INTERACTIVE SIMULATOR FOR OUTAGE STUDIES

A DISSERTATION

submitted in partial fulfilment of
the requirements for the award of the degree
of
MASTER OF ENGINEERING
in
ELECTRICAL ENGINEERING
(System Engineering & Operation Research)

By

AMIT BHARGAVA

DEPARTMENT OF ELECTRICAL ENGINEERING
UNIVERSITY OF ROORKEE
ROORKEE-247667 (INDIA)

April, 1988

CANDIDATE'S DECLERATION

I hereby, certify that the work presented in the dissertation INTERACTIVE SIMULATOR FOR OUTAGE STUDIES in partial fulfilment of requirements for the award of the degree of MASTER OF ENGINEERING in ELECTRICAL ENGINEERING AND OPERATION RESEARCH, submitted in Electrical Engineering Department, University of Roorkee, Roorkee (India), is an authentic record of my own work carried out for a period of about six months from August 1987 to March 1988 under supervision of Dr. J.D. Sharma, Professor, Electrical Engineering Department, Universith of Roorkee and Mr. A.D. Pandey, Reader, Earthquake Engineering Department, University of Roorkee, Roorkee.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

DATED: 6th April 1988

Amit Bhargava
(AMIT BHARGAVA)

This is to certify that the above statement made by the candidate is correct and best of our knowledge.

(A.D. PANDEY)
READER,
EARTHQUAKE ENGINEERING
DEPARTMENT,
UNIVERSITY OF ROORKEE,
ROORKEE - 247 667, INDIA

(J.D. SHARMA)
PROFESSOR,
ELECTRICAL ENGINEERING
DEPARTMENT,
UNIVERSITY OF ROORKEE,
ROORKEE- 247 667, INDIA

ABSTRACT

Interactive simulator for outage studies

Outage simulation is performed for accessing the security of power system which in turn can be used in operation and planning studies. In outage simulation, power system steady state performance is studied under various contingency conditions.

An effort is made in this work to develop an interactive outage simulator for simulating the generator and line outages in power system. This simulator provides graphical output and screen presented, menu driven, program and data control. For load flow studies fast decoupled method is used. The network sparcity is also exploited in data storage and calculations. This simulator is very flexible and data base modifications and restoration are very easy.

ACKNOWLEDGEMENT

Author express profound gratitude to Dr. J.D. Sharma, Reader in Electrical Engineering, University of Roorkee, Roorkee and Mr. A.D. Pandey, Reader in Earthquake Engineering Department, University of Roorkee, Roorkee, for their constant encouragement and valuable guidance.

Author wishes to thank his friends for their encouragement and company.

CONTENTS

CHAPTER-1

INTRODUCTION

An important aspect of the design and operation of a power system network is to mentain system security.

A secure operating state of power system is defined as that state which is invulnerable to unacceptable system condition such as:

- Cascading outages
- system sepration
- wide-spread outages

CHAPTER 1

- violation of emerging limits of line currents
- bus voltages, or system frequency
- loss of synchronization among generators

Analysis of system security is a ·i ::·, · in three major applications:

1. Long term planning
   - evaluation of generator capacity requirements
   - evaluation of interconnected system power exchange capabilities
   - evaluation of transmission system adequacy

2. Planning of Operations

- Determination of spinning reserves requirements
- scheduling of hourly generation as well as interchange scheduling among neighboring systems
- outage dispatching of transmission lines and transformers for maintenance and system operation.

3. On line Operation

- Monitoring of operating state of the system
- contingency evaluation
- prediction of level or measure of system security
- providing in puts to security enhancement functions.

The security assessment process itself consists of two primary functions:

1. Security Monitoring: this consists of the processing of incoming data, correlating it with available data in order to reliably determine the operating state of the system at present or in near future.

2. Security Analysis: this consists of simulating the system under various contingency conditions in order to

CHAPTER-1

INTRODUCTION

An important aspect of the design and operation of a power system network is to mentain system security.

A secure operating state of power system is defined as that state which is invulnerable to unacceptable system condition such as:

- Cascading outages
- system sepration
- wide-spread outages
- violation of emerging limits of line currents
- bus voltages, or system frequency
- loss of synchronization among generators

Analysis of system security is a primary function in three major applications:

1. Long term planning
   - evaluation of generator capacity requirements
   - evaluation of interconnected system power exchange capabilities
   - evaluation of transmission system adequacy

2. Planning of Operations

- Determination of spinning reserves requirements
- scheduling of hourly generation as well as interchange scheduling among neighboring systems
- outage dispatching of transmission lines and transformers for maintenance and system operation.

3. On line Operation

- Monitoring of operating state of the system
- contingency evaluation
- prediction of level or measure of system security
- providing in puts to security enhancement functions.

The security assessment process itself consists of two primary functions:

1. Security Monitoring: this consists of the processing of incoming data, correlating it with available data in order to reliably determine the operating state of the system at present or in near future.

2. Security Analysis: this consists of simulating the system under various contingency conditions in order to

evaluate the measure of system security and provide inputs to enhancement strategies.

In either of the above functions undated mathematical models of the system are required. These models are classified as steady - state (static) and dynamic. And each class can be deterministic or stochastic.

System disturbances are classified into load and event distrubances. Locd disturbances consist of small random fluctuations superimposed on slowly varying trend changes. Event disturbances consist of:

- fault on transmission lines
- cascading events due to protective relay action following severe over loads or violation of operating limits
- generator outages due to loss of synchronism or malfunction
- sudden and large load changes.

Transmission line outage are generally due to weather (lightning or storm), improper relaying, operator errors or accidents. Most such outages will effect single line. However multiple line outages may occur due to bus faults or accidents involving multiple line towns. Therefore they should not be disregarded entirely statistics on transmission line may or may not be avaialble in given utility. Generator outages statictics perhaps are more understood with data available on most systems.

The information available from outage studies ise essential for the continious evaluation of the current performance of a power system and for analysing the effectiveness of alternative plans for system expansion to meet increased load demand.

Effort has been made to develop interactive outage simulator for generator and line outages.

The input to be given either through cards or from an editor. A computer program is developed to input the data interacting Main advantages of inputing data through CRT are, firstly, field boundaries are not user's concern and secondly, only the essential part of data may be entered. The outages may be displayed selectively. During the program execution the user is asked if the display is needed. A hardcopy of display can be produced during program execution.

Selective data may be printed by defining 10 options. The option is hold true if it is assigned value unity. Without any options set bus data, line data, system data, no of interaction and maximum mismatches are printed. Option 1 produces additional bus listing. Option 2 produces additional branch listing. Option 4 writes active and reactive mismatches at each interation. Option 5 prints variation in active power generated at swing bus. Option 6 is used for change in reactive power or voltage specified at buses with limits. Option 7 prints variation of inphase transformer and drop of power in outage. Option 8 prints the voilation of reactive limits. Option 9 is used for printing bus loading, branch loading, shunt loses and series loses. Option 10 prints the redistribut[illegible] active power on generator in outage.

The outage are simulated for three test systems, i. e., 5 bus system given by EL-Abiad, IEEE-14 system bus and IEEE 118 system bus. The results were displayed for the five bus system. The display included lines, buses, generator, bus voltages and bus angles. The overloaded line are blinked for some time.

CHAPTER - 2

LOAD FLOW STUDIES

2.1 INTRODUCTION

Load flow calculation provide power flows and voltage for a specified power system subject to regulating capability of generators, condensors, and tap changing under loaded transformers as well as specified net inter ch... between individual operating systems. This information is essential for the continuous evaluation of the current performance of a power system and for analyzing the effectiveness of alternative plans for system expansion to meet increased load demand.

CHAPTER 2

The load flow problem consists of the calculation of power flows and voltages of a network for ... ...ified terminal or bus condition. Associated with ... four quantities, the real, reactive power, magnitude and the phase angle. It is nec... one bus, called the slack bus to provide ... and reactive power. The computing time per ... Newton's method vari... linearly with the ... the problem . For typical large systems one N... ...iteration is roughly equal to seven Gauss siedel ite...tions in computing time.

CHAPTER - 2

LOAD FLOW STUDIES

2.1 INTRODUCTION

Load flow calculation provide power flows and voltage for a specified power system subject to regulating capability of generators, condensors, and tap changing under loaded transformers as well as specified net inter change between individual operating systems. This information is essential for the continuous evaluation of the current performance of a power system and for analyzing the effectiveness of alternative plans for system expansion to meet increased load demand.

The load flow problem consists of the calculation of power flows and voltages of a network for spedified terminal or bus condition. Associated with each bus are four quantities, the real, reactive power, the voltage magnitude and the phase angle. It is necessary to select one bus, called the slack bus to provide additional real and reactive power. The computing time per iteration of Newton's method varies linearly with the size of the problem . For typical large systems one Newton iteration is roughly equal to seven Gauss siedel iterations in computing time.

2.1.1 Decoupled Methods

An inherent characteristic of any practical electric power transmission system operating in steady state is the strong interdependence between active powers and bus voltage angles, and between reactive powers and voltage magnitude. This decoupling is achieved by solving separately P-Q and Q-V problems. Over all saving in total core required is 35 percent- 40percent and the saving in time is 10 percent - 20 percent less than for the formal Newton method.

2.2 Fast decoupled method:

This method utilises the symmetry in P-Q and Q-V problems. The speed of each iteration is $1\frac{1}{2}$ times the Gauss seedel iterations or 1/5 in of a Newton's iteration. The method requires lesser space and take lesser amount of C.P.U. time than the Newton's method.

We make use of following variables:

$E_i=V_i\angle\theta_i$	Nodal Voltage
I_i	Nodal injected current
P_i	Active power generated
P_{Li}	Active power load

Q_{Gi}	Reactive power generated
Q_{Li}	Reactive power load
$P_i=P_{Gi}-P_{Li}$	Total Real power at a bus
$Q_i=Q_{Gi}-Q_{Li}$	Total Reactive power at a bus
$S_i=P_i+jQ_i$	Net nodal injected power
$\Delta S_i=\Delta P_i+J\Delta Q_i$	Power mismatch
ΔI_i	Current mismatch
$\Delta E_i=\Delta V_i \ \angle \Delta \theta_i$	connection to nodal voltage
Y	Nodal admittance matrix

From nodal analysis or Kirchoff's law. The relationship between current and voltage at buses may be expressed as :

$$I = YE$$

Where $I = [I_i \ldots I_n]^T$

and $E=[E_1 \ldots E_n]^T$

Y is a square complex matrix and n is the total number of nodes

The power at a bus may be expressed as :

$$S_i = E_i I_i^* = P_i + Q_i \qquad (2.2.1)$$

or

$$S_i^* = E_i \sum_{j=1}^{n} Y_{ij} F_j = P_j - JQ_j \qquad (2.2.2)$$

Thus if 2n equation in 4n variables. Thus Y2n variables are fixed then the solution is unique. In other words. If two of the variables P_i, Q_i, E_i, Q_i be known at each bus the above equation be solved.

Buses are classified accordingly to the variables defined on it. One bus is chosen as the slack or reference bus at this bus the voltage is fixed and the bus supplies the power loses to the system.

Various types of buses considered in this simulation are:

(1)	PQ buses	P_i and Q_i are fixed
(2)	PV buses	$\|E_i\|$ and P_i are fixed
(3)	PQ V buses	P_i and Q_i are fixed and there are limits on the $\|E_i\|$ on a bus
(4)	PV Q buses	P_i and $\|E_i\|$ is specified and Q_i has maximum and minimum limits
(5)	PV Q buses	Remotelly controlled P_i and $\|E_i\|$ specified and Q limits are also defined and the $\|E_i\|$ of the other bus is kept constant.

2.2.1 Derivation of Fast Decoupled Method

For each PQ bus i, the complex power mismatch is given as:

$$\Delta S_i = S_i^{Sp} - \Sigma E_i I_i^* = P_i^{Sp} + jQ_i^{Sp} - E_i \sum_{k=1}^{n} Y_{ik}^* E_k$$

let $Y_{ik} = G_{ik} + jB_{ik}$ x 1

Hence,

$$\Delta P_i = P_i^{Sp} - \text{Re}\ \{(e_i + jf_i) \sum_{k=1}^{n} (G_{ik} - jB_{ik})(e_k - jf_{ik}$$

$$= P_i^{Sp} - E_i \sum_{k=1}^{n} (G_{ik} \cos \theta_{ik} + B_{ik} \sin \theta_{ik})\ V_k$$

and

$$\Delta Q_i = Q_i^{Sp} - I_m \{(e_i + jf_i) \sum_{k=1}^{n} (G_{ik} - jB_{ik})(e_k - jf_k)\}$$

$$= Q_i^{Sp} - E_i \sum_{k=1}^{n} (G_{ik} \sin\theta_{ik} - B_{ik} \cos\theta_{ik})\, V_k$$

The convergence criteria is chosen as:

$\Delta P_i = \leq C_p$ for all PQ and PV buses

$\Delta Q_i = \leq C_q$ for all PQ buses

where C_p and C_q are tolerances

The change in the active the reactive power, voltage magnitude and angle may be expressed as

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \theta \\ \Delta V \end{bmatrix} \qquad (2.2.3)$$

Solution is approached by moving in the direction of negative slope, where

$$J_1 = -\frac{\partial(\Delta P)}{\partial(Q)}, \quad J_2 = \frac{-\partial(\Delta P)}{\partial(V)},$$

$$J_3 = \frac{-\partial(\Delta Q)}{\partial(\Delta Q)}, \quad J_4 = \frac{-\partial(\Delta Q)}{\partial(\Delta V)}$$

or in general

$$J = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \qquad (2.2.4)$$

where J is the Jacobian matrix.

As in case of decoupled metnods coupling between P-Q and Q-V components is relatively weak.

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & 0 \\ 0 & J_4 \end{bmatrix} \begin{bmatrix} \Delta Q \\ \Delta E \end{bmatrix}$$

let $\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} H & 0 \\ 0 & L \end{bmatrix} \begin{bmatrix} \Delta Q \\ \Delta E/E \end{bmatrix}$

It may be proved

$$H_{ij} = L_{ij} = E_i E_j \,(G_{ij} \sin \theta_{ij} - B_{ij} \cos\theta_{ij})$$

$$H_{ij} = -B_{ii} \; E_i^2 - Q_i$$

$$L_{ij} = -B_{ii} \, E_i^2 + Q_i$$

Following assumption are made in fast decoupled method:

$\cos \theta_{km} \simeq 1$, $G_{km} \sin \theta_{km} \ll B_{km}$

and $\theta_k \ll B_{kk} V^2$

Hence,

$[\Delta P] = [V B^1 V] [\Delta \theta]$ (2.2.5)

$[\Delta Q] = [V B^{11} V] [\Delta V/V]$ (2.2.6)

Following rules are observed in the formation of B^1 and B^{11} matrix

(a) Omitt form $[B']$ the representation of those network elements that dominantly affect MVAR flows, i.e. shunt- reactaness and off-noiral in-phase transformer taps.

(b) Omitting from $[B']$ angle shifting effects of phase shifters.

(c) V is assumed to be 1 p.u. and

(d) Neglecting series resistance in calculating the elements of $[B']$.

The final result is

$[\Delta P/V] = [B'] [\Delta \theta]$ (2.2.7)

$[\Delta Q/V] = [B''] [\Delta V]$ (2.2.8)

both $[B']$ and $[B'']$ are real and sparse. It phase shifters are not connected $[B']$ and $[B'']$ are symmetrical.

2.3 Method of Finding Inverse or Matrices [B′] and [B″]

The method used is given by Zollenkopf [ ]. The method is suitable for the matrices that are strictly symmetric and positive definate or diagonally dominant. In order to save on CPU time and storage, and optimally ordered storage scheme and special programming techniques are used.

A set of n linear equations can be expressed ina matrix notation as

$$Ax = b \qquad (2.3.1)$$

where A is a non singular nxn coefficient matrix

x is a coloumn vector of n unknowns.

b is a known vector.

