  FORMAT(20X,'RESISTANCE',6X,'REACTANCE',5X,'RESISTANCE',6X,'REACTAN
     $CE',5X,'LOSS COND.',4X,'SUSCEPTANCE',11X,'SPEED'//)
1004  FORMAT(10X,'MOTOR',I1,4X,F10.5,5X,F10.5,5X,F10.5,5X,F10.5,5X,F10.5
     $,5X,F10.5,6X,F10.5/)
      WRITE(OUT6,2000)
2000  FORMAT('1',60X,'MOTOR1',12X,'MOTOR2',12X,'MOTOR3',12X,'MOTOR4')
      RETURN
      END
18350
```

```
      SUBROUTINE REDLTC(TQLD,NP1,TNLTC,X)
      INTEGER TNLTC(4),X
      REAL TQLD(4,5,201)
      DO 10 J=1,NP1
      READ,TQLD(X,1,J)
10    CONTINUE
      IF(TNLTC(X).EQ.1)GO TO 201
      L=TNLTC(X)
      DO 20 I=2,L
      DO 30 J=1,NP1
      READ,TEMP
      TQLD(X,I,J)=TEMP+TQLD(X,1,J)
30    CONTINUE
20    CONTINUE
201   RETURN
      END
18350
```

```
      SUBROUTINE STPMOT(AVEL,TNMOT,OFF,ISTPRN,TOUT,I1)
      REAL AVEL(4),I1(4),TOUT(4)
      INTEGER ON(4),OFF(4),X,TNMOT
      COMMON /STATE/ON
      DO 10 X=1,4
      IF(OFF(X).EQ.0)GO TO 10
      ON(X)=0
      AVEL(X)=0.
      TOUT(X)=0.
      I1(X)=0.
10    CONTINUE
      IF(OFF(1).EQ.1)GO TO 1
      GO TO 5
1     IF(TNMOT.EQ.1)GO TO 4
      IF(OFF(2).EQ.1)GO TO 2
      GO TO 5
2     IF(TNMOT.EQ.2)GO TO 4
      IF(OFF(3).EQ.1)GO TO 3
      GO TO 5
3     IF(TNMOT.EQ.3)GO TO 4
      IF(OFF(4).EQ.1)GO TO 4
      GO TO 5
4     ISTPRN=1
5     RETURN
      END
18350
```

```
      SUBROUTINE COMAND(PCMD,MLD,TNMOT)
      INTEGER CHL1/'CHL1'/,CHL2/'CHL2'/
      INTEGER STRT/'STRT'/
      INTEGER PCMD(4),MLD(4),ON(4),X,TNMOT
      COMMON /STATE/ON
      DO 10 X=1,TNMOT
      IF(PCMD(X).EQ.STRT)GO TO 1
      IF(PCMD(X).EQ.CHL1)GO TO 2
      IF(PCMD(X).EQ.CHL2)GO TO 3
      GO TO 10
1     ON(X)=1
      MLD(X)=1
      GO TO 10
2     ON(X)=1
      MLD(X)=2
      GO TO 10
3     ON(X)=1
      MLD(X)=3
10    CONTINUE
      RETURN
      END
18350


      SUBROUTINE VOLTAG(VLNC,ZST,R2,SLIP,TNMOT,I)
      COMPLEX ZRO(4),ZFIELD,ZSH(4),ZMOT,ZST(4),YMOT(4),YMOTS,ZTOT,YCF,ZF
     $EED,VLNC,ILC,MTVOLT,YTEMP
      REAL R2(4),X2(4),IL,PF,SLIP(4)
      INTEGER TNMOT,X,ON(4)
      COMMON /VOLT/YCF,RF,XF,X2,ZSH,ZFEED
      COMMON /TRQ/ZRO,YMOT,MTVOLT
      COMMON /STATE/ON
      COMMON /OUT/IL,PF,VOLTIN
      DO 10 X=1,TNMOT
      IF(ON(X).EQ.0) GO TO 8
      ZRO(X)=CMPLX(R2(X)/SLIP(X),X2(X))
      ZFIELD=ZSH(X)*ZRO(X)/(ZSH(X)+ZRO(X))
      ZMOT=ZFIELD+ZST(X)
      GO TO 9
8     YMOT(X)=(0.,0.)
      GO TO 10
9     YMOT(X)=1/ZMOT
10    CONTINUE
      YTEMP=(0.,0.)
      DO 20 X=1,TNMOT
      YMOTS=YMOT(X)+YTEMP
      YTEMP=YMOTS
20    CONTINUE
      ZTOT=(1/(YMOTS+YCF))+ZFEED
      ILC=VLNC/ZTOT
      IL=CABS(ILC)
      PF=COS(ATAN(AIMAG(ZTOT)/REAL(ZTOT)))
      MTVOLT=VLNC-ILC*ZFEED
      VOLTIN=CABS(MTVOLT)*SQRT(3.)
      RETURN
      END
18350
```

```
      SUBROUTINE TQOUT(ZST,R2,TOUT,SLIP,TNMOT,I1)
      COMPLEX I1C,E1C,ZST(4),I2C,MTVOLT,YMOT(4),ZRO(4)
      REAL SYNAV(4),R2(4),SLIP(4),TOUT(4),I1(4),I2
      INTEGER TNMOT,X,ON(4)
      COMMON/STATE/ON
      COMMON /TRQ/ZRO,YMOT,MTVOLT
      COMMON /R8/RES,SYNAV
      DO 10 X=1,TNMOT
      IF(ON(X).EQ.0)GO TO 10
      I1C=MTVOLT*YMOT(X)
      I1(X)=CABS(I1C)
      E1C=MTVOLT-I1C*ZST(X)
      I2C=E1C/ZRO(X)
      I2 = CABS(I2C)
      TOUT(X)=(1./SYNAV(X))*3*(I2**2)*R2(X)/SLIP(X)
10    CONTINUE
      RETURN
      END
18350