Solution may be conputed directly as:

$$x = A^{-1} b \qquad (2.3.2)$$

let

$$L^{(n)} . L^{(n-1)} \ldots . L^{(1)} A R^{(1)} \ldots R^{(n-1)} R^{(n)} = I \qquad (2.3.3)$$

where

L are left hand factor matrices

R are righthand factor matrices

I is unity matrix

The equation (2.3.3) can be modified by simple transformation to:

$$A^{-1} = R^{(1)} R^{(2)} \ldots R^{(n)} L^{(n)} \ldots L^{(2)} L^{(1)} \quad (2.3.4)$$

In order to determine the factor matrices L and R the following sequence of inter midiate matrices are introduced:

$$A^{(0)} = A$$

$$A^{(1)} = L^{(1)} A^{(0)} R^{(1)}$$

$$A^{(j)} = L^{(1)} A^{(j-1)} R^{(j)} \qquad (2.3.5)$$

$$A^{(n-1)} = L^{(n-1)} A^{(n-2)} R^{(n-1)}$$

$$A^{(n)} = L^{(n)} A^{(n-1)} R^{(n)} = I$$

The matrices $A^{(i)}$, $L^{(i)}$ and $R^{(j)}$ may be calculated from the elements of $A^{(j-1)}$

let $A^{(j)} = [a_{ik}^{(j)}]$

$$a_{jj}^{(j)} = 1$$

$$a_{ij}^{(j)} = 0 \qquad (2.3.6)$$

$$a_j R^{(j)} = 0$$

$$a_{ik}^{(j)} = a_{ik}^{(j-1)} - \frac{a_{ij}^{(i-1)} a_{jk}^{(i-1)}}{a_{jj}^{(j-1)}}$$

where i is called p'ritol index for i and k varies from (j+1) ...n

Matrix $A^{(j)}$ is of the form

$$A^{(i)} = \begin{bmatrix} 1 & \cdots & 0 & \cdots & 0 \\ 0 & & 1 - (j) & \cdots & 0 \\ \vdots & & \vdots \ddots a_{ij} & \cdots & a_{nj}^{(i)} \\ \vdots & & \vdots & \ddots & \vdots \\ 0 & & 0 \; a_{nij}^{(i)} & \cdots & a_{nn}^{(i)} \end{bmatrix} \qquad (2.3.7)$$

Factor matrices $L^{(i)}$ is of the form

$$L^{(i)} = \begin{bmatrix} 1 \ddots & 0 & & \\ & 1 \;\; 0 & & O \\ & l_{ij}^{(i)} & & \\ O & \vdots & 1 & \\ & \vdots & 0 \ddots & \\ & l_{nj}^{(i)} & & 1 \end{bmatrix} \qquad (2.3.8)$$

where $l_{ij}^{(i)} = \frac{1}{a_{ij}(j-1)}$

$$l_{ij}^{(j)} = - a_{ij}^{(j-1)} / a_{jj}^{(j-1)}$$

$$l_{kk}^{(i)} = 1 \quad k \neq i$$

$$i = (j+1), \ldots n$$

$$k = 1, \ldots . n$$

Factor matrices $R^{(i)}$ is of the form

$$R^{(i)} = \begin{bmatrix} 1 & & & & & & \\ & \ddots & & & & 0 & \\ & & 1 & r_{j,j+1}^{(i)} & \cdots & r_{jn}^{(i)} & \\ & & & \ddots & & 0 & \\ & 0 & & & 1 & & \\ & & & & & \ddots & \\ & & & & & & 1 \end{bmatrix} \quad (2.3.9)$$

where

$$r_{ij}^{(i)} = -a_{jk}^{(j-1)} / a_{ij}^{(j-1)}$$

$$r_{kk}^{(i)} = 1, \quad k = (j+1), \ldots n \quad k=1,\ldots,n$$

If the matrix A is symmetrica the

$$a_{ik}^{(j-1)} = a_{ki}^{(j-1)}$$

and $r_{jk}^{(i)} = l_{ij}^{(j)}$ for $i = k \neq J$

Hence if $A^{(i)}$ is symmetrical

matrix j^{th} Row of $R^{(i)}$ is identical to j^{th} coloumn of $L^{(j)}$, except for the diagnolterm.

In order to exploit the benefit of sparcity, a packed matrix storage scheme in which only the non-zero terms are retained is employed. In addition to matrix elements themselves, tables of indexing information to identify the elements and to facilitate their addressing is made. Small memory requirements and short computation time come be realized because only non zero matrix terms are stored and processed. Symmetry can entirely be exploited in programming for matrices having symmetrical pattern of non zero terms.

2.4 Reactive limit check on Q limited bus

Let DQ_i be defined as the deviation of the calculated reactive power from the violated limit. The power at PQ, PQV and PQRV buses connected to the given buses are calculated. From this voltage correction ΔV_k are calculated. Correction is made for branch outages.

Using the voltage corrections ΔV_k the total power at the bus i is calculated

Let F1 be the total power

$$\text{Let } F2 = \frac{DQ_i}{V_i}$$

$$F3 = \frac{F2}{(V_i)^2}$$

$$\text{and } X_1 = \frac{F2}{(F1 + F3)}$$

for limit on bus bar to be true

$$-1.0 \leq x1 \leq 1.0$$

Voltage at all nodes except the give node is modified as

$$V_k = V_k + X1 * \Delta V_k \qquad k, \ 2, \ \ldots\ldots, x$$

for the node which is being considered

$$V_i = V_i + X1$$

2.4 Voltage limit check on voltage limited buses

Let DV_i be the deviation of the voltage from the violated limit.

Reactive power at the bus is taken as unity and all other reactive power is taken zero.

Let ΔV_k $k=1,\ldots,n$ be the voltage correction calculated from the factorized matrix.

Then, sensivity factor SQ is defined as

$$SQ = 1.0 / \Delta V_i$$

The voltage at all buses except the slack bus is modified. The modified voltage is

$$V_k = V_k + \Delta V_k * \frac{DV_i}{\Delta V_i} \qquad k = 2,\ldots.n.$$

The reactive power generated at the bus is modifies as

$$Q_i = Q_i + \frac{DV_i}{\Delta V_i} \qquad V_i$$

CHAPTER 3

CHAPTER - 3

OUTAGE STUDIES

3.1 INTRODUCTION

An important aspect of design and operation of a power system network is to maintain system security. If a generator is disconnected from the system due to failure, then enough power should be generated without in admissible frequency drop or without shedding of load. The line must be designed such that, if a line is damaged and removed from the system by relays, the other system buses do not become overloaded. This is to reduce cascading failures.

Several methods available for outage study are:

( ) Gauss-seidel method

(2) Explicit matrix inversion method

(3) Direct solution method using triangular factorization.

Gauss seidel method is lest complex to program but is slow. Spare matrix method in triangular factorization is fast and effecient.

S/S Das.

IC C-18

C-19

Rourkela

1. There are many spelling mistakes and gramatical errors. (verb is missing usually).
2. What do you mean by "interactive outage"
3. The sentence is not intelligible.
4. What does option 3 produce?
5. What do you mean by option?
6. In steady state interdependance exist between which parameters of powersystems? [illegible] P-θ & Q-V
7. What is the blank space?
8. What is the objective of the Dissertation?
9. What are the conclusions.
10. Adv. of decoupled load flow?
    fast & memory economy
    Disadv. — Convergence is poor particularly if lines have high R/X ratio

Every time outage takes place the bus matrix must change, and hence a new system is formed. To save time and space on a computer method using the same factorized matrix and little extra effort are most suited for the computer. The space and time needed for refactorization.

3.2 Line Outage

The method for the outage studies is in combination of fast decoupled load flow method. Advantage is taken of a technique which mathamatically models outage system by its pre-contingency by adding changes in the injected powers at the terminal buses of outaged branches.

In principle a line or transformer outage causes a system confugration change. An equivalent mathematical model is made which has original confugration except that at the terminal buses of outaged elements additional active and reactive power, equal to that which would flow if the line was present with modified system voltages are injected. The maximum number of ΔP_I, ΔQ_I variables for each outage is 4.

Outaged System state

$$P_{km} = V_k V_m \, [G_{km} \cos \theta_{km} + B_{km} \sin\theta_{km}] - V_k{}^2 (G_{km} \; G_{km}') \quad (3.2.1)$$

$$Q_{km} = V_k V_m [G_{km} \sin\theta_{km} - B_{km} \cos\theta_{km}] + V_k{}^2 (B_{km} \quad (3.2.2)$$

$$Pmk = V_m V_k (G_{km} \cos\theta_{mk} - B_{km} \sin\theta_{mk}] + V_m{}^2 (B_{km} - B_{km}') \quad (3.2.3)$$

$$Q_{mk} = V_m V_k [G_{km} \cos\theta_{mk} - B_{km} \sin\theta_{mk}] + V_m{}^2 (B_{km} - B_{km}) \quad (3.2.4)$$

where $Q_{km} = \theta_k - \theta_m \quad = - \theta_{mk}$

$G_{km} + jB_{km}$ (k,m)the element of admittance matrix

$G_{km}' + jB_{km}' \quad = \frac{1}{2}$ (line changing admittance)

Similarly for post contingency variables

$V_k' = V_{ko} + \Delta V_k$

$\theta_k' = \theta_{ko} + \Delta\theta$

$P_{km}' = P_{km_o} + \Delta P_{km}$

$P_{mk}' = P_{km_o} + \Delta P_{mk}$

and similar equations may be written for post contingency variables

let
$$\begin{bmatrix} \Delta P_{km} \\ \\ \Delta Q_{km} \end{bmatrix} = \begin{bmatrix} R & U \\ \\ T & S \end{bmatrix} \begin{bmatrix} \Delta \theta \\ \\ \Delta V/V \end{bmatrix} \qquad (3.2.5)$$

Assuming decoupling i.e.

$$U = 0 \quad , T = 0$$

we have

$$P_{km} = V_k V_m \left[G_{km} \cos(\theta_k - \theta_m) + B_{km} \sin(\theta_k - \theta_m)\right]$$
$$- V_k^{\,2}(G_{km} - G'_{km})$$

$$Q_{km} = V_k V_m \left[G_{km} \sin(\theta_k - \theta_m) - B_{km} \cos(\theta_k - \theta_m)\right]$$
$$+ V_k^{\,2}(B_{km} - B'_{km})$$

Assuming $\cos \theta_{km} \approx 1$

and $G_{km} \sin \theta << B_{km}$

and $\sqrt{V_k/V_m} \simeq 1.0$

we have $P_{km} = V_k V_m \left[G_{km} + B_{km} \sin(\theta_k - \theta_m)\right]$
$$- V_k^{\,2}(G_{km} - G'_{km})$$

$$\frac{\partial P_{km}}{\partial \theta_k} = V_k V_m B_{km}$$

$$\frac{\partial P_{km}}{\partial \theta_m} = - V_k V_m B_{km}$$

$$\Delta P_{km} = \frac{\partial P_{km}}{\partial \theta_k} \Delta Q_k + \frac{\partial P_{km}}{\partial \theta_m} \Delta \theta_n$$

$$= V_k V_m \{ B_{km} \Delta\theta_k - B_{km} \Delta\theta_m \}$$

$$\frac{\Delta P_{km}}{\sqrt{V_k V_m}} = B_{km} * V_k * \sqrt{\frac{V_m}{V_k}} \Delta\theta_k$$

$$- B_{km} * V_m * \sqrt{\frac{V_k}{V_m}} \Delta\theta_m$$

Since $\sqrt{V_k/V_m} \approx 1.0$

We have $\frac{\Delta P_{km}}{\sqrt{V_k}\sqrt{V_m}} = B_{km} \Delta\theta_k - B_{km} \Delta\theta_m$

Similarly $\frac{\Delta P_{mk}}{\sqrt{V_k V_m}} = - B_{km} \Delta \theta_k + B_{km} \Delta\theta_m$

Which may be represented as

$$\begin{bmatrix} \frac{\Delta P_{km}}{\sqrt{V_k}\sqrt{V_m}} \\ \frac{\Delta P_{mk}}{\sqrt{V_k V_m}} \end{bmatrix} = \begin{bmatrix} B_{km} & -B_{km} \\ -B_{km} & B_{km} \end{bmatrix} \begin{bmatrix} V_k & 0 \\ 0 & V_m \end{bmatrix} \begin{bmatrix} \Delta\theta_k \\ \Delta\theta_m \end{bmatrix} \quad (3.2.6)$$

We have

$$\theta_{km} = V_k V_m \{ - B_{km}] + V_k^2 [B_{km} - B'_{k1m}]$$

$$\frac{\partial \theta_{km}}{\partial V_k} = -B_{km} V_m + 2V_k B_{km} - 2V_k B'_{km}$$

$$\frac{\partial \theta_{km}}{\partial V_m} = - B_{km} V_k$$

$$\Delta\theta_{km} = \frac{\partial\theta_{km}}{\partial V_k}\Delta V_k + \frac{\partial\theta_{km}}{\partial V_m}\Delta V_m$$

$$= \{ - B_{km} V_m + 2V_k[B_{km} - B'_{km}]) \Delta V_k - B_{km} V_k \Delta V_m$$

$$\frac{\Delta\theta_{km}}{\sqrt{V_k V_m}} = \{ - B_{km}\sqrt{\frac{V_m}{V_k}} + 2\frac{V_e}{V_m}[B_{km} - B'_{km}] \} \Delta V_k$$

$$- B_{km}\sqrt{\frac{V_k}{V_m}} \Delta V_m$$

Since $\sqrt{\frac{V_k}{V_m}} \approx 1.0$

$$\frac{\Delta\theta_{km}}{\sqrt{V_k V_m}} = \{ -B_{km} + 2[B_{km} - B'_{km}] \} (\frac{\Delta V_k}{V_k}) * V_k$$

$$+ \{ -B_{km} \} (\frac{\Delta V_m}{V_m}) V_m$$

$$= \{ B_{km} - 2B'_{km} \} V_k (\frac{\Delta V_k}{V_k})$$

$$+ \{ -B_{km} \} V_m (\frac{\Delta V_m}{V_m})$$

Similarly

$$\frac{\Delta\theta_{mk}}{V_k V_m} = -B_{km} * V_k * (\frac{\Delta V_k}{V_k})$$

$$+ [B_{km} - 2B'_{km}] * V_m (\frac{\Delta V_m}{V_m})$$

Hence

$$\begin{bmatrix} \dfrac{\Delta\theta_{km}}{\sqrt{V_k V_m}} \\ \\ \dfrac{\Delta\theta_{km}}{\sqrt{V_k V_m}} \end{bmatrix} = \begin{bmatrix} B_{km} - 2B_{km} & -B_{km} \\ \\ -B_{km} & B_{kn} - 2B_{km} \end{bmatrix}$$

$$* \begin{bmatrix} V_k & 0 \\ 0 & V_m \end{bmatrix} * \begin{bmatrix} \Delta V_k / V_k \\ \Delta V_m / V_m \end{bmatrix} \quad (3.2.7)$$

The equations (3.2.6) and (3.2.7) can be written in the form

$$[\Delta P/ VV]_{k,m} = [B_3]_{k,m} [V]_{k,m} (\Delta\theta)_{k,m} \quad (3.2.8)$$

and

$$[\Delta\theta/ \sqrt{VV}]_{k,m} = [B_4]_{k,m} [V)_{k,m} [\Delta V/V]_{k,m} \quad (3.2.9)$$

decoupling process is completed by :

(1) Omitting from (B_3) the representation of these network elements that pre dominantly affect reactive power flow.

(2) Omitting from $[B_4]$ the angle shifting effect of phase shifter.

(3) Setting all elements of $[V]$ to 1.0 p.u.

We have

$$[\frac{\Delta P}{VV}]_{k,m} = [B_3]_{k,m} [\Delta\theta]_{k,m} \quad (3.2.10)$$

$$[\Delta Q/ VV]_{k,m} = [B_4]_{k,m} [\Delta V]_{k,m} \quad (3.2.11)$$

3.3 Computation of sensivity matrix

To complete the i^{th} column of a sensivity matrix let a column (ei) be defined as zero vector except its i^{th} element is unity, therefore

$$[J] \; [S] \; [ei] = [I] \; [ei]$$

$$[J] \; [S] = [e_i] \quad (3.2.12)$$

where S is the i^{th} collumn of sensivity matrix [S] and is calculated by solving the factorized Jacobian matrix (J) and (e_i) by Zollen koph Bi factorization direct solution subroutine.

Assuming that the loads and real power output of generating plants remains unchanged and since the outage of a line k m connecting two load buses k and m is being simulated by changes in the power injected into bus k and m only, therefore based on the fast decoupled load flow method

$$[\frac{\Delta P}{V}] = [B_1] [\Delta\theta] \quad \text{or} \quad [\Delta\theta] = [S_1] [\frac{\Delta P}{V}]$$

$$[\frac{\Delta\theta}{V}] = [B_2] [\Delta V] \quad \text{or} \quad \Delta V = [S_2] [\frac{\Delta Q}{V}]$$

Only two columns of each sensivity matrix S_1 and S_2, the ΔP_{Ik} and ΔP_{Im} are given by

$$[\Delta P_I]_{k,m} = [I] - [SP]^{-1}[P_o]_{k,m}$$

Similarly

$$[\Delta Q_I]_{k,m} = [I] - [SQ]^{-1}[Q_o]_{k,m}$$

Formulation of [SP] and [SQ] is discussed in next section

3.4 Multiple branch outage simulation

Consider outage of line 1,2,...,n connected between load buses (a,b), (c,d)..., (y,z).

The changing the injected power (ΔP_I, ΔQ_I) into the buses (a,b), (c,d),....(y,z)
are given by

$$2n\,[\Delta INJECT] = 2n\,[POWER_o] + 2n[\Delta POWER] \qquad (3.4.1)$$

where [ΔINJECT] are the changes in injected powers at 2n buses (POWER$_o$] are the precontingency power flow in lines and (ΔPOWER] are the changes in these power flow due to outages. Above equation applies for both active and reactive power.

The relations between [ΔPOWER] and changes in bus voltage magnitudes and angles are expressed in a general form by the following equations

$$[\Delta POWER] = [\sqrt{VV}]\,[\bar{B}]\,[\Delta X] \qquad (3.4.2)$$

where Δ POWER = ΔP, ΔX = Δθ

$$\bar{B}_{a,b} = [B_3]_{ab} = B_{ab}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$$

or Δ POWER = ΔQ , ΔX = ΔV and

$$\bar{B}_{a,b} = [B_4]_{a,b} = \begin{bmatrix} B_{ab} - 2B'_{ab} & -B_{ab} \\ -B_{ab} & B_{ab} - 2B'_{ab} \end{bmatrix} \qquad (3.4.3)$$

$$= B_{ab}\begin{bmatrix} C & -1 \\ -1 & C \end{bmatrix}$$

where $C = \dfrac{B_{ab} - 2B'_{ab}}{B_{ab}}$

We have

$$[\Delta X] = [S]\left[\frac{-\Delta INJECTED}{V}\right] \qquad (3.4.5)$$

hence

$$[\Delta POWER] = [\sqrt{VV}]\,[\bar{B}]\,[S]\,[V^{-1}][\Delta INJECTED]$$

$$= [\bar{B}][S]\,[\sqrt{VV}]\,[V]^{-1}[\Delta INJECTED]$$

$$= [BS]\,[\Delta INJECTED] \qquad (3.4.6)$$

Since $\sqrt{VV}$ and $[V]^{-1}$ are diagnoe matrices, $[\sqrt{VV}]\,[V]^{-1}$ = [I] (unity matrix)

Since $\sqrt{V_i/V_j} \approx 1$

and $[BS] = [\bar{B}]\,[S]$

Matrix [BS] in formulated row by row as

Row a = [C * row a of [S] - low b * B_{ab} of [S]]

Row b = [C * row b of [S] - row a of [S] * B_{ab}]

Therefore we do not need to store

$[B_3]$, $[B_4]$,[$\sqrt{VV}$] and $[V]^{-1}$ we need only [S]

$[B_3]$ and $[B_4]$ are multiplied implicitly from equation [3.4.1] and [3.4.6]

$$[\Delta \text{ INJECTED}] = \left[[I] - [BS]\right]^{-1}[POWER_o]$$

$$= [BS'] \, [POWER_o]$$

By krowing the 2n columns of sensivity matrix, ΔQ and ΔV, the correction due to line outages, are calculated to obtain V' and Q' for all system buses. Post contignecy line flows are therefore determined

3.5 Simulation of single line outages

Single line branch outage is simulated by open circuiting each branch. Bus and branch variables are modified as the branch is taken out.

Unity active power is injected at the two buses and the angle connecting using original matrix are computed

A factor D2 is calculated as

$$D2 = \left| \delta \theta_{sending} - \delta \theta_{receiving} - \frac{1}{XX} \right|$$

where XX = line reactance of outaged branch

For split condition $D2 \approx 0$.

For split condition topological check is made. The circuit continuity is checked. For the system connected to refrence bus the refrence remains same. for the other system the bus, receiving or sending whicheven is connected, is taken as the second refrence

$$\text{Let} \quad D1 = \frac{-1}{\delta \theta_{sending} - \delta \theta_{receiving} - \frac{1}{XX}}$$

a variable $THCORR_k$ is defined for all buses as

$$THCORR_k = D_1 * \delta \theta_k$$

If receiving and sending bus is one of the PV, PQ and PQRV then active power at receiving bus is assumed -1.0 and power at sending bus as 1.0. For all other cases both active powers are taken as unity.

The voltage correction is calculated.

A variable D3 is defined as

$$D3 = - \frac{1.0}{\delta V_{sending} - \delta V_{receving} - \frac{XX}{z}}$$

Variable $VHCORR_k$ is defined for all buses as

$$VHCORR_k = D3 * \delta V_k$$

Outage solution is carried out in same way except the voltages and angles at different buses are modified as

$$\theta_k = \theta_k + \delta \theta_k + THCORR_k * THIKO$$

$$V_k = V_k + \delta V_k + VHCORR_k * VHIKO$$

where

$$VHIKO = \delta V_{sinding} - \delta V_{receving}$$

$$THIKO = \delta \theta_{sinding} - \delta \theta_{receiving}$$

CHAPTER 4

CHAPTER-4

GRAPHIC IMPLEMENTATION

4.1 System and Software Package:

An IBM - compatable PC-XT was used for the purpose of graphic implementation. Micro-soft Fortran i.e. Fortran-77 was used for writing programs. The system was monochrome with hercules graphic card. The software package used was called as GRAPH-X

4.1.1 Main Features of GRAPH-X

Graph-X can be used for plotting points drawing lines, circles, arcs and reactangles It allows text writing. It allow to switch colour levels from dark to green.

4.1.2 On screen graphic facilities.

Following on screen graphic facilities are available:

INT 10.COM	-	extension to DOS for on screen graphics
FOR 2 GRH,OBJ	-	linkage to FORTRAN
HCG.COM	-	confugration file for graphic card.

4.1.3 Printing facilities

Following print facilities are available:

HARCOPY.COM	-	extension to DOS for screen printing
PRINTER.DEF	-	definition file for IBM or Epson dot matrix printer.

Both INTIO.COM and HARCOPY.COM must be loaded before using graphics.

4.1.4 Coordinate system

Graphic screen may be considered as two dimension array with X being horizontal and Y - being vertical axis. The origin of the axis is the upper left corner. The addressable pixels are:-

X (horizontal)	:	0 to 719
Y (vertical)	:	0 to 347

Any part of figure outside the legal boundary is clipped at the edges.

Any letter corrsing the boundary is suppressed fully.

Height of the pixel is 1.5 times more than its width. To draw figures with same scales on both axises, vertical dimensions are multiplied 2/3.

4.1.5 Screen Colour level

Figures may be drawn green or black in any background, also the figure may be drawn in colour opposite to the background. The colour levels are:

0 - causes the figure to be drawn black

1 - causes the figure to be drawn green

2 - causes pixel to change colour it causes green figures on black colour and black figures on green background

Repeated drawing of a figure with level 2 will cause it to blink.

4.1.6 Text Writing

Text is drawn 9 pixel wide and 14 pixel high. Background and the colour of the text depends on the set level. The character must be inputed in ASCII form. If the character are more they may be defined as double precision or character.

4.1.7 Graphic pages

There are two independent pages in which graphic display is stored . Each graphic page is independent and requires 16 K memory. Both these pages can be used independently for display and writing. Caution has to be taken while using page 0. The first 4K of page 0 is shared by text mode buffer. Any text mode operation will contaminate graphic page D. The run time error are eclipsed when thescreen is in graphic mode.

4.1.8 Using GRAPH-X with fortran

Few precaution are necessary for using GRAPH-X with FORTRAN.

Each function or subroutine of GRAPH-X must be declared as EXTERNAL in the program. Variables should not be passed directly to GRAPH-X routine. Number must be assigned to a variable, which is then passed as an argument to the routine,

4.2 GRAPH-X defined subroutine.

GRAPH-X provide subroutine to set up graphics, draw figures and printhard copy. The subroutines defined by GRAPH-X are described below:

Subroutine ARC

This subroutine draws a quarter circle on the screen give the centre of the arc radius and the guadrant in which the arc is to be drawn

Calling sequence: CALL ARC(X,Y,RADIUS,QUAD)

Arguments:-

X,Y = Cordinates of Centre of the arc.

RADIUS	=	Number of pixel between point X,Y and the arc in X-axis
QUAD	=	Number of quadrant in which arc is to be drawn. Numbers are from 1 through 4 with first quadrant as 1 and increasigg counter clockwise.

Subroutine BLKFIL

Given height, width and the lower left corner, this subroutine draws a solid rectangle.

Calling sequence: CALL BLKFIL(X,Y,WIDTH,HEIGHT)

Arguments:

X,Y,	=	Cordinates of lower left corner
WIDTH	=	width in pixels
HEIGHT	=	height in pixels.

Subroutine CIRC

Given the centre and the radius the subroutine draws a circle

Calling sequence: CALL CIRC(X,Y,RADIUS)

X,Y	=	cordinates of centre point
RADIUS	=	number of pixels between centre and circumfrence on X - axis.

Subroutine CLSCR

This subroutine clears the graphic page currently written into :

Calling sequence: CALL CLRSCR

Subroutine DISP

This subroutine set the page to be displayed on the screen

Calling sequence: CALL DISP(BUFPAGE)

Arguments:

BUFPAGE = 0 or 1 buffer page

Subroutine DLINE

This subroutine draws a line from current sursor position to specified cursor position.

Calling sequence: CALL DLINE (X,Y)

Arguments : X,Y = cordinates of end position

Subroutine FILL

This subroutine fills the area in a convexpolygon by reverse colour, given a point inside the pl polygon

Calling sequence : CALL FILL (X,Y)

Arguments:

X,Y, = Cordinates of a point lying inside the corvex polygon.

Subroutine PUTPT arguments:

This subroutine moves the imagenary cursor to specified position on the screen may be used with DLINE subroutine.

Calling sequence : CALL PUTPT (X,Y)

Arguments:

X,Y = Cordinates of the imaginary cursor

Subroutine GETPT

This subroutine reads the intensity of a given pixel any where within legal cordinates.

Calling sequence : CALL GETPT (X,Y,INTENS)

Arguments:-

X,Y → Cordinate of the point whose intensity is needed

INTENS = Intensity value

0 - Black

1 - Green

Calling sequence : CALL FILL (X,Y)

Arguments:

X,Y, = Cordinates of a point lying inside the corvex polygon.

Subroutine PUTPT arguments:

This subroutine moves the imagenary cursor to specified position on the screen may be used with DLINE subroutine.

Calling sequence : CALL PUTPT (X,Y)

Arguments:

X,Y = Cordinates of the imaginary cursor

Subroutine GETPT

This subroutine reads the intensity of a given pixel any where within legal cordinates.

Calling sequence : CALL GETPT (X,Y),INTENS)

Arguments:-

X,Y → Cordinate of the point whose intensity is needed

INTENS = Intensity value

0 - Black

1 - Green

Subroutine GMODE

This subroutine puts graphic card into graphic mode. It must be called before calling any graphic function or subroutine.

Calling sequence:

CALL GMODE

Subroutine GPAGE

Subroutine determine the page to be written into

Calling sequence: CALL GPAGE (BUFPAGE)

Arguments:

BUFPAGE = Buffer page 0 or 1

Subroutine LEVEL

Subroutines sets the level to be used by subsequent graphic function.

Calling sequence : CALL LEVEL (INTENS)

Arguments:

INTENS = 0 black
1 Green
2 XOR

Subroutine PLOT

Plots a given point on the screen depending on the colour level set.

Calling sequence : CALL PLOT (X,Y)

Arguments:

X,Y = Cordinates of points to be plotted.

Subroutine TMODE

This subroutine puts graphic card into normal text mode:

Calling sequence : CALL TMODE

Subroutine TEXTP

This subroutine writes array of characters at a desired point on screen character are written horizontally. Upto 4 character may be accommodated in single precision, 8 characters in double precision and upto 132 in CHARACTER xn decleration.

Calling sequence : CALL TEXTP (X,Y,LEN,MSG)

Arguments:

X,Y = Cordinate of first letter in the array. The cordinate is of lower left corner.

LEN = Length of character in text string

MSG = Array of character

Subroutine HRDCPY

This subroutine generates hard copy of the graphic page on the dot matrix printer.

Calling sequence : CALL HRDCPY(OPT CHAR)

Arguments:

OPTCHAR = '1' Graphic page 0
'2' Graphic page 1
'3' Graphic page 0 reversevideo
'4' Graphic page 1 severse video
'5' Graphic page 1 and page 0
'6' Graphic page 0 and page 8 reverse video.

4.3 Graphic Display of **outages:**

GRAPH -X subroutines are used to display the results of load flow and outages. Display consists of buses, lines generators, voltage and angles.

In the main program subroutine OUT is called whenever the results of load flow and outlage simulation are to be stored on the disk.

This subroutine also writes the following data in mporary file:

1. System Name
2. Branches or generators involved in outage

3. Bus name, voltage and angle at the bus

4. line data: Sending bus, receiving bus, overload on lives and : live loadings.

This data is read by subroutine ABC. This subroutine generators graphic display.

4.3.1 Subroutines for graphic display of outage:

Subroutine name : ABC

This subroutine reads the data written by subroutine OUT . It draws buses, lines and generators. It also writes heading,angle and voltages at the buses.

Calling sequence : CALL ABC

Calls : : GRAF, HEAD,DBUS, GENER, DLGN, BLINK,TMOD

Variables:

IHX1 IHY1	=	Cordinates of first line of heading cordinates are of lower left corner letter
IHX2,IHY2	=	Cordinates of second line of of heading
TYPE	=	Type of bus 'H' Horinzontal 'V' Vertical

IX1,IY1	=	Centre point of bus.
IW	=	width or height, whichever is greater, of bus.
IVX1,IVY1	=	Cordinate of lower left pointfor writing voltages
INX1, INY1	=	Cordinate of lower left point for writing angles.
IBX1, IBY1	=	Cordinate for writing bus name
(IX2, IY2)	=	
IX3, IY3		
IX4, IY4		four successive point defining bus
IX5, IY5		
IG1	=	Indicator to indicate presence of a generator 0 Generator not present 1 Generator present
IRX1. IRY1	=	Coordinate of centre point of generator.

Subroutine GRAP

This subroutine clears ~~screen~~, puts screen in graphic mode chooses page one for both writing and display.

IX1,IY1	=	Centre point of bus.
IW	=	width or height, whichever is greater, of bus.
IVX1,IVY1	=	Cordinate of lower left pointfor writing voltages
INX1, INY1	=	Cordinate of lower left point for writing angles.
IBX1, IBY1	=	Cordinate for writing bus name
(IX2, IY2)	=	
IX3, IY3		
IX4, IY4		four successive point defining bus
IX5, IY5		
IG1	=	Indicator to indicate presence of a generator 0 Generator not present 1 Generator present
IRX1. IRY1	=	Coordinate of centre point of generator.

Subroutine GRAP

This subroutine clears ~~screen~~screen, puts screen in graphic mode chooses page one for both writing and display.

Calling sequence : CALL GRAF

Subroutine HEAD

This subroutine writes two lines of text showing information about the system. First line displays system name. Second line displays type of outage, generator of line out and drop of power in generator outage.

Calling sequence : CALL HEAD

Variables:-

IHX1, IHY1	=	Cordinates of first line
IHX2, IHY2	=	Cordinates of second line
N	=	system name
B1	=	sending bus
B2	=	Reciving bus
B3	=	drop of power at the generator

Subroutine DBUS

This subroutine draws a bus at a given location of centre point of bus. It displays, name of the bus, angle and voltage at the bus.

Calling sequence:-

CALL DBUS (B,V,A,IX1,IY1,IW, IVX1,IVY1,INX1, INY1,IBX1,IBY1,TYPE)

Arguments:-

B	=	Bus name
V	=	Voltage at bus
A	=	angle at the bus
IX1,IY1	=	position of the centre point at the bus.
IW	=	width of the bus in pixels
IVX1,IVY1	=	position of voltage text
INX1,INY1	=	position of angle text
IBX1,IBY1	=	position for the bus name
Type	=	type of bus 'H' for horizontal. 'V' for vertical

Subroutine DLIN

This subroutine draws a time between two buses.

Calling sequence:-

```
CALL DLIN(IMVA,IX2,IY2,IX3,IY3,IX4.IY4,IX5,IY5)
```

Arguments:-

IMVA	=	switch to indicate the out branch in outage studies 0 - branch out 1 - branch present

IX2, IY2

IX3, IY3 = point describing path between

IX4, IY4 two buses

IX5, IY5

Subroutine BLINK

This subroutine blinks overloaded line.

Calling sequence:- CALL BLINK (IX2,IY2,IY3,IX4,IY4,
IX5,IY5)

Arguments:-

IX2, IY2

IX3, IY3 = define line between two buses

IX4, IY4

IX5, IY5

Subroutine GENER

This subroutine draws a generator given bus location and the location of the centre point of generator.

Ca Calling sequence:- CALL (IX1, IY1, TYPE,IRX1,IRY1)

Arguments:-

IX1,IY1 = cordinates of the centre point of the bus

TYPE	=	type of bus
		'H' Horizontal
		'V' vertical.
IRX1,IRY1	=	coordinates of centre point of the generator.