      SUBROUTINE RUNMOT(TNMOT,SLIP,CHGTME,TMRES,AVEL,I,MLD,TQLD,TOUT,PRO
     $CED)
      REAL TQLD(4,5,201),AVEL(4),SLIP(4),TOUT(4)
      INTEGER TNMOT,X,MLD(4),PROCED,CHGTME,ON(4)
      COMMON /STATE/ON
      DO 10 X=1,TNMOT
      IF(ON(X).EQ.0)GO TO 10
      IMLD=MLD(X)
      CALL TEST(X,TQLD,TOUT,IMLD,PROCED)
      GO TO(11,10,13),PROCED
11    CALL DCELR8(X,SLIP,TQLD,TOUT,IMLD,AVEL,I,TMRES)
      GO TO 10
13    CALL ACELR8(X,SLIP,TQLD,TOUT,IMLD,AVEL,I,TMRES)
10    CONTINUE
9     RETURN
      END
18350

      SUBROUTINE TEST(X,TQLD,TOUT,IMLD,PROCED)
      REAL TQLD(4,5,201),TOUT(4)
      INTEGER PROCED,X,ACCEL,DECEL,NVELCG,ITINDX(4)
      COMMON /DYNMIC/ACCEL,DECEL,NVELCG
      COMMON /INDEX/ITINDX
      JTINDX=ITINDX(X)
      DTRQ=TOUT(X)-TQLD(X,IMLD,JTINDX)
      IF(DTRQ.GT.0.)PROCED=ACCEL
      IF(DTRQ.LT.0.)PROCED=DECEL
      IF(DTRQ.EQ.0.)RROCED=NVELCG
      RETURN
      END
18350
```

```
      SUBROUTINE WRTOUT(VLNC,TOUT,AVEL,I1,I,TMRES,TQLD,SLIP,PROCED)
      COMPLEX VLNC
      REAL TOUT(4),AVEL(4),I1(4),SPEED(4),IL,TEXT(4),POUT(4),TQLD(4,5,20
     $1),SLIP(4),SYNAV(4)
      INTEGER X,OUT6,ON(4),ITINDX(4),PROCED
      COMMON /OUT/IL,PF,VOLTIN
      COMMON /STATE/ON
      COMMON /INDEX/ITINDX
      COMMON /R8/RES,SYNAV
      PI=3.14159
      OUT6=6
      DO 10 X=1,4
      SPEED(X)=AVEL(X)*60./(2.*PI)
      IF(ON(X).EQ.1)GO TO 5
      TEXT(X)=0.0
      GO TO 4
5     IF(I.EQ.1)GO TO 1
      GO TO(2,1,1),PROCED
1     PTINDX=ITINDX(X)+1
      GO TO 3
2     PTINDX=ITINDX(X)-1
3     JTINDX=ITINDX(X)
      TINDX=(-(((SLIP(X)-1.)/RES)-1.))
      ANLTQ=((TQLD(X,1,PTINDX)-TQLD(X,1,JTINDX))/(PTINDX-JTINDX))*
     $(TINDX-JTINDX)+TQLD(X,1,JTINDX)
      TEXT(X)=TOUT(X)-ANLTQ
4     POUT(X)=TEXT(X)*AVEL(X)/746.
10    CONTINUE
      VLN=CABS(VLNC)
      POWER=3.*IL*VLN
      TIME=I*TMRES-TMRES
      WRITE(OUT6,1000)TIME,SPEED(1),SPEED(2),SPEED(3),SPEED(4)
      WRITE(OUT6,1001)IL,TEXT(1),TEXT(2),TEXT(3),TEXT(4)
      WRITE(OUT6,1002)PF,I1(1),I1(2),I1(3),I1(4)
      WRITE(OUT6,1003)POWER,POUT(1),POUT(2),POUT(3),POUT(4)
      WRITE(OUT6,1004)VOLTIN
1000  FORMAT(10X,'TIME',10X,F10.5,5X,'SPEED',13X,F10.2,8X,F10.2,8X,
     $F10.2,8X,F10.2)
1001  FORMAT(10X,'LINE CURRENT',2X,F10.2,5X,'TORQUE OUT',8X,F10.2,8X,
     $F10.2,8X,F10.2,8X,F10.2)
1002  FORMAT(10X,'POWER FACTOR',2X,F10.2,5X,'MOTOR CNT',9X,F10.2,8X,
     $F10.2,8X,F10.2,8X,F10.2)
1003  FORMAT(10X,'POWER',4X,F15.2,5X,'POWER OUT',9X,F10.2,8X,F10.2,8X,
     $F10.2,8X,F10.2)
1004  FORMAT(10X,'MOTOR VOLTAGE',1X,F10.2/)
      RETURN
      END
18350
```

```fortran
      SUBROUTINE DCELR8(X,SLIP,TQLD,TOUTM,IMLD,AVELM,I,TMRES)
      REAL SLIP(4),SYNAV(4),AVELM(4),TQLD(4,5,201),TOUTM(4),JW(4)
      INTEGER X,ITINDX(4)
      COMMON /R8/RES,SYNAV
      COMMON /INDEX/ITINDX
      COMMON /INERT/JW
      AVELTS=SYNAV(X)*(1.-SLIP(X))
      PTINDX=ITINDX(X)-1
      JTINDX=ITINDX(X)
      TINDX=(-(((SLIP(X)-1.)/RES)-1.))
      ATQLD=((TQLD(X,IMLD,PTINDX)-TQLD(X,IMLD,JTINDX))/(PTINDX-JTINDX))
     1*(TINDX-JTINDX)+TQLD(X,IMLD,JTINDX)
      DTRQ=TOUTM(X)-ATQLD
      IF(DTRQ.GE.0.)GO TO 4
      DAVEL=(1./JW(X))*DTRQ*TMRES
      GO TO 5
4     DAVEL=0
5     AVELM(X)=DAVEL+AVELTS
      SLIP(X)=(SYNAV(X)-AVELM(X))/SYNAV(X)
      TINDX=(-(((SLIP(X)-1.)/RES)-1.))
      ITINDX(X)=IFIX(TINDX)
      RETURN
      END
18350