CHAPTER - 5

STRUCTURE OF PACKAGE

5.1 Objective:

The object of the program is to perform load flow and outage studies using fast decoupled method. It allows the specific and automatic simulation of outages. The load flow techniques is one of the fastest technique available for large system.

5.2 Main Features:

The main features of the program are as follows:

- A system is given a unique name by which it is referred.
- Two or more circuit may be inputed and interconnection defined between them.
- Each bus can be given a unique name by which it referred in all subsequent I/O operation.
- A bus may be voltage bus, load bus, reactive limited bus, voltage limited bus or a remotely controlled bus.

- Branch may be defined between two buses which, may be a line, fixed-transformer, controllable transformer, fixed interconnection, controllable interconnection or a pahse shifter.
- A shunt inductance a at a bus can be defined.
- MVA limits on bus may be defined program will indicate any violation.
- Outages can be simulated automatically or can be specified specially.
- Outage simulated are single line outages, double parallel outages, generator outages
- Split cases may be included or excluded from the study.
- Additional generator data if present may be considered separately.
- Active power may be distributed in the split conditions.
- Voltage and reactive power limits may be removed in the outage studies.

5.3 Structure of Package:

The main program (EX) is used to perform various steps of load flow and outage studies. The main program performs various function such as inputing load flow data, performing factorizing initializing the initial vectors, outputting the result and performing outage studies. Program has one input, one output and five units for temporary storage on disk. Software has been dimensioned for:

100	Nodes
200	Branches
50	Controllable transformers
10	Systems
20	Interconnection
20	Phase-shifters
40	Generators
40	Busbars with reactive limits
40	Busbars with voltage limits

The sub routines with their description is given below:

5.3.1 Program EX

This is the main program which calls various routines to input data, perform, Load flow, and outage studies.

Subroutine Calls: IN1, IN2, FACTOR, INITIL LOAD, OUT, IN3, IN4, AUTSIM, SEPSIM

5.3.2 Subroutine IN1

This subroutine allows user to enter the data interactivity from CRT

Subroutine calls : NONE.

5.3.3 Subroutine IN2

This subroutine reads line and branch data and checks its validity. It also reads systemdata. It sorts the buses alphabatically. It also produces a listing of input data. Also addition branch listing and bus listing consisting of B′ matrix elements can also produced

Calls : ASRT, HEADI, ERROR1, NSRT, BNASR, CHKIN

5.3.4 Subroutine FACTOR

This subroutine factorizes B′ and B″ matries for angle and voltage calculation. It calculates inverse of B′ and B″ matnices so that correction in angle and voltage may be calculated.

Calls: INV1, INV2, INV3, UP1

5.3.5 Subroutine INV1

This subroutine initializes the arrays for the calculation of matrix inverse.

Calls: NONE

5.3.6 Subroutine INV2

This subroutine carries out pivoting modification of the arrays.

Calls: NONE

5.3.7 Subroutine INV3

This subroutine performs back substitution for the calculation of inverse.

Calls: NONE

5.3.8 Subroutine INITIL

This subroutine saves values which are modified by subroutine LOAD so that they may be used later. The saved values are initial active power at swing bus bar, initial setting of tap, initial voltage at remote controlling busbar, initial reactive power generated at controlled bus and voltage at reactive limited buses.

CALLS: NONE

5.3.9 Subroutine LOAD

This subroutine solves the load flow problem. Active and reactive power is calculated, from which voltage and angle corrections are computed updated. Violation of limits on reactive power orvoltages at buses are checked and corrected. Power in interconnection iscalculated. Tap portion is corrected and solution is checked for convergence.

CALLS : REACHK, AVRCHK, INV4, SWICHK, UP2, VACRC, UP2, TAPCHK, VOLCHK

5.3.10 Subroutine INV4

This subroutine finds the angle and voltage correction from the given A′ and B′′ matrix. The result is obtained in same array as the inout vector.

CALLS: NONE

5.3.11 Subroutine VACRC

This subroutine obtains non-constant scalar which multiplies the constant correction vectors of B′ and B′′. These corrections are applied in case of outage studies.

CALLS : NONE

5.3.12 Subroutine SWICHK

This subroutine calculate power in the interconnection and corrects active power generated at swing bus.

CALLS : UP2

5.3.13 Subroutine AVRCHK

This subroutine calculates reactive power generated for nodes for which AVR has not yet operated. It is called when generator data is present.

CALLS : NONE.

5.3.14 Subroutine TAPCHK

This subroutine checks voltage limits on buses controlled by a variable in phase transformer and corrects the tap portion.

CALLS : UP2

5.3.15 Subroutine VOLCHK

This subroutine checks voltage limits on PQ buses and corrects reactive power generated at the same node or correct the voltage at a PV bus depending in the way busbar has been defined as either remote controlled or local controlled.

CALLS : FNSRT, INV4, VACRC, UP1.

5.3.16 Subroutine REACHK

This subroutine checks reactive limit on PV Q buses and correct the voltage magnitude.

CALLS : REACT, UP1, VACRC, FNSRT, INV4

5.3.17 Subroutine REACT

This subroutine calculates reactive power generated in slack, swing, PV and PV with Q limit nodes.

Calls : UP3, UP4

5.3.18 Subroutine OUT

This subroutine prints output and check for over load, busbar limits and system exchange. In calculates reactive power at bus and the powers sent and received at each line. It also checks for losses.

CALLS : REACT, LOCALC, HEAD 2, PCALC, UP3, UP4.

5.3.19 Subroutine LOCALC

Calculates MVA loading of a branch and compare with limits. There are two limits with which the loading is compared.

CALLS : NONE

5.3.20 Subroutine PCALC

This subroutine calculates the common values to lines, in-pahse transformers and phase-shifters, needed for calculation of active and reactive power flow.

Calls : NONE

5.3.21 Subroutine IN3

This subroutine reads selection of studies to be carried out and if indicated reads the generator data for all the studies.

CALLS : INGEN, ERROR2.

5.3.22 Subroutine INGEN

This subroutine reads generator data as indicated in subroutine IN3.

Calls : ERROR2, BNASR, ERROR2

5.3.23 Subroutine IN4

This subroutine reads parameters for outage study. Intialize the voltages and powers by calling subroutine INITIL. It saves the result of base case voltages, angle, reactive power and active power.

CALLS : INT2, INITIL

5.3.24 Subroutine INT2

This subroutine refactorize B'' matrix in case of generator data.

CALLS : INV1, INV2, IN3, INV4, UP1, ERROR2

5.3.25 Subroutine AUTSIM

This subroutine simulates outages. The outage that may be simulated are single branch outage, double parallel branch outage, half loss generation and full loss generation.

CALLS : RESB, INT3, OUT, VCHIK, LOAD, GSIM, BSIM, RESG, UP3

5.3.26 Subroutine VCHK

This subroutine checks the change in voltage at a bus caused by outage with the permissible drop. If drop exceeds the permissible value it is printed.

CALLS : HEAD3

5.3.27 Subroutine INT3

This subroutine initialize PG, QG, V, TH and Y matrix for change in tap for controllable transformer.

CALLS : UP2

5.3.28 Subroutine BSIM

This subroutine simulates branch outages. Outaged branch parameter are changed. Split condition is checked, correction factor for voltage and angles are calculated.

CALLS : SPLCHK, INV4, BNSR, ERROR2

5.3.29 Subroutine SPLCHK

This subroutine handles split cases. The circuit is checked topologically for split condition. Power in outaged branch iscalculated and B' and B'' refactorize.

CALLS : UP1, FACTOR, GRES

5.3.30 Subroutine GRES

This subroutine redistributes active power accordingly to either governor droop or according to spare capacity.

CALLS : NONE

5.3.31 Subroutine GSIM

This subroutine simulates generator outages. Qlimits of generator is reduced and the reactive power is also reduced.And fictious Q limits are assigned if there is no Q limits.

CALLS : GRES.

5.3.32 Subroutine RESG

This subroutine resaturate all the values modified in routine GSIM

CALLS : NONE

5.3.33 Subroutine RESB

Resaturation of branch values modified in routine BSIM subroutine is performed in this subroutine.

CALLS : UP4

5.3.34 Subroutine SEPSIM

This subroutine simulates specified outages.

CALLS : GRES, RESB, LOAD, ERROR2, INT3, BNASR, OUT, GSIM, JPSR, BSIM, RESG.

5.3.35 Subroutine HEAD1

Prints titles for the printing of input data in the load flow study.

CALLS : NONE

5.3.36 Subroutine HEAD2

Prints titles for printing of output data in load flow study.

CALLS : None

5.3.37 Subroutine HEAD3

Prints heading for the voltage difference in a line during outage.

CALLS : NONE.

5.3.38 Subroutine ERROR1

This subroutine prints error message in load flow study.

CALLS None.

5.3.39 Subroutine ERROR2

This subroutine prints error message in the outage studies.

CALLS : NONE

5.3.40 Subroutine UP1 (L,I,K,N)

Obtains sending number I, receiveing number K of a branch packed in JUMP(L) also entry order of branch packed in NBRANC (L).

CALLS : NONE

5.3.41 Subroutine UP2 (J, I,K)

This subroutine obtains sending bus number I and receiving bus number K of branch packed in J.

CALLS : NONE

5.3.42 Subroutine UP3(L,T,K,N,NC)

This subroutine obtains sending number I, receiving number K, branch entry order N and circuit number NC fromJUMP(L) and NBRANC (L)

5.3.43 Subroutine UP4 (J,I,K,NC)

This subroutine obtains sending bus number I and receiving bus number K of branch packed in J and circuit number NC is also obtained.

CALLS : NONE.

5.3.44 Subroutine CHKIN (CNOM1,CN1,INI,IFIN,K)

This subroutine checks if name CN1 is already in table CNOM1.

INI, IFIN = limits of search.

K = if not in table

CALLS : NONE

5.3.45 Subroutine ASRT (CNOM1, ITAB, INI,IFIN)

This subroutine sorts array CNOM1 alphabatically. ITAB is parallel array arranged is same order as CNOM1.

INI, IFIN = limits of CNOM1 between which sorting takes place.

CALLS : NONE

5.3.46 Subroutine NSRT (SSOR, ITAB, INI, IFIN)

Numerical sort of array JSOR is performed. ITAB is parallel array to JSOR

INI, IFIN = limits of JSOR between which sorting take place.

5.3.47 Subroutine BNNSR (N2,NI, J)

Binary search for numerical arrays are performed. Branch entry order is N2, retruning position N1, J is the array selected.

CALLS : NONE

5.3.48 Subroutine BNASR (CNOM1, CN1, JNI, IFJN1)

Binary search of name CN1 in table CNOM1

INI, IFIN = limits between which search take place.

K = portion of name CN1 in table CNOM1

CALLS : NONE

5.3.49 Subroutine FNSRT (L,L10)

Searches in JUMP the first element in which busbar number L appears and return the position in L10.

5.3.50 Subroutine JPSR (III, KKK, NSEC,LSE1)

The subroutine searchs element III, KKK in circuit NSEC in array JUMP.LSE1 is the portion in jump

54 Variables used in the Packag

5.4.1 Variables dimensiond for buses

IFLAG	=	Flag indicator
ANOM1	=	Bus Name
PG	=	Active power generated
QG	=	Reactive power generated
PL	=	Active power load
QL	=	Reactive power load
V	=	Voltage magnitude
BK	=	Shunt susceptance
BKK	=	Capacitor and shunt susceptance
YSR	=	Real part diagnol of admittance matrix
YSI	=	Imaginary part diagnol of admittance matrix
PMM	=	working array = short circuit rating
TH	=	Voltage angle
NOZE , LCOL, LCOLB, NSEQ	=	used in factorization routine
THCORR	=	Vector correction for B'
VHCORR	=	Vector correction for B''
PGSTO	=	PG base case load flow solution

VHSTO = Voltage magnitude base case load flow solution

THSTO = Voltage angle base solution

IAUX = Auxillary storage

5.4.2 Variable dimensioned for lines

GL = Inverse of reactance

YR = Real part of mutual admittance

YT = Imaginary part of mutual admittance

J01L2 = 10000 * MVA Limit 1 + MVA limit2

JUMP = 1000000 * sending bus bar + 1000 * Receiving bus bar + Number of circuit

SSNL = Total line suseptance/2 ortapsetting

KLS, GLS, ILS, used in factorization routine

5.4.3 Variable dimensioned for factorization subroutine

Dimension = 2 x dimension of branchee, + dimension of nodes

DE, DB, ITAGB, LNXT, LNXTB

5.4.4 Variables dimensioned for phase shifter

TAPB	=	Value of quadnature tap
YRK1	=	Imag part of mutual admitance - TAPB
YIK1	=	Real part of mutual admittance- TAPB
NLP	=	Array relating JPIKL, TAPB, YRK1, YIK1 to branch entry order
JPIKL	=	as JUMP

5.4.5 Variables dimensioned for controllable transformer

TAPA	=	present value of tap
BLMT	=	Lower limit of tap
STEP	=	increment of tap per step
TLMT	=	upper limit of tap
NLT	=	array relating TAPA, BLMT, STEP, TLMT, VSPEC, JTIKL, TVSPEC to branch entry order
JTIKL	=	as JUMP
VSPEC		specified voltage magnitude
TVSPEC	=	Tolerance specified in voltage magnitude
YRT	=	Real part of mutual admittance without tap
YIT	=	Imaginary part of mutual admittance without tap
TAP	=	Initial setting of tap

5.4.6 Variables dimensioned for controllable phase-shifter

These arrays are provided for future implementation but are not used in the program

BLMB, STEB, TLMB, PPSPC, TPPSPC

5.4.7 Vriables dimensioned for voltage limited buses

VMIN	=	Minimum voltage limit
VMAX	=	Maximum voltage limit
ITABL	=	array relating VMIN, VMAX to controlling bus bar
ITAB4	=	Array relating VMIN, VMAX to controlling bus bar
ANOMR1	=	Name of controlling bus bar
VS	=	Initial voltage at remote controlling bus bar.
QGS	=	Initial reactive power generated at controlled bus bar
SQ	=	sensivity factor for PQ V or PQ RV bus bar

5.4.8 Variables dimentioned for system

NSISV	=	number of the system
INIS	=	beginning of the system in array ANOM1
IFINS	=	final of system in array ANOM1

NBXSTS	=	number of bus bars of the system
NRXSTS	=	number of branches of the system
PSPEC	=	active power exchanged for the system
TTSPEC	=	tolarance in exchange specified for the system
CNOMS	=	Name of the system
PGS	=	Initial active power at swing bus

5.4.9 Integer variables

JIN	=	Input unit number
JOUT	=	Output unit numver
JTAPE		
JTEPE		
JITPE	=	Workfiles
JTOPE		
JTUPE		
NODE	=	1 Reference bus
		2 PV bus
		3 PQ bus
		4 swing bus
		5 PV with Q limits
		6 PQ with V limits (local source)
		7 PQ with V limits (Remote source)

NBRANC	=	1 Line
		2 Fixed Transformer
		3 Controllable Transformer
		4 Fixed interconnection
		5 Controllable Interconnection
		6 Fixed phase shifter
NK	=	Total number of nodes
NL	=	Total number of Branches
NK5	=	Number of PVQ buses
NUSIS	=	Number of system
NOTIV	=	Number of controllable intercomm - ection
NOVR	=	Number of PQV and PQRV buses
NOTV	=	Number of controllable
NPHASE	=	Number of phase shifters
NL4	=	Number of fixed interconnection
NURUTA	=	1 outage study

5.4.10 Indicator variables

KJLIT	=	Number of irterations of which adjustments are automatically applied.
KILL	=	switch to indicate error
IAREA	=	Indicators of Area inter changes

IIREF	=	Second reference bar
LFMAX	=	2 - dimension of branches - dimension of nodes
ITER	=	no of iterations
MAXIT	=	Maximum number of iteration
IDIVE	=	Indicator of divergence
ICP	=	Switch to indicate Area interchanges is required
ICQ1	=	switch to indicate nat voltage limits adjustment is required
ICQ 2	=	switch to indicate that on line control tap adjustment is required
ICQ3	=	Switch to indicate that reactive limit adjustment is required
KP1	=	switch to indicate that active power has been modified in swing bus
KQ 1	=	switch to indicate that PQV and PQRV buses have been modified
KQ3	=	switch to indicate that voltage of PVQ bus has been modified
KQ4	=	switch to indicate that AVR has been modified
ICGEN	=	switch indicate there is generator data

IOUT	=	switch to indicate that load flow routine is used for outage simulation
TOUTI	=	Switch to indicate wether correction is required for 1-B and B 2. B only 3. B only 4. None.
DCONVA	=	Specified initial convergence to introduce adjustments.
IVIO	=	Indicator that there is something wrong in load flow solution
IJOL1	=	Indicator used to read only once in routine LOCALC the array JOIL1L2 from JTEPG
IOU	=	numbers of branch outage
IOUL1	=	number of load outages
IOUG	=	number of generator outages
IGEN	=	number of generators used for outage studies
NGEN	=	Total number of generators
IIDI2	=	switch to define redistribution accordance to governor drop
IIDI3	=	Switch to indicate redistribution according to spare cpacity.
IPARAL	=	Switch = 0 when automatic calculation of double parallel outages
IOFF	=	Indicator of something wrong in simulation.