      SUBROUTINE ACELR8(X,SLIP,TQLD,TOUTM,IMLD,AVELM,I,TMRES)
      REAL SLIP(4),SYNAV(4),AVELM(4),TQLD(4,5,201),TOUTM(4),JW(4)
      INTEGER X,ITINDX(4)
      COMMON /R8/RES,SYNAV
      COMMON /INDEX/ITINDX
      COMMON /INERT/JW
      AVELTS=SYNAV(X)*(1.-SLIP(X))
      PTINDX=ITINDX(X)+1
      JTINDX=ITINDX(X)
      TINDX=(-(((SLIP(X)-1.)/RES)-1.))
      ATQLD=((TQLD(X,IMLD,PTINDX)-TQLD(X,IMLD,JTINDX))/(PTINDX-JTINDX))
     1*(TINDX-JTINDX)+TQLD(X,IMLD,JTINDX)
      DTRQ=TOUTM(X)-ATQLD
      IF(DTRQ.LE.0.)GO TO 4
      DAVEL=(1./JW(X))*DTRQ*TMRES
      GO TO 5
4     DAVEL=0.
5     AVELM(X)=DAVEL+AVELTS
      IF(AVELM(X).GE.SYNAV(X))AVELM(X)=SYNAV(X)-.001*SYNAV(X)
      SLIP(X)=(SYNAV(X)-AVELM(X))/SYNAV(X)
      TINDX=(-(((SLIP(X)-1.)/RES)-1.))
      ITINDX(X)=IFIX(TINDX)
      RETURN
      END
18350
```

APPENDIX C

MOTOR LOAD TORQUES

The Computer Program

The computer program consists of a main calling routine and three subroutines. The first subroutine, MOTHYD, is called after the dimension and common statements. MOTHYD reads the length and size of the feeder line and calculates its impedance. MOTHYD also reads the equivalent circuit parameters for the motor. This data is used to calculate the torque and slip the motor must have for a given set of voltage, current, and power-factor inputs. The equations used are those derived in the theoretical development section of this report. These torque and slip values along with the corresponding voltage, current, and power-factor are then printed in order of input. Subroutine SORT is then called to sort the torque values in order of decreasing slip, and the values are printed out in order of decreasing slip. The actual load torque values are then calculated, printed, and graphed in order of input. SORT is used again to arrange the load-torque values in order of decreasing slip. These values then are printed and graphed. The graphing routine, GRAPH, uses computer center subroutines. SCALEN and GRAPHN.

The following section is a variable listing for each subroutine. Variables used in more than one routine are listed with the first routine in which they appear. Any variable not included is a dummy programming variable whose meaning is evident from the program control. Afterwards, a listing of the complete program and subroutines is given.

Program Variables

Subroutine MOTHYD

WLNGTH	length of the feeder
ISIZE	size of the feeder
ROR	resistance per 1000 ft of the feeder
ROX	reactance per 1000 ft of the feeder
CZFEED	impedance of the full feeder line
IHP	horsepower of the motor
IVLL	rated line - line voltage of the motor
IIN	rated line current of the motor
ISPD	synchronous speed of the motor
R1HYD	R_1 of the equivalent circuit
X1HYD	X_1 of the equivalent circuit
R2HYD	R_2 of the equivalent circuit
X2HYD	X_2 of the equivalent circuit
RCHYD	R_c of the equivalent circuit
XMHYD	X_m of the equivalent circuit
PLSHYD	power loss term in torque equation (5)
IPOLE	number of poles the motor has
CHDRX1	$R_1 + jX_1$ of the equivalent circuit
CHDRX2	$0_1 o + jX_2$ of the equivalent circuit
CHDCGB	$\dfrac{1}{RC + jXm}$ of the equivalent circuit
CHDCR2	$R_2 + ix0$ of the equivalent circuit

Main Calling Routine

VI	input line - line voltage
I1	input line current

PF	power factor between line to neutral voltage and line current
CI1	$I_i \underline{\theta}$ of the equivalent circuit
CE1	$E1 \underline{\phi}$ of the equivalent circuit
CI2	$I2 \underline{\delta}$ of the equivalent circuit
CSLIP	the complex slip
S	the magnitude of CSLIP
PERCOM	the percent complex of the slip
TOUT	output torque
DELTOR	ΔT of equation (8)
SLIPTL	slip of equation (14)
TORLD3	the load torque of equation (13)

Subroutine SORT

SLARGE	temporary variable used during sorting
K	array

Subroutine GRAPH

SCLFAC	an array for scale factors for converting points for plotting
MIN	an array for min function values for the function being plotted
MAX	an array for max function values for the function being plotted
LABEL	an array to hold labelling points
SLIP	the independent variable (slip) being plotted
TOUT	the independent variable (torque) being plotted
VALUE	an array to convert slip and torque to double precision values

Subroutine SCALEN

    Variables not known, internal computer program used to set the

    scale factors for plotting

Subroutine GRAPHN

    Variables not known, internal computer program used to prepare the

    input values (slip and torque) in a line for printing.

Sample Run

    This demonstration was made on a Joy 10 CM continuous miner oper-

ating in the Pittsburgh Seam. The example is for a maneuver operation

where only the hydraulic pump motor is used. Only a small set of

input data is used to give an idea of the type of output from the pro-

gram. The input values are line-to-line voltage, line current and

power-factor. Table 5 is a listing of trailing cable statistics and

information about the specific motor used in this run. Table 6 shows

values of motor torque and slip for a particular time input. The com-

plex slip and percent complex are also printed to check for invalid

points. Input voltage, current, and power-factor values are also

listed. The time increment of the input values is 0.2 seconds between

points. Table 7 is a print out of the same data in order of decreasing

slip. Table 8 gives the value of slip, ΔT, and load torque, respec-

tively. These torque values are the ones which are used for the load-

torque curves. Figure 12 shows a plot versus time of the load torque

and slip values. Table 9 is a listing of these points printed in order

of decreasing slip, and Figure 13 is the corresponding computer plot.

    During this operation, the load on the motor is not constant but

is actually represented by a series of changing loads as can be shown

by looking at Figure 12. Reading from top to bottom, one possible explanation is that initially the continuous miner is operating on the level and requiring fairly constant torque. Then, the continuous miner comes to a down slope requiring less torque to run the motor because gravity would aid in this motion. Next, the continuous miner has reached an upward incline and, to overcome the added pull of gravity, the motor must supply more torque. Finally, the machine goes back down the incline and either ends up on the level or continues down the incline. There is only one possible explanation for this set of data. To determine which operation these loads actually represent, many more points must be considered to see if torque patterns develop related to time studies. If no pattern can be found, more data may have to be taken on a continuous miner with a better time study on operating conditions.

Table 5. Feeder Line (Trailing Cable) and Motor Parameters.