5.4.11 Variables dimensioned for Q limited buses and generator

WMIN	=	minimum reactive power generation
QMAX	=	maximum reactive power generation
ITAB5	=	Array relating Q MAX, QMIN to alphabaticalorder
VSS	=	Initial voltage at PVQ buses
SQQ	=	Sensivity factor for reactive limits

5.4.12 Variables dimensioned for generator

NDOEG	=	10 - Number of bus bars + Node type
EG	=	Voltage behind synchronous reactance
EGG	=	Not used
BBB	=	inverse synchronous reactance
ESTA	=	Governor droop or 1/spare capacity
FREVA	=	No load frequency
JPMIMA	=	10000 - PMIN + PMAX
TA	=	Minimum reactive limit of generator outaged
TC	=	Maximum reactive limit of generator outaged
JTA		10000 - Minimum active power + maximum active power of Gen.out

5.5 Input Structure

For the ease of reading data from the card reader the data has been described as 80 coloumn wide. The data is formatted.

The first two data card read eight character ASCII control variables. Total number of times program is to be excuted is also defined. The value of control when found in the first 8 coloumns of a data card signifies either end of certain type of data or start of a new data.

The control variables in 1st card are:

Coloumn	Format	Variable	discription.
1	A8	ATIT	Start of system data
9	A8	AMIS	Start of commend cards
17	A8	ASIS	Start reading system data
25	A8	ABAR	Start reading bus data
33	A8	ALIN	Start of line data
41	A8	AINT	start of interconnection data
49	A8	ACAM	Go for outage study
57	A8	AFIN	Finish study or finish interconnection data
65	A8	ASTUDY	Read if generator data present
73	A8	AGENER	Start of outage data

Vwriables defined in second card are:

Coloumn	Format	Variable	Description
1	A8	AOUPAR	Start of outage data
33	A8	AFFIN	Start of second execution
72	I8	ITOTI	Total number of exeutions.

Various types of records in sequence are:

(a) System record

This is a two card record. The record begins with control variable ATIT on the first card

Coloumn	Format	Variable	Description
1	10A8/6A8	ANOM	system heading
49	I3	NEST	Study
52	I3	NSCAO	Case
55	F53	DCONV	Maximum MW/MVAR mismatch
60	I4	MAXIT	Maximum number of iteration
64	Fu4	BASE	MVA Base
68	10I1	IOPT	Ten option for printing
78	F3.0	P	Convergence factor

5.4.11 Variables dimensioned for Q limited buses and generator

WMIN	=	minimum reactive power generation
QMAX	=	maximum reactive power generation
ITAB5	=	Array relating Q MAX, QMIN to alphabaticalorder
VSS	=	Initial voltage at PVQ buses
SQQ	=	Sensivity factor for reactive limits

5.4.12 Variables dimensioned for generator

NDOEG	=	10 - Number of bus bars + Node type
EG	=	Voltage behind synchronous reactance
EGG	=	Not used
BBB	=	inverse synchronous reactance
ESTA	=	Governor droop or 1/spare capacity
FREVA	=	No load frequency
JPMIMA	=	10000 - PMIN + PMAX
TA	=	Minimum reactive limit of generator outaged
TC	=	Maximum reactive limit of generator outaged
JTA		10000 - Minimum active power + maximum active power of Gen.out

TX	=	Governer droop or 1/spare capacity
TD	=	not used
TE	=	inverse of synchronous reactance of generator outage
TF	=	Voltage behind synchronous reactance of generator outaged
JAUX	=	1000* Generator entry number + Q limit entry number.
JEUX	=	1000 * Fictitious Q limit entry order + generator entry number.
TJ	=	minimum voltage of controlled bus bar
JK	=	Maximum vlotage of controlled bus bar.
ITC	=	Pointer to entry order of voltage limits.

5.4.13 Variables diemnsioned for controllable interconnection

JIIKL	=	as JUMP
ITAB3	=	Arrary relating interconnection to entry order
ITAB6	=	100 * sending system + recieving system

(b) Comment cards

These cards are optional. It begins control and variable AMIS. Upto 10 comments cards of 80 column wide may be accomadated.

(c) System data

For each new system the circuit data is read. It begins with control variable ASIS. The variable read are:

Coloumn	Format	Variable	Description
1	A8	AREFER	Refrence bus name
9	I4	NSIS	System number
13	F 5.0	PS	active power exchange
18	F3.0	TPS	Tolerance in active power exchange
21	7A8	ANOM	System name

(d) Bus data

The bus data begins with variable ABAR The data describes and selects the type of bus. The records repeated until all buses have been described. The variable are:

Column	Format	Variable	Description
1	A8	CONTROL	Bus name
9	F6.4	VK	Voltage at the bus
15	F6.1	PGK	Active power generated
21	F6.1	PLK	Reactive power generated
27	F6.1	PLK	Active power load
33	F6.1	QLK	Reactive power load
39	F6.1	QMINK	Minimum reactive power generated
45	P6.1	QMAXK	Maximum reactive power generated
51	F6.4	VMINK	Minimum voltage limit
57	F6.4	VMAXK	Maximum voltage limit
63	F5.0	VBASEK	Base voltage
68	A8	CNAMEK	Controlling bus
76	F5.0	RATI	Short circuit rating

(e) Line data

This data begins with variable AL in .It may repeated till all the lines have been described. This data ends with ACAT or AFIN.

Column	Format	Variable	Description
1	A8	CONTROL	Sending bus
9	A8	CNAMEK	Receiving bus
17	F7.5	RR	Line resistance in P.U.
24	F7.5	XX	Line reactance in P.U.
31	F7.5	SS	Total susepbance in P.U.
38	I1	INDK	Indicated for presence of phase shifter
39	F5.2	TAP	./. initial tap
44	F5.2	BB	./. lower tap
49	F 4.2	ST	./. increment tap
53	F5.2	TT	./. upper tap
64	F6.4	TS	tolerance specification
70	I5	LF1	lower MVA rating
75	I5	LF2	upper MVA rating
80	I1	NC	Area number

If INDIC = 1 then next card contains following data

Coloumn	Format	Variable	Description
1	F5.2	TEP	Value of gued tap
6	F5.2	BB	./. Lower tap
10	F4.2	ST	./. increment tap
15	F5.2	TT	./. upper tap
19	F6.1	VPS	specified voltage
25	F6.1	TS	Tolerance specification

(f) Inter connection data

This variable begins where AINT and ends with variable AFIN. The variables read are:

Column	Format	Variable	Description
1	A8	CONTROL	Sending bus
9	A8	CONTRK	Receiving bus
17	F7.5	RR	Line resistance in P.U.
24	F.7.5	XX	Line reactance in P.U.
31	F7.5	SS	Total susptance in P.U.
38	I2	NS1	System sending No.
40	I2	NS2	System receiving No.
70	I5	LF1	Lower MVA limit
85	I5	LF2	Upper MVA limit
80	I1	NC	Area number

(f) Inter connection data

This variable begins where AINT and ends with variable AFIN. The variables read are:

Column	Format	Variable	Description
1	A8	CONTROL	Sending bus
9	A8	CONTRK	Receiving bus
17	F7.5	RR	Line resistance in P.U.
24	F.7.5	XX	Line reactance in P.U.
31	F7.5	SS	Total susptance in P.U.
38	I2	NS1	System sending No.
40	I2	NS2	System receiving No.
70	I5	LF1	Lower MVA limit
75	I5	LF2	Upper MVA limit
80	I1	NC	Area number

(g) Generator input data

This data begins with control card ASTUDY. The variables read are:

Column	Format	Variable	Description
1	I2	ISTUD1	1 for no generator data
3	I2	ISTUD2	0 for no generator data
5	I2	ISTUD3	0 for no generator data
7	I2	ICGEN	0 for no generator data
9	F5.2	FIPER	Frequency drop behind generator.

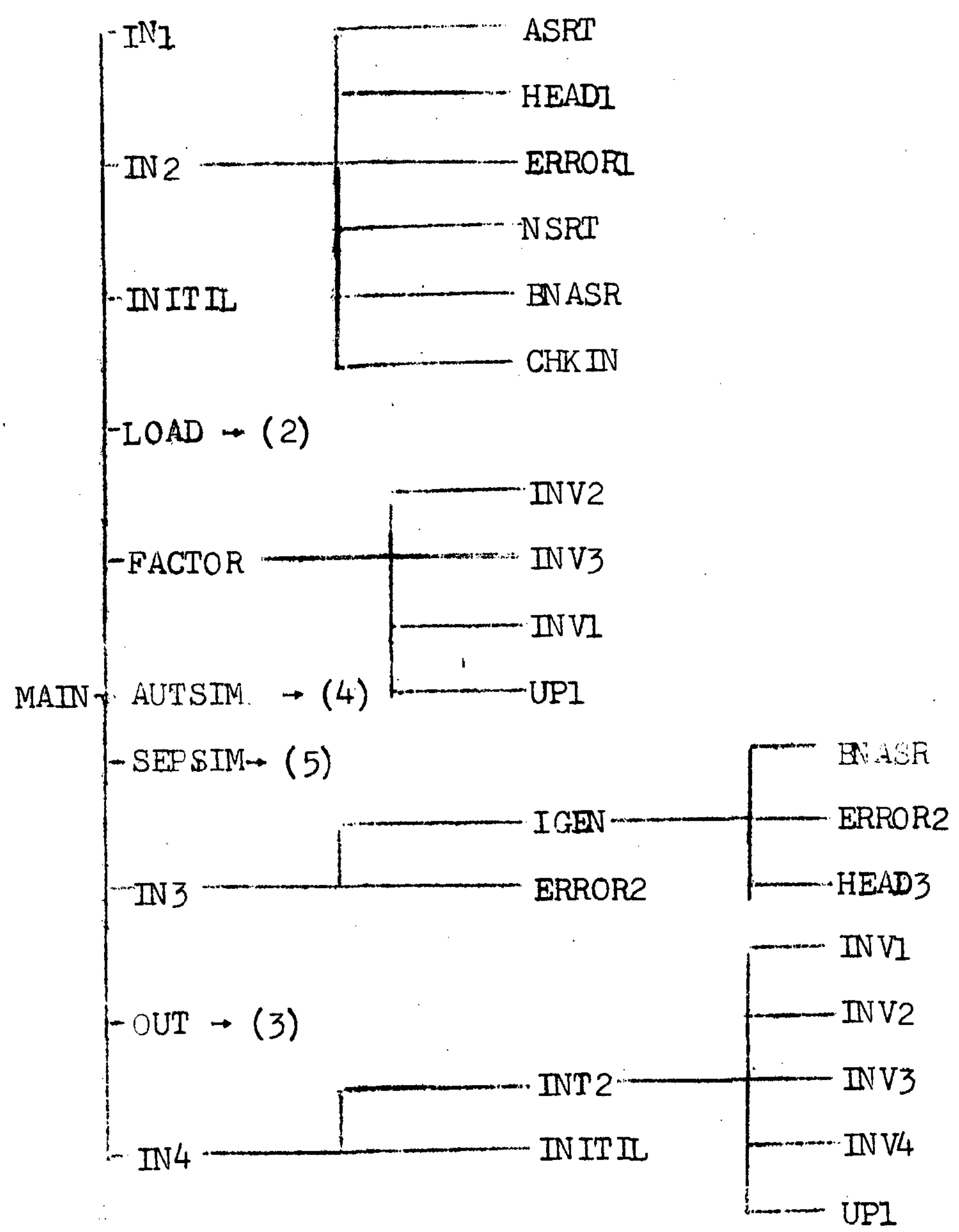
(h) Outage data

This data instructs the type of outage studies to be carried out. The data begins with control card AOUPAR. The vatiables read are:

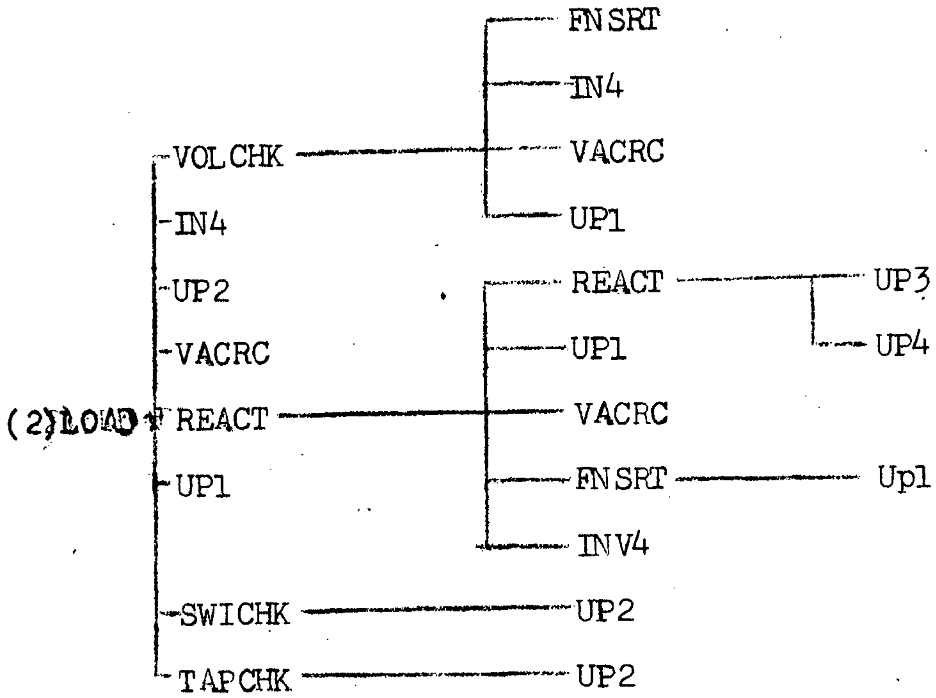
Column	Format	Variable	Description
1	I1	IL1	Single line outage
2	I1	IL2	Double parallel outage
3	I1	IL3	Specified line outage
4	I1	IG1	Half loss generation
5	I1	IG2	Full loss generation
6	I1	IG3	Sepcified calculation
7	I1	ICP	Area interchanges
8	I1	ICP2	Redistribution of power on split condition
9	I1	ICQ1	On line tap changing
10	I1	ICQ2	V limits on PQ V or PQRV buses
11	I1	ICQ3	Q limits on PVQ buses
12	I1	ISPLIT	Consideration of split
25	F4.2	VDROP1	Single outage voltage drop limit
33	F4.2	VDROP2	Double outage voltage drop limit
33	7I1	IOPT	Options for printing (option 4- option 10)

APPENDIX A.1

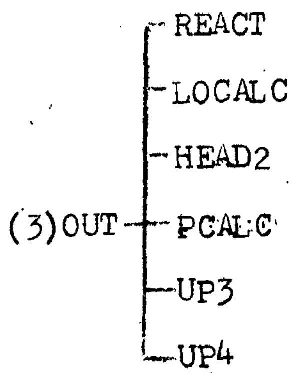
Tree for subroutines called in the outage studies



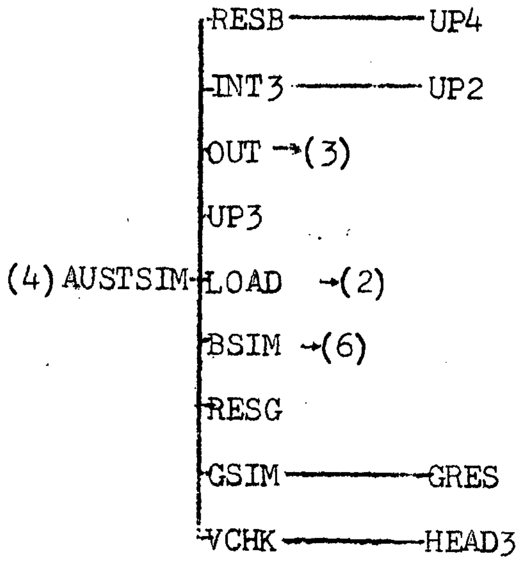
Tree for program MAIN



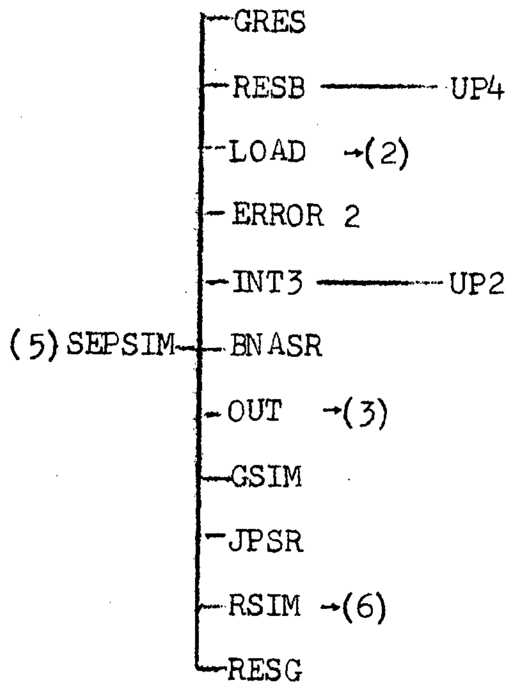
Tree for subroutine LOAD



Tree for subroutine OUT

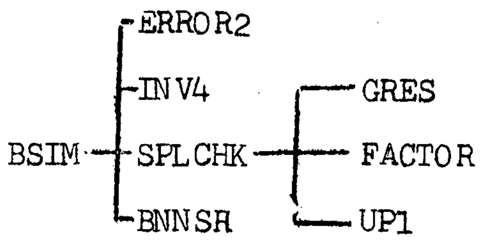


Tree for subroutine AUSTSIM



Tree for subroutine SEPSIM

(6)



Tree for subroutine BSIM

*** S Y S T E M 1 ***

BUS DATA

IN (P.U.)