```
        ***   FEEDER LINE SPECIFICATIONS   ***

            LENGTH=  800.00 FEET
            SIZE=  4/0 GAUGE
            RESISTANCE= 0.07170 OHMS/1000. FEET
            REACTANCE=  0.02900 OHMS/1000. FEET
            FEEDER IMPEDANCE=( 0.05736 0.02320 ) OHMS




        ***   HYDRAULIC MOTOR PARAMETERS   ***


            135 HORSEPOWER     1800 RPM
            440 VOLTS L-L       165 AMPS
                4 POLE

            R1=  0.0290 OHMS    X1=  0.1900 OHMS
            R2=  0.0195 OHMS    X2=  0.1790 OHMS
            RC=    93.0 OHMS    XC=     4.6

            WINDAGE,FRICTION,ETC. LOSSES=  2000.00 WATTS
```

Table 6. Motor Torque and Slip at a Specified Time.

*** VALUES PRINTED ACCORDING TO TIME ORDER OF INPUT ***

TIME	SLIP	TORQUE (NT.M.)	COMPLEX SLIP	PERCENT COMPLEX	MAGNITUDE INPUT VOLTAGE (VOLTS)	MAGNITUDE INPUT CURRENT (AMPS)	POW FAC
1	0.00458	239.76	(0.00458-0.00005)	1.0659	480.47	86.86	0.71
2	0.00449	235.85	(0.00449 0.00002)	0.3411	480.47	85.52	0.71
3	0.00456	238.77	(0.00456-0.00003)	0.7169	480.47	86.52	0.71
4	0.00435	228.24	(0.00435 0.00000)	0.0829	480.47	84.19	0.70
5	0.00443	233.47	(0.00443 0.00011)	2.4736	480.47	84.19	0.71
6	0.00447	235.81	(0.00446 0.00016)	3.5224	480.47	84.19	0.72
7	0.00463	244.63	(0.00462 0.00020)	4.2940	480.47	85.52	0.73
8	0.00478	252.54	(0.00477 0.00022)	4.6986	480.47	86.86	0.74
9	0.00495	262.42	(0.00494 0.00030)	6.0735	480.47	88.16	0.76
10	0.00477	252.25	(0.00477 0.00022)	4.5749	480.47	86.86	0.74
11	0.00482	255.64	(0.00481 0.00029)	6.0438	480.47	86.86	0.75
12	0.00454	239.05	(0.00454 0.00008)	1.8035	480.47	85.52	0.72
13	0.00364	189.32	(0.00363-0.00017)	4.5497	480.47	78.84	0.63
14	0.00379	199.01	(0.00379 0.00001)	0.1622	480.47	78.84	0.66
15	0.00377	197.41	(0.00377-0.00002)	0.5924	480.47	78.84	0.66
16	0.00368	192.09	(0.00368-0.00012)	3.1677	480.47	78.84	0.64
17	0.00413	216.98	(0.00412 0.00006)	1.5563	480.47	81.51	0.69
18	0.00617	324.75	(0.00616 0.00030)	4.8603	480.47	101.56	0.80
19	0.00630	331.60	(0.00629 0.00032)	5.1351	480.47	102.90	0.81
20	0.00658	346.41	(0.00656 0.00041)	6.1913	480.47	105.57	0.82
21	0.00661	349.19	(0.00659 0.00048)	7.3175	480.47	105.57	0.83
22	0.00684	360.69	(0.00683 0.00048)	7.0755	480.47	108.24	0.83
23	0.00687	362.57	(0.00685 0.00054)	7.8229	480.47	108.24	0.84
24	0.00680	356.96	(0.00679 0.00038)	5.5720	480.47	108.24	0.83
25	0.00640	326.07	(0.00638-0.00050)	7.8682	480.47	108.24	0.76
26	0.00593	304.18	(0.00591-0.00041)	6.9901	480.47	102.90	0.75
27	0.00426	224.02	(0.00426 0.00006)	1.4392	480.47	82.85	0.70

Table 7. - Motor Torque and Slip in Order of Decreasing Slip

*** VALUES PRINTED ACCORDING TO SLIP IN DESCENDING ORDER ***

TIME	SLIP	TORQUE (NT.M.)	COMPLEX SLIP	PERCENT COMPLEX	MAGNITUDE INPUT VOLTAGE (VOLTS)	MAGNITUDE INPUT CURRENT (AMPS)	POW FAC
23	0.00687	362.57	(0.00685 0.00054)	7.8229	480.47	108.24	0.84
22	0.00684	360.69	(0.00683 0.00048)	7.0755	480.47	108.24	0.83
24	0.00680	356.96	(0.00679 0.00038)	5.5720	480.47	108.24	0.83
21	0.00661	349.19	(0.00659 0.00048)	7.3175	480.47	105.57	0.83
20	0.00658	346.41	(0.00656 0.00041)	6.1913	480.47	105.57	0.82
25	0.00640	326.07	(0.00638-0.00050)	7.8682	480.47	108.24	0.76
19	0.00630	331.60	(0.00629 0.00032)	5.1351	480.47	102.90	0.81
18	0.00617	324.75	(0.00616 0.00030)	4.8603	480.47	101.56	0.80
26	0.00593	304.18	(0.00591-0.00041)	6.9901	480.47	102.90	0.75
9	0.00495	262.42	(0.00494 0.00030)	6.0735	480.47	88.16	0.76
11	0.00482	255.64	(0.00481 0.00029)	6.0438	480.47	86.86	0.75
8	0.00478	252.54	(0.00477 0.00022)	4.6986	480.47	86.86	0.74
10	0.00477	252.25	(0.00477 0.00022)	4.5749	480.47	86.86	0.74
7	0.00463	244.63	(0.00462 0.00020)	4.2940	480.47	85.52	0.73
1	0.00458	239.76	(0.00458-0.00005)	1.0659	480.47	86.86	0.71
3	0.00456	238.77	(0.00456-0.00003)	0.7169	480.47	86.52	0.71
12	0.00454	239.05	(0.00454 0.00008)	1.8035	480.47	85.52	0.72
2	0.00449	235.85	(0.00449 0.00002)	0.3411	480.47	85.52	0.71
6	0.00447	235.81	(0.00446 0.00016)	3.5224	480.47	84.19	0.72
5	0.00443	233.47	(0.00443 0.00011)	2.4736	480.47	84.19	0.71
4	0.00435	228.24	(0.00435 0.00000)	0.0829	480.47	84.19	0.70
27	0.00426	224.02	(0.00426 0.00006)	1.4392	480.47	82.85	0.70
17	0.00413	216.98	(0.00412 0.00006)	1.5563	480.47	81.51	0.69
14	0.00379	199.01	(0.00379 0.00001)	0.1622	480.47	78.84	0.66
15	0.00377	197.41	(0.00377-0.00002)	0.5924	480.47	78.84	0.66
16	0.00368	192.09	(0.00368-0.00012)	3.1677	480.47	78.84	0.64
13	0.00364	189.32	(0.00363-0.00017)	4.5497	480.47	78.84	0.63

Table 8. Slip, Torque Change, and Load Torque

TIME	SLIP	DELTOR	LOAD TORQUE
1	0.0045	0.0458	237.7605
2	0.0045	-0.0342	237.3465
3	0.0045	0.1101	233.3981
4	0.0044	-0.0429	230.8995
5	0.0044	-0.0191	234.6580
6	0.0045	-0.0850	240.3043
7	0.0047	-0.0774	248.6610
8	0.0049	-0.0924	257.5725
9	0.0049	0.0946	257.2441
10	0.0048	-0.0268	253.9716
11	0.0047	0.1470	247.1976
12	0.0041	0.4787	213.7059
13	0.0037	-0.0834	194.2456
14	0.0038	0.0136	198.1976
15	0.0037	0.0457	194.7084
16	0.0039	-0.2341	204.7729
17	0.0051	-1.0793	271.9480
18	0.0062	-0.0689	328.2439
19	0.0064	-0.1451	339.1472
20	0.0066	-0.0185	347.8171
21	0.0067	-0.1222	355.0632
22	0.0069	-0.0121	361.6421
23	0.0068	0.0363	359.7273
24	0.0066	0.2108	341.3052
25	0.0062	0.2473	314.8767
26	0.0051	0.8808	263.2170

LOAD TORQUE AND SLIP VERSUS TIME
0.00364   0.00396   0.00428   0.00461   0.00493   0.00525   0.00557   0.00590   0.00622   0.00654   0.00687
   0.00   110.00   220.00   330.00   440.00   550.00   660.00   770.00   880.00   990.00   1100.00

Figure 12. Computer Plot of Load Torque and Slip.

Table 9. Slip, Torque Change, and Load Torque
          in Order of Decreasing Slip.

TIME	SLIP	DELTOR	LOAD TORQUE
22	0.0069	-0.0121	361.6421
23	0.0068	0.0363	359.7273
21	0.0067	-0.1222	355.0632
24	0.0066	0.2108	341.3052
20	0.0066	-0.0185	347.8171
19	0.0064	-0.1451	339.1472
18	0.0062	-0.0689	328.2439
25	0.0062	0.2473	314.8767
17	0.0051	-1.0793	271.9480
26	0.0051	0.8808	263.2170
8	0.0049	-0.0924	257.5725
9	0.0049	0.0946	257.2441
10	0.0048	-0.0268	253.9716
7	0.0047	-0.0774	248.6610
11	0.0047	0.1470	247.1976
6	0.0045	-0.0850	240.3043
1	0.0045	0.0458	237.7605
2	0.0045	-0.0342	237.3465
3	0.0045	0.1101	233.3981
5	0.0044	-0.0191	234.6580
4	0.0044	-0.0429	230.8995
12	0.0041	0.4787	213.7059
16	0.0039	-0.2341	204.7729
14	0.0038	0.0136	198.1976
15	0.0037	0.0457	194.7084
13	0.0037	-0.0834	194.2456