N A M E	VOLTAGE	GENERATION REAL	GENERATION REACTIV	L O A D REAL	L O A D REACTIVE	REATIVE LIMITS MIN.	REATIVE LIMITS MAX.	VOLTAGE LIMITS MIN.	VOLTAGE LIMITS MAX.	CONTROL BUS
NORTH	1.0600	.000	.000	.000	.000					
ELM		.000	.000	.600	.100					
LAKE		.000	.000	.450	.150					
MAIN		.000	.000	.400	.450					
SOUTH		.400	.300	.200	.100					

*** S Y S T E M 1 ***

BRANCH DATA

SENDING B U S	RECIVING B U S	N	RESIST. P.U.	REACTANCE P.U.	TOTAL SUSC. P.U.	INITIAL TAP	LOWER TAP P.U.	INCR.	UPPER TAP P.U.	VOLTAGE TOLER. SPECIFIED P.U.	POWER LIM 1 MVA	POWER LIM 2 MVA
NORTH	SOUTH	1	.02000	.06000	.06000						100	100
NORTH	LAKE	1	.08000	.24000	.05000						100	100
SOUTH	LAKE	1	.06000	.18000	.04000						100	100
SOUTH	MAIN	1	.06000	.18000	.04000						100	100
SOUTH	ELM	1	.04000	.12000	.03000						100	100
LAKE	MAIN	1	.01000	.03000	.02000						100	100
MAIN	ELM	1	.08000	.24000	.05000						100	100

*** S Y S T E M 1 ***

BUSBAR LOADINGS

N A M E	TYPE	VOLTAGE MAGNITUDE (P.U.)	VOLTAGE ANGLE (DEG)	GENERATION ACTIVE (MW)	GENERATION REACTIV (MVAR)	LOAD ACTIVE (MW)	LOAD REACTIV (MVAR)	SHUNT REACTIV (MVAR)
NORTH	REF.	1.0600	.00	130.4	36.4	.0	.0	.0
ELM	PQ	.9925	-5.92	.0	.0	60.0	10.0	.0
LAKE	PQ	.9906	-4.57	.0	.0	45.0	15.0	.0
MAIN	PQ	.9833	-4.79	.0	.0	40.0	45.0	.0
SOUTH	PQ	1.0304	-2.56	40.0	30.0	20.0	10.0	.0
T O T A L				170.4	66.4	165.0	80.0	.0

*** S Y S T E M 1 ***

BRANCH LOADINGS

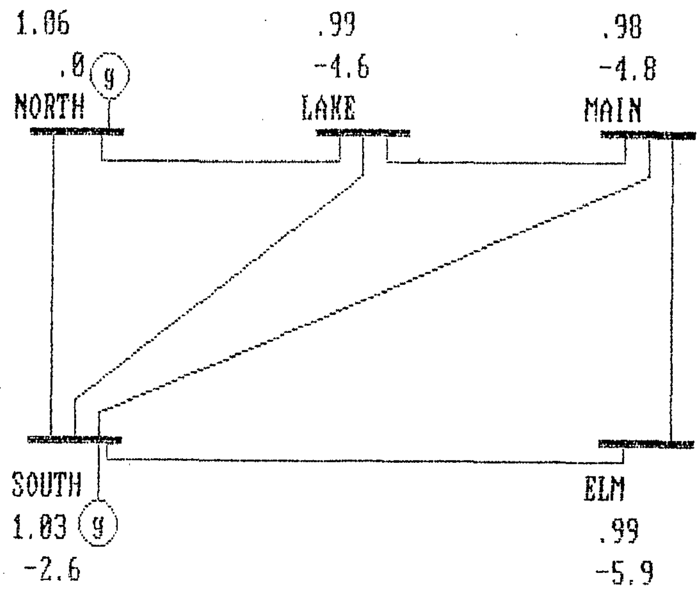
SENDING BUS	RECEIVING BUS	N.	POWER SENT ACTIVE (MW)	POWER SENT REACTIV (MVAR)	POWER RECIEVED ACTIVE (MW)	POWER RECIEVED REACTIV (MVAR)	LINE LOSSES ACTIVE (MW)	LINE LOSSES REACT. (MVAR)	LINE LOSSES PERCEN-NTAGE	M V A ACTUAL MVA	M V A LIM1 MVA	M V A LIM2 MVA	OVER-LOAD	TAP SETT-ING (P.U.)
NORTH	LAKE	1	41.0	15.6	39.5	16.5	1.44	-.96		43	100	100		
MAIN	ELM	1	6.1	-8.1	6.0	-3.4	.06	-4.71		10	100	100		
LAKE	MAIN	1	18.9	17.0	18.8	18.7	.07	-1.74		26	100	100		
NORTH	SOUTH	1	89.4	20.9	87.9	22.8	1.53	-1.97		91	100	100		
SOUTH	ELM	1	55.2	14.1	54.0	13.4	1.24	.65		56	100	100		
SOUTH	LAKE	1	24.8	12.8	24.3	15.4	.47	-2.67		28	100	100		
SOUTH	MAIN	1	28.0	16.0	27.3	18.2	.63	-2.18		32	100	100		