```
LOAD TORQUE AND SLIP VERSUS TIME
0.00364    0.00396    0.00428    0.00461    0.00493    0.00525    0.00557    0.00590    0.00622    0.00654    0.00687
   0.00      110.00     220.00     330.00     440.00     550.00     660.00     770.00     880.00     990.00    1100.00
      *..........*..........*..........*.........*..........*..........*..........*..........*..........*..........*..........*
    --------------------------------------------------------------------------------------------------------------------------
    I                              T                                                                                       SI
    I                              T                                                                                     S I
    I  .                          T                                                                                 S      I
    I                            T                                                                            S            I
    I                            T                                                                            S            I
    I                           T                                                                       S                 I
    I                          T                                                                 S                        I
    I                        T                                                               S                           I
    I                      T                                                          S                                  I
    I                     T                                    S                                                         I
    I                    T                               S                                                              I
    I                   T                             S                                                                 I
    I                  T                           S                                                                    I
    I                  T                        S                                                                       I
    I                 T                      S                                                                          I
    I                 T              S                                                                                  I
    I                 T              S                                                                                  I
    I                 T            S                                                                                    I
    I                T        S                                                                                         I
    I                T        S                                                                                         I
    I                T  S                                                                                               I
    I             S      T                                                                                              I
    I         S          T                                                                                             I
    I      S              T                                                                                            I
    I    S                T                                                                                            I
    I  S                  T                                                                                            I
      *..........*..........*..........*.........*..........*..........*..........*..........*..........*..........*..........*
    --------------------------------------------------------------------------------------------------------------------------
```
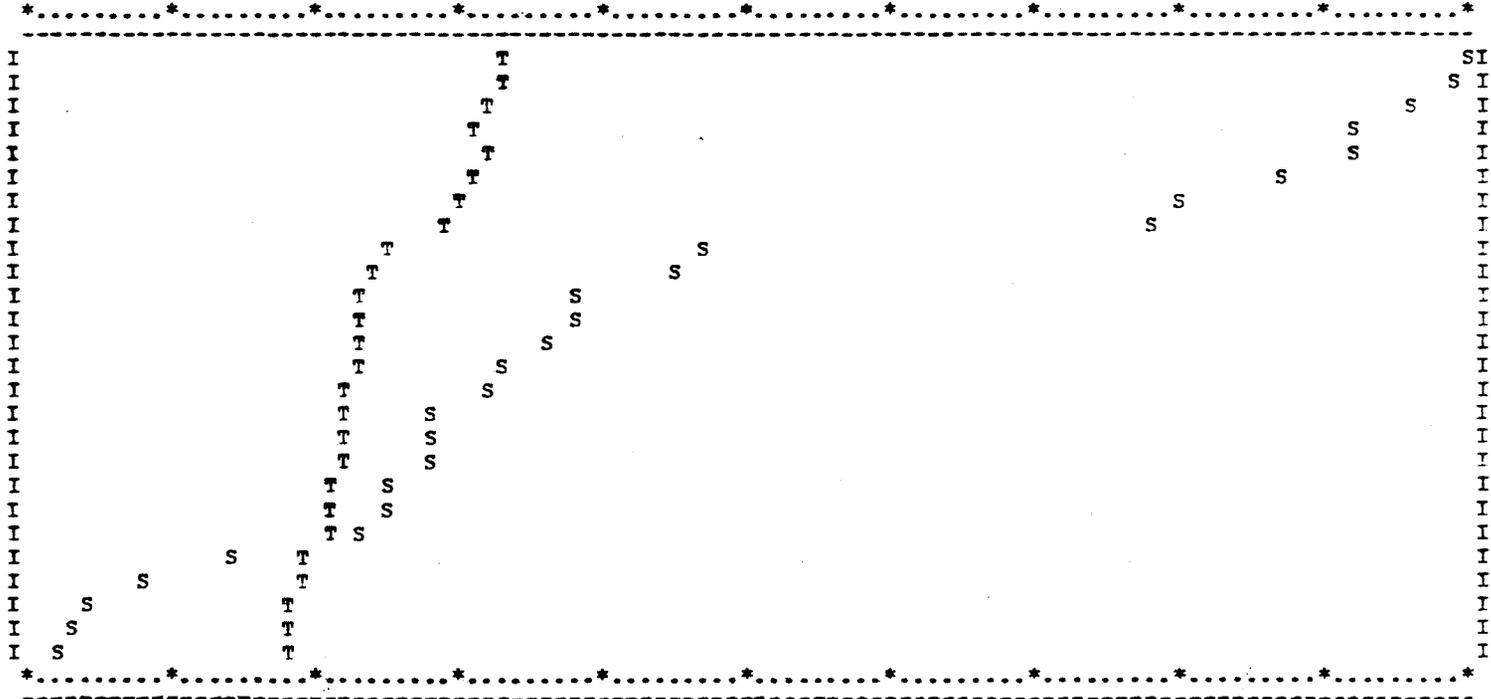
Figure 13.   Computer Plot of Load Torque and Slip in Order of Decreasing Slip.

Program Listing