SYSTEM LOSSES

	ACTIVE MW	REACTIVE MVAR
SERIES	5.43	16.30
SHUNT		-29.86
TOTAL	5.43	-13.56

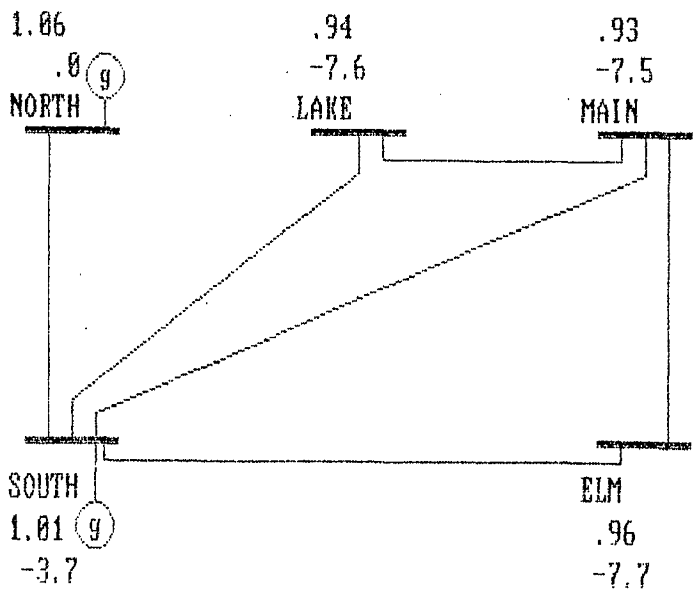
SYSTEM 1

LOAD FLOW STUDY



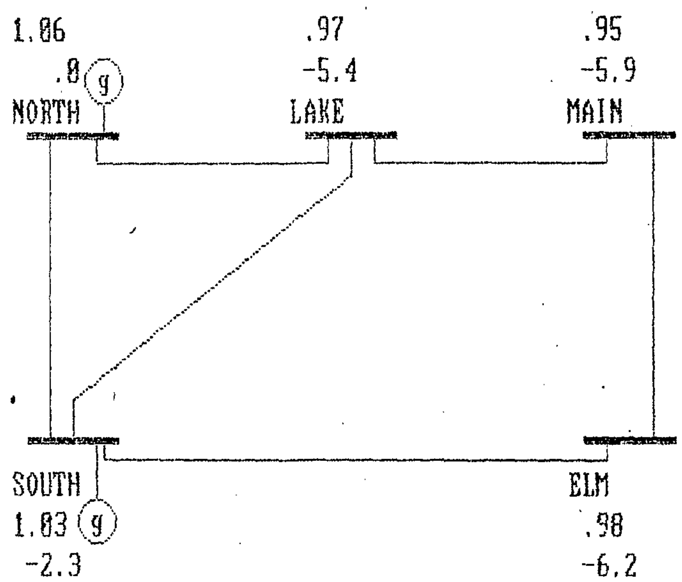
SYSTEM 1

OUTAGE STUDY BRANCH OUT LAKE NORTH



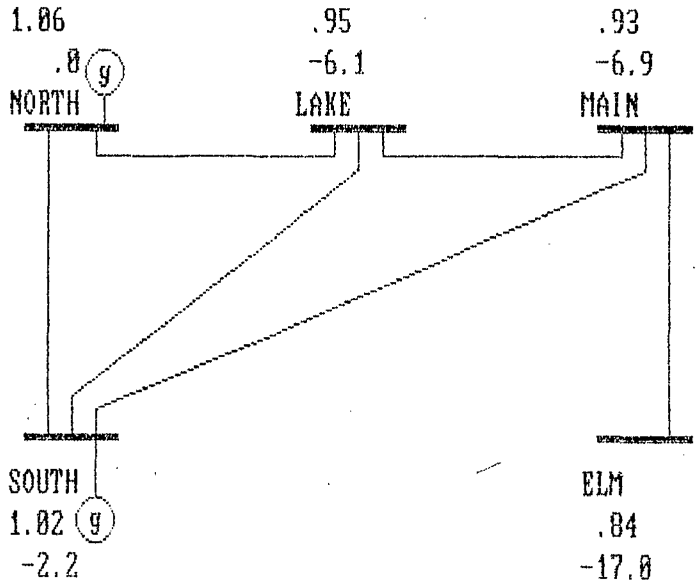
SYSTEM 1

OUTAGE STUDY BRANCH OUT SOUTH MAIN



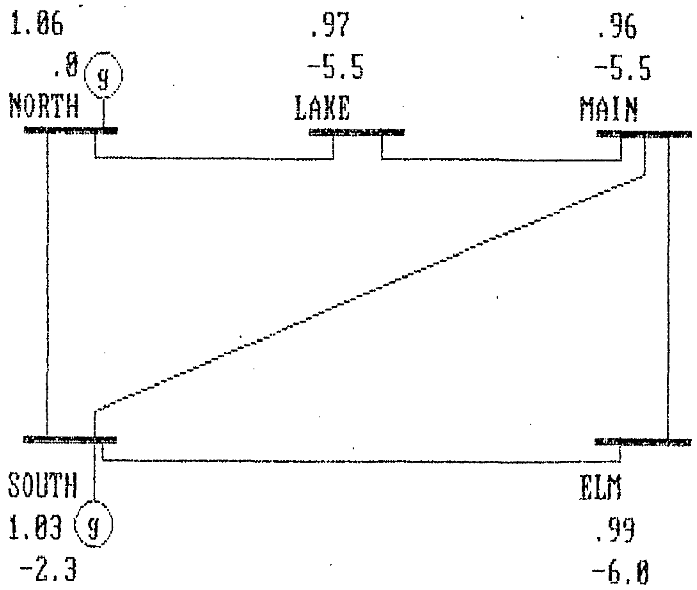
SYSTEM 1

OUTAGE STUDY BRANCH OUT SOUTH ELM



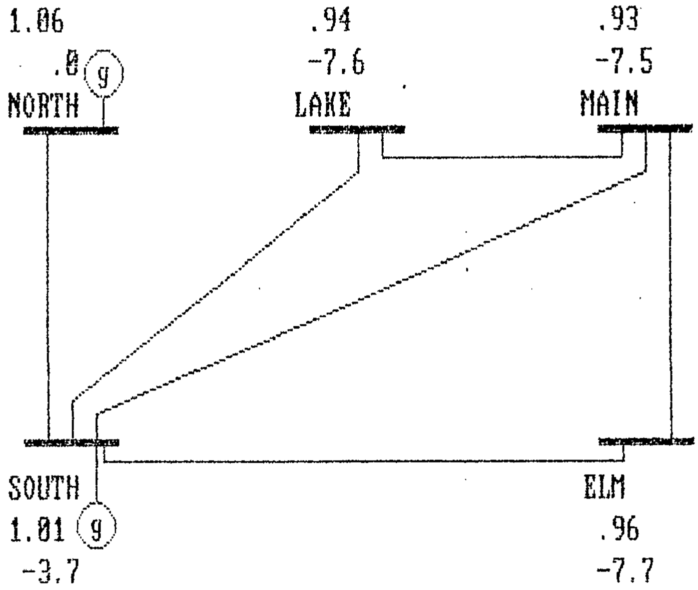
SYSTEM 1

OUTAGE STUDY BRANCH OUT SOUTH LAKE



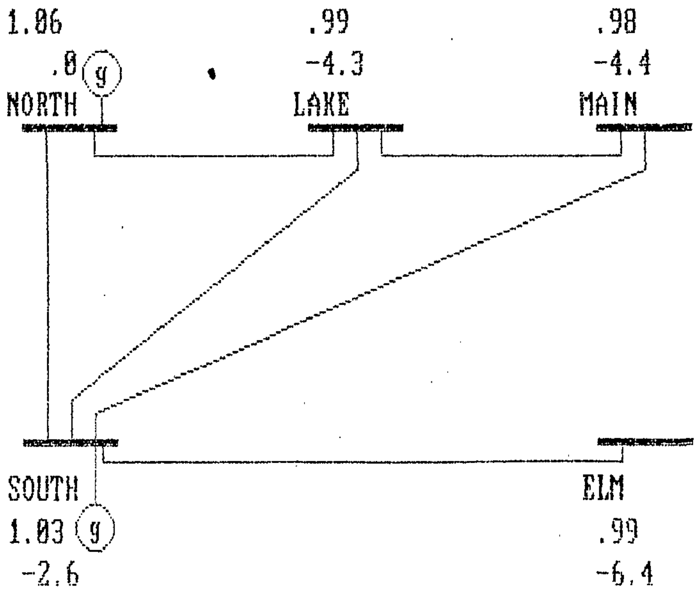
SYSTEM 1

OUTAGE STUDY BRANCH OUT LAKE NORTH



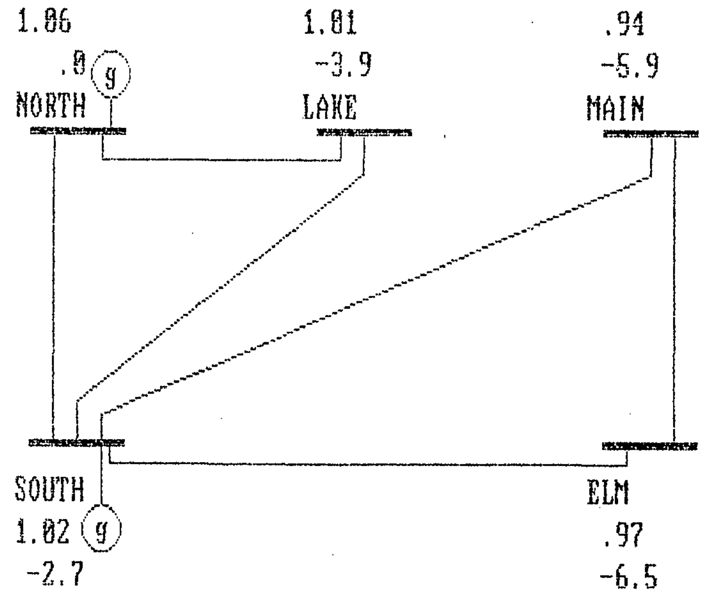
SYSTEM 1

OUTAGE STUDY BRANCH OUT MAIN ELM



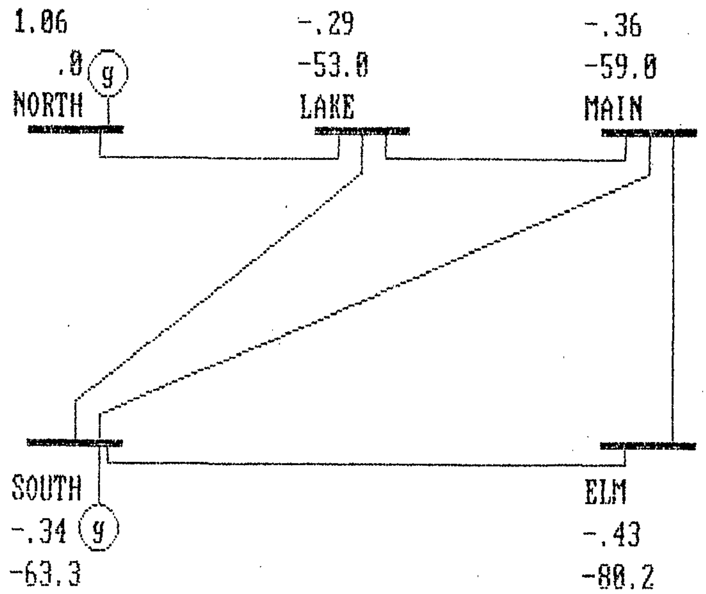
S Y S T E M 1

OUTAGE STUDY BRANCH OUT MAIN LAKE



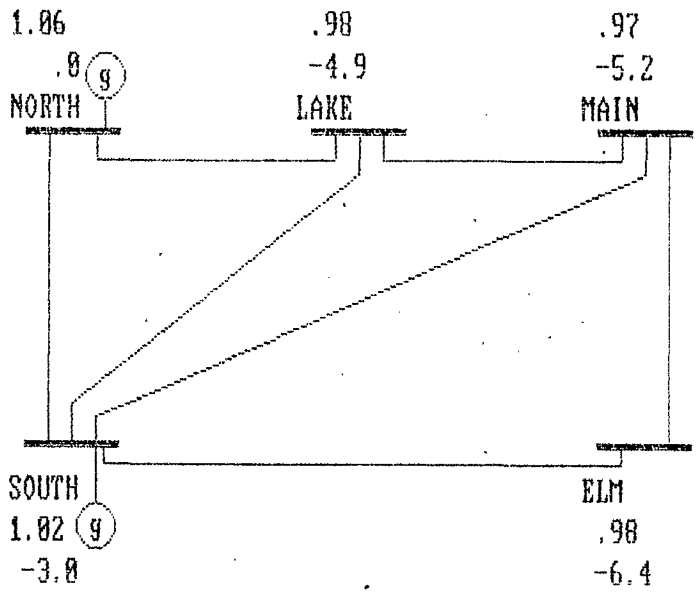
S Y S T E M 1

OUTAGE STUDY BRANCH OUT SOUTH NORTH



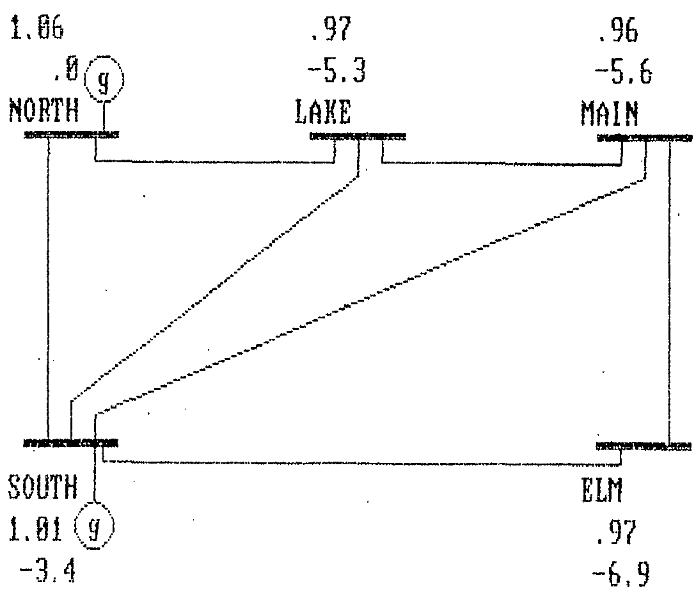
S Y S T E M   1

OUTAGE STUDY GENERATOR OUT SOUTH   DROP= 20.0 M.W.



S Y S T E M   1

OUTAGE STUDY GENERATOR OUT SOUTH   DROP= 40.0 M.W.



*** IEEE-14 BUS ***

BUS DATA

IN (P.U.)

N A M E	VOLTAGE	GENERATION REAL	GENERATION REACTIV	L O A D REAL	L O A D REACTIVE	REATIVE LIMITS MIN.	REATIVE LIMITS MAX.	VOLTAGE LIMITS MIN.	VOLTAGE LIMITS MAX.	CONTROL BUS
FOURTEEN	1.0600	.000	.000	.000	.000					
ONE		.000	.000	.149	.050					
TEN	1.0900	.000	.000	.000	.000	-.060	.240			
TWO		.000	.000	.135	.058					
SIX		.000	.000	.035	.018					
NINE		.000	.000	.295	.166					
FIVE		.000	.000	.076	.016					
FOUR		.000	.000	.478	-.039					
THREE		.000	.000	.061	.016					
SEVEN		.000	.000	.000	.000					
EIGHT		.000	.000	.090	.058					
ELEVEN	1.0700	.000	.000	.112	.075	-.060	.240			
TWELEVE	1.0100	.000	.000	.942	.190	.000	.400			
THIRTEEN	1.0450	.400	.000	.217	.127	-.400	.500			

*** IEEE-14 BUS ***

BRANCH DATA

SENDING BUS	RECIVING BUS	N	RESIST. P.U.	REACTANCE P.U.	TOTAL SUSC. P.U.	INITIAL TAP	LOWER TAP P.U.	INCR.	UPPER TAP P.U.	VOLTAGE TOLER. SPECIFIED P.U.	POWER LIM 1 MVA	POWER LIM 2 MVA
FOURTEEN	THIRTEEN	1	.01938	.05917	.05280						200	200
FOURTEEN	FIVE	1	.05403	.22304	.04920						100	100
THIRTEEN	TWELEVE	1	.04699	.19797	.04380						100	100
THIRTEEN	FOUR	1	.05811	.17632	.03740						100	100
THIRTEEN	FIVE	1	.05695	.17388	.03400						100	100
TWELEVE	FOUR	1	.06701	.17103	.03460						100	100
FOUR	FIVE	1	.01335	.04211	.01280						100	100
ELEVEN	SIX	1	.09498	.19890	.00000						100	100
ELEVEN	THREE	1	.12291	.25581	.00000						100	100
ELEVEN	TWO	1	.06615	.13027	.00000						100	100
SEVEN	TEN	1	.00000	.17615	.00000						100	100
SEVEN	NINE	1	.00000	.11001	.00000						100	100
NINE	EIGHT	1	.03181	.08450	.00000						100	100
NINE	ONE	1	.12711	.27038	.00000						100	100
TEN	SIX	1	.08205	.19207	.00000						100	100
THREE	TWO	1	.22092	.19988	.00000						100	100
TWO	ONE	1	.17093	.34802	.00000						100	100
FOUR	SEVEN	1	.00000	.20912	.00000	.9780					100	100
FOUR	NINE	1	.00000	.55618	.00000	.9690					100	100
FIVE	ELEVEN	1	.00000	.25202	.00000	.9320					100	100
NINE				-5.26316								

*** IEEE-14 BUS ***

BUSBAR LOADINGS

NAME	TYPE	VOLTAGE MAGNITUDE (P.U.)	VOLTAGE ANGLE (DEG)	GENERATION ACTIVE (MW)	GENERATION REACTIV (MVAR)	LOAD ACTIVE (MW)	LOAD REACTIV (MVAR)	SHUNT REACTIV (MVAR)
FOURTEEN	REF.	1.0600	.00	232.6	-21.5	.0	.0	.0
ONE	PQ	.9647	-17.17	.0	.0	14.9	5.0	.0
TEN	PV Q	1.0291	-14.79	.0	24.0	.0	.0	.0
TWO	PQ	.9752	-15.73	.0	.0	13.5	5.8	.0
SIX	PQ	1.0091	-14.83	.0	.0	3.5	1.8	.0
NINE	PQ	.9910	-16.24	.0	.0	29.5	16.6	18.7
FIVE	PQ	1.0301	-8.86	.0	.0	7.6	1.6	.0
FOUR	PQ	1.0219	-10.42	.0	.0	47.8	-3.9	.0
THREE	PQ	.9798	-15.56	.0	.0	6.1	1.6	.0
SEVEN	PQ	1.0033	-14.39	.0	.0	.0	.0	.0
EIGHT	PQ	.9831	-16.58	.0	.0	9.0	5.8	.0
ELEVEN	PV Q	.9949	-14.51	.0	24.0	11.2	7.5	.0
TWELEVE	PV Q	1.0100	-12.73	.0	21.4	94.2	19.0	.0
THIRTEEN	PV Q	1.0450	-4.98	40.0	34.7	21.7	12.7	.0
TOTAL				272.6	82.6	259.0	73.5	18.7

*** IEEE-14 BUS ***

BRANCH LOADINGS

SENDING BUS	RECEIVING BUS	N.	POWER SENT ACTIVE (MW)	POWER SENT REACTIV (MVAR)	POWER RECIEVED ACTIVE (MW)	POWER RECIEVED REACTIV (MVAR)	LINE LOSSES ACTIVE (MW)	LINE LOSSES REACT. (MVAR)	LINE LOSSES PERCEN-NTAGE	M ACTUAL MVA	V LIM1 MVA	A LIM2 MVA	OVER-LOAD	TAP SETT-ING (P.U.)
TWO	ONE	1	6.7	-.3	6.6	-.4	.08	.16		6	100	100		
TEN	SIX	1	4.1	8.9	4.1	8.8	.07	.18		9	100	100		
NINE	ONE	1	8.4	5.7	8.3	5.4	.13	.29		10	100	100		
FOURTEEN	FIVE	1	75.8	-1.1	73.0	-7.1	2.77	6.04		75	100	100		
FOUR	NINE	1	17.9	.8	17.9	-1.0	.00	1.81		17	100	100		1: .9690
FIVE	FOUR	1	68.1	-1.2	67.5	-1.7	.58	.49		68	100	100		
THREE	TWO	1	1.8	.3	1.8	.3	.01	.01		1	100	100		
SEVEN	TEN	1	4.1	-14.7	4.1	-15.1	.00	.41		15	100	100		
SEVEN	NINE	1	29.1	11.7	29.1	10.6	.00	1.07		31	100	100		
FOUR	SEVEN	1	33.2	-.7	33.2	-3.0	.00	2.31		33	100	100		1: .9780
NINE	EIGHT	1	9.0	5.9	9.0	5.8	.04	.10		10	100	100		
ELEVEN	TWO	1	18.7	5.7	18.4	5.2	.25	.50		19	100	100		
SIX	ELEVEN	1	.6	7.0	.5	6.9	.05	.10		6	100	100		
FIVE	ELEVEN	1	37.3	-11.4	37.3	-15.6	.00	4.17		40	100	100		1: .9320
ELEVEN	THREE	1	7.9	2.1	7.9	1.9	.08	.17		8	100	100		
FOUR	TWELEVE	1	23.6	-3.4	23.2	-.8	.36	-2.66		23	100	100		
FOURTEEN	THIRTEEN	1	156.8	-20.4	152.5	-27.7	4.29	7.26		158	200	200		
THIRTEEN	FIVE	1	40.9	-4.9	40.0	-3.9	.88	-.98		41	100	100		
THIRTEEN	FOUR	1	56.7	-4.3	55.0	-5.5	1.71	1.21		56	100	100		
THIRTEEN	TWELEVE	1	73.3	3.6	70.9	-1.6	2.32	5.17		73	100	100		

SYSTEM LOSSES

	ACTIVE MW	REACTIVE MVAR
SERIES	13.64	56.22
SHUNT		-28.42
TOTAL	13.64	27.80

*** IEEE-118 BUS ***

BUS DATA

IN (P.U.)

NAME	VOLTAGE	GENRATION REAL	GENRATION REACTIVE	LOAD REAL	LOAD REACTIVE	REACTIVE LMITS MIN.	REACTIVE LMITS MAX.	VOLTAGE LIMITS MIN.	VOLTAGE LIMITS MAX.	CONTROL BUS
1	1.0350	0.000	0.000	0.000	0.000					
10	.9920	-0.130	0.000	0.000	0.000					
100		0.000	0.000	0.200	0.100					
101		0.000	0.000	0.110	0.070					
102		0.000	0.000	0.210	0.100					
103		0.000	0.000	0.480	0.100					
104		0.000	0.000	0.120	0.070					
105		0.000	0.000	0.300	0.160					
106		0.000	0.000	0.420	0.310					
107		0.000	0.000	0.380	0.150					
108		0.000	0.000	0.150	0.090					
109		0.000	0.000	0.340	0.080					
11	1.0500	2.200	0.000	0.000	0.000					
110		0.000	0.000	0.220	0.150					
111		0.000	0.000	0.050	0.030					
112		0.000	0.000	0.430	0.160					
113		0.000	0.000	0.020	0.010					
114		0.000	0.000	0.080	0.030					
115		0.000	0.000	0.080	0.030					
116		0.000	0.000	0.220	0.070					
117		0.000	0.000	0.200	0.080					
118		0.000	0.000	0.330	0.150					
12	1.0150	3.140	0.000	0.000	0.000					
13	.9680	-0.090	0.000	0.620	0.130					
14	.9670	0.070	0.000	0.430	0.270					
15	.9630	0.000	0.000	0.590	0.230					
16	.9840	0.000	0.000	0.590	0.260					
17	.9800	0.000	0.000	0.310	0.170					
18	.9700	-0.460	0.000	0.200	0.230					
19	.9850	-0.590	0.000	0.370	0.230					
2	.9980	-0.090	0.000	0.300	0.120					
20	1.0050	0.190	0.000	0.280	0.100					
21	1.0250	2.040	0.000	0.870	0.300					
22	.9550	0.480	0.000	1.130	0.320					
23	.9520	0.000	0.000	0.630	0.220					
24	.9540	0.000	0.000	0.840	0.180					
25	.9850	1.550	0.000	2.770	1.130					
26	.9950	1.600	0.000	0.000	0.000					
27	.9980	0.000	0.000	0.770	0.140					
28	1.0050	3.910	0.000	0.000	0.000					
29	1.0500	3.920	0.000	0.390	0.180					
3	.9900	0.000	0.000	0.520	0.220					
30	.9550	0.000	0.000	0.510	0.270					
31	.9840	0.000	0.000	0.660	0.200					
32	.9800	-0.120	0.000	0.000	0.000					
33	.9910	-0.060	0.000	0.000	0.000					
34	.9580	0.000	0.000	0.680	0.270					
35	.9430	0.000	0.000	0.680	0.360					
36	1.0060	0.000	0.000	0.610	0.280					
37	1.0400	4.770	0.000	1.300	0.260					

*** IEEE-118 BUS ***

BUS DATA

IN (P.U.)

NAME	VOLTAGE	GENRATION REAL	GENRATION REACTIVE	LOAD REAL	LOAD REACTIVE	REACTIVE LMITS MIN.	REACTIVE LMITS MAX.	VOLTAGE LIMITS MIN.	VOLTAGE LIMITS MAX.	CONTROL BUS
38	.9850	0.000	0.000	0.240	0.150					
39	1.0150	0.000	0.000	0.000	0.000					
4	1.0150	-0.280	0.000	0.000	0.000					
40	1.0050	6.070	0.000	0.000	0.000					
41	.9850	-0.850	0.000	0.780	0.420					
42	.9800	-0.100	0.000	0.000	0.000					
43	.9900	0.000	0.000	0.650	0.100					
44	1.0100	-0.420	0.000	0.000	0.000					
45	1.0170	2.520	0.000	0.370	0.180					
46	1.0100	0.400	0.000	0.230	0.160					
47	.9710	0.000	0.000	0.380	0.250					
48	.9650	0.000	0.000	0.310	0.260					
49	.9520	-0.220	0.000	0.280	0.120					
5	1.0500	4.500	0.000	0.000	0.000					
50	.9730	0.000	0.000	0.390	0.300					
51	.9800	0.360	0.000	0.000	0.000					
52	.9750	-0.430	0.000	0.250	0.130					
53	.9930	-0.060	0.000	0.000	0.000					
54	1.0050	-1.840	0.000	0.000	0.000					
55		0.000	0.000	0.200	0.090					
56		0.000	0.000	0.390	0.100					
57		0.000	0.000	0.000	0.000					
58		0.000	0.000	0.190	0.020					
59		0.000	0.000	0.000	0.000					
6	.9900	0.850	0.000	0.470	0.100					
60		0.000	0.000	0.700	0.230					
61		0.000	0.000	0.340	0.160					
62		0.000	0.000	0.140	0.010					
63		0.000	0.000	0.250	0.100					
64		0.000	0.000	0.110	0.030					
65		0.000	0.000	0.180	0.030					
66		0.000	0.000	0.140	0.080					
67		0.000	0.000	0.100	0.050					
68		0.000	0.000	0.070	0.030					
69		0.000	0.000	0.170	0.070					
7	.9700	0.000	0.000	0.900	0.300					
70		0.000	0.000	0.240	0.040					
71		0.000	0.000	0.000	0.000					
72		0.000	0.000	0.230	0.090					
73		0.000	0.000	0.330	0.090					
74		0.000	0.000	0.000	0.000					
75		0.000	0.000	0.000	0.000					
76		0.000	0.000	0.270	0.110					
77		0.000	0.000	0.370	0.100					
78		0.000	0.000	0.180	0.070					
79		0.000	0.000	0.160	0.080					
8	.9730	0.000	0.000	0.600	0.340					
80		0.000	0.000	0.530	0.220					
81		0.000	0.000	0.340	0.000					
82		0.000	0.000	0.200	0.110					
83		0.000	0.000	0.170	0.040					

*** IEEE-118 BUS ***

BUS DATA

IN (P.U.)