```
C   >>
C   >>      HYDRAULIC MOTOR TRIAL MAIN CALLING ROUTINE
C   >>
        IMPLICIT COMPLEX(C)
        DIMENSION CSLIP(500)
        REAL VI(500),II(500),PF(500),TOUT(500),PERCOM(500),SLIP(500)
        REAL SLIPTL(500),TORLD3(500),DELTOR(500)
        INTEGER K(500),M(500),JJAA(500),KKMM(500)
        COMMON /CORFAC/ CZFEED,SQR3
        COMMON /HYDMOT/ CHDRX1,CHDCGB,CHDCR2,CHDCX2,R2HYD,PLSHYD,RPLHYD,SP
       1DHYD
        COMMON /VARIAL/ CSLIP,VI,I1,PF,TOUT,SLIP,PERCOM,K,M
        IN5=5
        IOUT6=6
C   >>
C   >>      CALL SUBROUTINE MOTHYD TO READ IN AND PRINT THE FEEDER LINE
C   >>      IMPEDANCE VALUES AND THE MOTOR PARAMETERS
C   >>
        CALL MOTHYD
        WRITE(IOUT6,2020)
 2020   FORMAT('1***  VALUES PRINTED ACCORDING TO TIME ORDER OF INPUT  ***
       1')
        WRITE(IOUT6,4000)
 4000   FORMAT('- TIME      SLIP      TORQUE       COMPLEX SLIP       PERCENT
       1MAGNITUDE INPUT     MAGNITUDE INPUT     POW FAC '/' ',17X,'(NT.M.)',
       223X,'COMPLEX    VOLTAGE (VOLTS)     CURRENT (AMPS)'/' ')
C   >>
C   >>      SECTION TO CALCULATE THE TORQUE AND SLIP VALUES
C   >>
        JJ=0
        DO 10 I=1,10000
        READ(IN5,100,END=88)VI(I),II(I),PF(I)
 100    FORMAT(8F10.4)
        VI(I)=VI(1)
        RII=II(I)
        PFF=PF(I)
        IF(ABS(PFF).LE.1.0) GO TO 3
        JJ=JJ+1
        M(JJ)=I
        GO TO 10
 3      CI1=CMPLX(RII*PFF,RII*SIN(-ARCOS(PFF)))
        CE1=(CMPLX(VI(I)/SQR3,0.0))-((CZFEED+CHDRX1)*CI1)
        CI2=CI1-(CE1*CHDCGB)
        CSLIPC=CHDCR2/((CE1/CI2)-CHDCX2)
        CSLIP(I)=CSLIPC
        S=CABS(CSLIPC)
        SLIP(I)=S
        PERCOM(I)=100.*ABS(AIMAG(CSLIPC)/REAL(CSLIPC))
        TOUT(I)=(((1.-S)*3.*(CABS(CI2)**2)*R2HYD/S)-PLSHYD)/((1.-S)*SPDHY
       1D*.1047198)
        KJ=I-JJ
        K(KJ)=I
        WRITE(IOUT6,4010) I,S,TOUT(I),CSLIPC,PERCOM(I),VI(I),RII,PF(I)
 10     CONTINUE
 4010   FORMAT(' ',I4,F9.5,F11.2,'   (',2F8.5,')',F10.4,6X,F9.2,10X,F9.2,6X
       1,F9.2)
 88     IF(JJ.EQ.0) GO TO 7
        WRITE(IOUT6,7000) (M(L),L=1,JJ)
```

```
7000    FORMAT('3*** ERROR THESE INPUT POINTS WERE INVALID, POWER FACTOR G
       1REATER THAN 1.0'/' ',4( 4X,I4,18(',',I4)))
C   >>
C   >>      CALL SUBROUTINE SORT TO SORT THE TORQUE VALUES ACCORDING TO
C   >>      DECREASING ORDER OF SLIP
C   >>
7       CALL SORT(KJ,K,SLIP)
        WRITE(IOUT6,2000)
2000    FORMAT('1***  VALUES PRINTED ACCORDING TO SLIP IN DESCENDING ORDER
       1  ***')
        WRITE(IOUT6,4000)
        DO 40 J=1,KJ
        I=K(J)
        WRITE(IOUT6,4010) I,SLIP(I),TOUT(I),CSLIP(I),PERCOM(I),VI(I),II(I)
       1,PF(I)
40      CONTINUE
        SLPMAX=SLIP(K(1))
        SLPMIN=SLIP(K(KJ))
        WRITE(IOUT6,6000)
6000    FORMAT('1','TIME',9X,'SLIP',7X,'DELTOR',2X,'LOAD TORQUE'/' ')
C   >>
C   >>      CALCULATING THE ACTUAL LOAD TORQUE AND SLIP
C   >>
        KJM1=KJ-1
        DO 50 JA=1,KJM1
        DELTOR(JA)=(.56)*(188.4)*(SLIP(JA)-SLIP(JA+1))/(.2)
        SLIPTL(JA)=SLIP(JA)+((SLIP(JA+1)-SLIP(JA))/2.0)
        TORLD3(JA)=(TOUT(JA)+((TOUT(JA+1)-TOUT(JA))/2.))-DELTOR(JA)
        JJAA(JA)=JA
50      CONTINUE
        DO 53 JJDD=1,KJM1
        WRITE(IOUT6,5000) JJDD,SLIPTL(JJDD),DELTOR(JJDD),TORLD3(JJDD)
        KKMM(JJDD)=JJDD
5000    FORMAT(' ',I4,6(3X,F10.4))
53      CONTINUE
C   >>
C   >>    CALL SUBROUTINE GRAPH TO PLOT LOAD TORQUE AND SLIP ACCORDING
C   >>    TO TIME ORDER OF INPUT
C   >>
        CALL GRAPH(KJM1,SLPMIN,SLPMAX,SLIPTL,TORLD3,KKMM)
C   >>
C   >>      CALL SUBROUTINE SORT TO SORT THE LOAD TORQUE VALUES ACCORDING
C   >>      TO DECREASING ORDER OF SLIP
        CALL SORT(KJM1,JJAA,SLIPTL)
        WRITE(IOUT6,6000)
        DO 55 INC=1,KJM1
        JAINC=JJAA(INC)
        WRITE(IOUT6,5000) JAINC,SLIPTL(JAINC),DELTOR(JAINC),TORLD3(JAINC)
55      CONTINUE
C   >>
C   >>      CALL SUBROUTINE GRAPH TO PLOT LOAD TORQUE AND SLIP IN ORDER OF
C   >>      DECREASING SLIP
C   >>
        CALL GRAPH(KJM1,SLPMIN,SLPMAX,SLIPTL,TORLD3,JJAA)
        STOP
        END
```

```
       SUBROUTINE MOTHYD
C   >>
C   >>      SUBROUTINE TO READ AND PRINT THE FEEDER VALUES AND THE MOTOR
C   >>      PARAMETERS
C   >>
       IMPLICIT COMPLEX(C)
       COMMON /HYDMOT/ CHDRX1,CHDCGB,CHDCR2,CHDCX2,R2HYD,PLSHYD,RPLHYD,SP
      1DHYD
       COMMON /CORFAC/ CZFEED,SQR3
       IN5=5
       IOUT6=6
       SQR3=SQRT(3.0)
       READ(IN5,300) WLNGTH,ISIZE,ROR,ROX
300    FORMAT(F8.2,I2,F10.6,F10.6)
       CZFEED=CMPLX(WLNGTH*ROR/1000.,WLNGTH*ROX/1000.)
       WRITE(IOUT6,5000) WLNGTH,ISIZE,ROR,ROX
5000   FORMAT('1***  FEEDER LINE SPECIFICATIONS   ***'/'0        LENGTH=',F8.
      12,' FEET'/'         SIZE=',I3,'/0 GAUGE'/'        RESISTANCE=',F8.5,' O
      2HMS/1000. FEET'/'        REACTANCE= ',F8.5,' OHMS/1000. FEET')
       WRITE(IOUT6,5010) CZFEED
5010   FORMAT('        FEEDER IMPEDANCE=(',2F8.5,' ) OHMS')
       READ(IN5,200) IHP,IVLL,IIN,ISPD
200    FORMAT(4I10)
       SPDHYD=FLOAT(ISPD)
       READ(IN5,100) R1HYD,X1HYD,R2HYD,X2HYD,RCHYD,XMHYD,PLSHYD
100    FORMAT(8F10.4)
       IPOLE=120*60/ISPD
       WRITE(IOUT6,2000)
2000   FORMAT('3***  HYDRAULIC MOTOR PARAMETERS  ***')
       WRITE(IOUT6,1000) IHP,ISPD,IVLL,IIN,IPOLE
1000   FORMAT('-    ',I3,' HORSEPOWER   ',I4,' RPM'/'     ',I3,' VOLTS L-L
      1   ',I4,' AMPS'/'     ',I4,' POLE')
       WRITE(IOUT6,1010) R1HYD,X1HYD,R2HYD,X2HYD,RCHYD,XMHYD,PLSHYD
1010   FORMAT('0   R1=',F8.4,' OHMS   X1=',F8.4,' OHMS'/'     R2=',F8.4,'
      1OHMS   X2=',F8.4,' OHMS'/'     RC=',F8.1,' OHMS   XC=',F8.1/'0   WI
      2NDAGE,FRICTION,ETC. LOSSES= ',F8.2,' WATTS')
       CHDRX1=CMPLX(R1HYD,X1HYD)
       CHDCX2=CMPLX(0.0,X2HYD)
       CHDCGB=CMPLX(1.0/RCHYD,-1.0/XMHYD)
       CHDCR2=CMPLX(R2HYD,0.0)
       RETURN
       END
```

```
      SUBROUTINE SORT(KJ,K,SLIP)
C  >>
C  >>     SUBROUTINE TO SORT THE VALUES
C  >>
      DIMENSION K(500),SLIP(500)
      IIM1=KJ-1
      DO 20 J=1,IIM1
      SLARGE=SLIP(K(J))
      JP1=J+1
      IFLAG=0
      DO 30 L=JP1,KJ
      IF(SLARGE.GE.SLIP(K(L)))GO TO 30
      IFLAG=1
      SLARGE=SLIP(K(L))
      N=L
30    CONTINUE
      IF(IFLAG.EQ.0) GO TO  20
      TEMP=K(J)
      K(J)=K(N)
      K(N)=TEMP
20    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE GRAPH(NUM,SLPMIN,SLPMAX,SLIP,TOUT,K)
C   >>
C   >>     SUBROUTINE FOR PLOTING USING INTERNAL COMPUTER PROGRAMS
C   >>
      DOUBLE PRECISION MIN(2),MAX(2),SCLFAC(2),LABEL(11),VALUE(2)
      REAL SLIP(NUM),TOUT(NUM)
      INTEGER K(NUM)
      LOGICAL*1 CH(2),LINE(103)
      DATA CH/'S','T'/,MIN(2)/0.0D0/,MAX(2)/1100.0D0/
      IOUT6=6
      MIN(1)=SLPMIN
      MAX(1)=SLPMAX
      SCLFAC(1)=(MAX(1)-MIN(1))/10.0D0
      SCLFAC(2)=(MAX(2)-MIN(2))/10.0D0
      CALL SCALEN(2,MIN,SCLFAC)
      WRITE(IOUT6,1000)
1000  FORMAT('1',25X,'LOAD TORQUE AND SLIP VERSUS TIME')
      DO 20 KP=1,11
      LABEL(KP)=(KP-1)*SCLFAC(1)+MIN(1)
20    CONTINUE
      WRITE(IOUT6,2000) LABEL
2000  FORMAT(' ',9X,'SLIP',9X,11F10.5)
      DO 30 KU=1,11
      LABEL(KU)=(KU-1)*SCLFAC(2)+MIN(2)
30    CONTINUE
      WRITE(IOUT6,3000) LABEL
3000  FORMAT(' ',6X,'TORQUE (N.M.)',3X,11F10.2)
      WRITE(IOUT6,4000)
4000  FORMAT(' ',29X,10('*.........'),'*'/' ',29X,101('-'))
      DO 40 M=1,NUM
      KM=K(M)
      VALUE(1)=SLIP(KM)
      VALUE(2)=TOUT(KM)
      CALL GRAPHN(2,LINE,VALUE,CH)
      WRITE(IOUT6,5000) M,LINE
5000  FORMAT('S',I13,9X,A1,'I',101A1,'I',A1)
40    CONTINUE
      WRITE(IOUT6,4000)
      RETURN
      END
```