NAME	VOLTAGE	GENRATION REAL	GENRATION REACTIVE	LOAD REAL	LOAD REACTIVE	REACTIVE LMITS MIN.	REACTIVE LMITS MAX.	VOLTAGE LIMITS MIN.	VOLTAGE LIMITS MAX.	CONTROL BUS
38	.9850	0.000	0.000	0.240	0.150					
39	1.0150	0.000	0.000	0.000	0.000					
4	1.0150	-0.280	0.000	0.000	0.000					
40	1.0050	6.070	0.000	0.000	0.000					
41	.9850	-0.850	0.000	0.780	0.420					
42	.9800	-0.100	0.000	0.000	0.000					
43	.9900	0.000	0.000	0.650	0.100					
44	1.0100	-0.420	0.000	0.000	0.000					
45	1.0170	2.520	0.000	0.370	0.180					
46	1.0100	0.400	0.000	0.230	0.160					
47	.9710	0.000	0.000	0.380	0.250					
48	.9650	0.000	0.000	0.310	0.260					
49	.9520	-0.220	0.000	0.280	0.120					
5	1.0500	4.500	0.000	0.000	0.000					
50	.9730	0.000	0.000	0.390	0.300					
51	.9800	0.360	0.000	0.000	0.000					
52	.9750	-0.430	0.000	0.250	0.130					
53	.9930	-0.060	0.000	0.000	0.000					
54	1.0050	-1.840	0.000	0.000	0.000					
55		0.000	0.000	0.200	0.090					
56		0.000	0.000	0.390	0.100					
57		0.000	0.000	0.000	0.000					
58		0.000	0.000	0.190	0.020					
59		0.000	0.000	0.000	0.000					
6	.9900	0.850	0.000	0.470	0.100					
60		0.000	0.000	0.700	0.230					
61		0.000	0.000	0.340	0.160					
62		0.000	0.000	0.140	0.010					
63		0.000	0.000	0.250	0.100					
64		0.000	0.000	0.110	0.030					
65		0.000	0.000	0.180	0.030					
66		0.000	0.000	0.140	0.080					
67		0.000	0.000	0.100	0.050					
68		0.000	0.000	0.070	0.030					
69		0.000	0.000	0.170	0.070					
7	.9700	0.000	0.000	0.900	0.300					
70		0.000	0.000	0.240	0.040					
71		0.000	0.000	0.000	0.000					
72		0.000	0.000	0.230	0.090					
73		0.000	0.000	0.330	0.090					
74		0.000	0.000	0.000	0.000					
75		0.000	0.000	0.000	0.000					
76		0.000	0.000	0.270	0.110					
77		0.000	0.000	0.370	0.100					
78		0.000	0.000	0.180	0.070					
79		0.000	0.000	0.160	0.080					
8	.9730	0.000	0.000	0.600	0.340					
80		0.000	0.000	0.530	0.220					
81		0.000	0.000	0.340	0.000					
82		0.000	0.000	0.200	0.110					
83		0.000	0.000	0.170	0.040					

*** IEEE-118 BUS ***

BUS DATA

IN (P.U.)

NAME	VOLTAGE	GENRATION REAL	GENRATION REACTIVE	LOAD REAL	LOAD REACTIVE	REACTIVE LMITS MIN.	REACTIVE LMITS MAX.	VOLTAGE LIMITS MIN.	VOLTAGE LIMITS MAX.	CONTROL BUS
84		0.000	0.000	0.170	0.080					
85		0.000	0.000	0.180	0.050					
86		0.000	0.000	0.230	0.110					
87		0.000	0.000	0.120	0.030					
88		0.000	0.000	0.120	0.030					
89		0.000	0.000	0.780	0.030					
9	.9620	0.000	0.000	0.450	0.250					
90		0.000	0.000	0.000	0.000					
91		0.000	0.000	0.000	0.000					
92		0.000	0.000	0.280	0.070					
93		0.000	0.000	0.000	0.000					
94		0.000	0.000	0.000	0.000					
95		0.000	0.000	0.470	0.110					
96		0.000	0.000	0.710	0.260					
97		0.000	0.000	0.390	0.320					
98		0.000	0.000	0.000	0.000					
99		0.000	0.000	0.540	0.270					

*** IEEE-118 BUS ***

BRANCH DATA

SENDING BUS	RECEIVING BUS	N	RESIST. P.U.	REACTANCE P.U.	TOTAL SUSC. P.U.	INITIAL TAP P.U.	LOWER TAP P.U.	INCR. P.U.	UPPER TAP P.U.	VOLTAGE TOLER. SPECIFIED P.U.	POWER LIM 1 MVA	POWER LIM 2 MVA
30	55	1	.03030	0.09990	.01260						100	100
30	56	1	.01290	0.04240	.00540						100	100
55	6	1	.01870	0.06160	.00780						100	100
56	57	1	.02410	0.10800	.01420						100	100
56	6	1	.04840	0.16000	.02020						100	100
2	60	1	.02090	0.06880	.00860						100	100
2	57	1	.00180	0.00800	.00100						150	150
57	60	1	.02030	0.06820	.00860						100	100
57	3	1	.01190	0.05400	.00700						100	100
3	58	1	.00450	0.02080	.00260						100	100
58	6	1	.00860	0.03400	.00420						100	100
4	71	1	.00430	0.05040	.25700						100	100
4	59	1	.00240	0.03050	.58100						450	450
59	5	1	.00260	0.03220	.61500						500	500
60	6	1	.00590	0.01960	.00240						100	100
60	61	1	.02220	0.07310	.00940						100	100
6	63	1	.02120	0.08340	.01060						100	100
6	117	1	.03290	0.14000	.01780						100	100
6	62	1	.02150	0.07070	.00900						100	100
61	7	1	.07440	0.24440	.03120						100	100
62	7	1	.05950	0.19500	.02500						100	100
7	64	1	.01320	0.04370	.02220						150	150
7	9	1	.01200	0.03940	.00500						100	100
7	72	1	.03800	0.12440	.01600						100	100
63	64	1	.04540	0.18010	.02320						100	100
64	53	1	.00910	0.03010	.00380						100	100
64	8	1	.01230	0.05050	.00640						100	100
64	14	1	.04740	0.15630	.02000						100	100
8	9	1	.01110	0.04930	.00560						100	100
9	65	1	.02520	0.11700	.01480						100	100
9	16	1	.07520	0.24700	.03160						100	100
65	66	1	.01830	0.08490	.01080						100	100
66	67	1	.02090	0.09700	.01220						100	100
67	68	1	.03420	0.15900	.02020						100	100
68	15	1	.03170	0.11530	.05860						100	100
68	10	1	.01350	0.04920	.02480						100	100
68	11	1	.01560	0.08000	.04320						200	200
10	31	1	.10220	0.41150	.05100						100	100
10	32	1	.04880	0.19600	.02440						100	100
11	13	1	.03180	0.16300	.08820						150	150
12	71	1	.00790	0.08600	.45400						250	250
13	15	1	.02290	0.07550	.00960						100	100
13	116	1	.01640	0.07410	.00980						100	100
13	69	1	.01910	0.08550	.01020						100	100
69	70	1	.02370	0.09430	.01180						100	100
70	14	1	.01080	0.03310	.00400						100	100
71	75	1	.00460	0.05400	.21100						100	100
14	15	1	.02980	0.09850	.01240						100	100
15	53	1	.06150	0.20300	.02580						100	100
15	115	1	.01350	0.06120	.00800						100	100

*** IEEE-118 BUS ***

BRANCH DATA

SENDING BUS	RECEIVING BUS	N	RESIST. P.U.	REACTANCE P.U.	TOTAL SUSC. P.U.	INITIAL TAP P.U.	LOWER TAP P.U.	INCR. P.U.	UPPER TAP P.U.	VOLTAGE SPECIFIED P.U.	TOLER.	POWER LIM 1 MVA	POWER LIM 2 MVA
30	55	1	.03030	0.09990	.01260							100	100
30	56	1	.01290	0.04240	.00540							100	100
55	6	1	.01870	0.06160	.00780							100	100
56	57	1	.02410	0.10800	.01420							100	100
56	6	1	.04840	0.16000	.02020							100	100
2	60	1	.02090	0.06880	.00860							100	100
2	57	1	.00180	0.00800	.00100							150	150
57	60	1	.02030	0.06820	.00860							100	100
57	3	1	.01190	0.05400	.00700							100	100
3	58	1	.00450	0.02080	.00260							100	100
58	6	1	.00860	0.03400	.00420							100	100
4	71	1	.00430	0.05040	.25700							100	100
4	59	1	.00240	0.03050	.58100							450	450
59	5	1	.00260	0.03220	.61500							500	500
60	6	1	.00590	0.01960	.00240							100	100
60	61	1	.02220	0.07310	.00940							100	100
6	63	1	.02120	0.08340	.01060							100	100
6	117	1	.03290	0.14000	.01780							100	100
6	62	1	.02150	0.07070	.00900							100	100
61	7	1	.07440	0.24440	.03120							100	100
62	7	1	.05950	0.19500	.02500							100	100
7	64	1	.01320	0.04370	.02220							150	150
7	9	1	.01200	0.03940	.00500							100	100
7	72	1	.03800	0.12440	.01600							100	100
63	64	1	.04540	0.18010	.02320							100	100
64	53	1	.00910	0.03010	.00380							100	100
64	8	1	.01230	0.05050	.00640							100	100
64	14	1	.04740	0.15630	.02000							100	100
8	9	1	.01110	0.04930	.00560							100	100
9	65	1	.02520	0.11700	.01480							100	100
9	16	1	.07520	0.24700	.03160							100	100
65	66	1	.01830	0.08490	.01080							100	100
66	67	1	.02090	0.09700	.01220							100	100
67	68	1	.03420	0.15900	.02020							100	100
68	15	1	.03170	0.11530	.05860							100	100
68	10	1	.01350	0.04920	.02480							100	100
68	11	1	.01560	0.08000	.04320							200	200
10	31	1	.10220	0.41150	.05100							100	100
10	32	1	.04880	0.19600	.02440							100	100
11	13	1	.03180	0.16300	.08820							150	150
12	71	1	.00790	0.08600	.45400							250	250
13	15	1	.02290	0.07550	.00960							100	100
13	116	1	.01640	0.07410	.00980							100	100
13	69	1	.01910	0.08550	.01020							100	100
69	70	1	.02370	0.09430	.01180							100	100
70	14	1	.01080	0.03310	.00400							100	100
71	75	1	.00460	0.05400	.21100							100	100
14	15	1	.02980	0.09850	.01240							100	100
15	53	1	.06150	0.20300	.02580							100	100
15	115	1	.01350	0.06120	.00800							100	100

*** IEEE-118 BUS ***

BRANCH DATA

SENDING BUS	RECEIVING BUS	N	RESIST. P.U.	REACTANCE P.U.	TOTAL SUSC. P.U.	INITIAL TAP P.U.	LOWER TAP P.U.	INCR. P.U.	UPPER TAP P.U.	VOLTAGE SPECIFIED P.U.	TOLER.	POWER LIM 1 MVA	POWER LIM 2 MVA
72	74	1	.04150	0.14200	.01820							100	100
16	17	1	.00870	0.02680	.00280							100	100
16	74	1	.00260	0.00940	.00480							150	150
16	78	1	.04130	0.16810	.02100							100	100
73	17	1	.00220	0.01020	.00120							100	100
73	74	1	.01100	0.04970	.00660							100	100
74	76	1	.03210	0.10600	.01340							100	100
74	18	1	.05930	0.16800	.02100							100	100
75	28	1	.00900	0.09860	.52300							200	200
76	18	1	.01840	0.06050	.00760							100	100
18	77	1	.01450	0.04870	.00600							100	100
18	19	1	.05550	0.18300	.02320							100	100
77	19	1	.04100	0.13500	.01720							100	100
19	21	1	.03580	0.16100	.08600							150	150
78	79	1	.06080	0.24540	.03020							100	100
79	80	1	.02240	0.09010	.01120							100	100
80	20	1	.04000	0.13560	.01660							100	100
80	21	1	.06840	0.18600	.02220							100	100
20	81	1	.03800	0.12700	.01580							100	100
20	82	1	.06010	0.18900	.02360							100	100
81	21	1	.01910	0.06250	.00800							100	100
81	1	1	.08440	0.27780	.03540							100	100
82	21	1	.01790	0.05050	.00620							100	100
21	83	1	.02670	0.07520	.00920							100	100
21	84	1	.04860	0.13700	.01700							100	100
21	29	1	.00900	0.04590	.02480							300	300
21	1	1	.09850	0.32400	.04140							100	100
21	22	1	.03980	0.14500	.07340							100	100
83	87	1	.04740	0.13400	.01660							100	100
84	85	1	.02030	0.05880	.00700							100	100
84	88	1	.02550	0.07190	.00880							100	100
85	86	1	.04050	0.16350	.02020							100	100
86	22	1	.02630	0.12200	.01540							100	100
22	23	1	.01690	0.07070	.01000							100	100
22	24	1	.00270	0.00950	.00360							100	100
22	25	1	.05030	0.22930	.02980							100	100
23	24	1	.00480	0.01510	.00180							100	100
23	25	1	.04730	0.21580	.02820							100	100
24	87	1	.03430	0.09660	.01200							100	100
24	88	1	.03430	0.09660	.01200							100	100
24	25	1	.04070	0.12000	.05520							100	100
25	89	1	.03170	0.14500	.01880							100	100
25	26	1	.03280	0.15000	.01940							100	100
89	26	1	.00260	0.01350	.00720							150	150
89	27	1	.01230	0.05610	.00720							100	100
26	27	1	.00820	0.03760	.00480							100	100
27	29	1	.04820	0.21800	.02880							100	100
27	92	1	.02580	0.11700	.01540							100	100
90	91	1	.00170	0.02000	.10800							200	200
91	28	1	.00270	0.03020	.19000							200	200
28	93	1	.00140	0.01600	.31900							150	150

*** IEEE-118 BUS

***

BRANCH DATA

SENDING BUS	RECEIVING BUS	N	RESIST. P.U.	REACTANCE P.U.	TOTAL SUSC. P.U.	INITIAL TAP P.U.	LOWER TAP P.U.	INCR. P.U.	UPPER TAP P.U.	VOLTAGE TOLER. SPECIFIED P.U.	POWER LIM 1 MVA	POWER LIM 2 MVA
29	92	1	.02240	0.10150	.01340						400	400
93	54	1	.00030	0.00400	.08200						400	400
93	98	1	.00170	0.02020	.40400						400	400
1	95	1	.04050	0.12200	.06200						150	150
1	36	1	.03090	0.10100	.05180						100	100
1	31	1	.03000	0.12700	.06100						150	150
31	94	1	.00880	0.03550	.00420						100	100
31	34	1	.04010	0.13230	.01680						100	100
31	95	1	.04280	0.14100	.01800						100	100
94	32	1	.04460	0.18000	.02220						100	100
94	33	1	.00870	0.04540	.00580						100	100
34	95	1	.01230	0.04060	.00500						100	100
95	118	1	.01450	0.04810	.00580						100	100
95	36	1	.06010	0.19990	.02480						100	100
35	118	1	.01640	0.05440	.00680						100	100
35	36	1	.04440	0.14800	.01840						100	100
36	96	1	.00370	0.01240	.00620						100	100
36	37	1	.01080	0.03310	.03500						200	200
36	99	1	.02980	0.08530	.04080						100	100
96	97	1	.00540	0.02440	.00320						100	100
97	37	1	.01560	0.07040	.00920						100	100
37	107	1	.03560	0.18200	.02460						100	100
37	108	1	.01830	0.09340	.01260						100	100
37	109	1	.02380	0.10800	.01420						100	100
37	44	1	.04540	0.20600	.02720						100	100
99	107	1	.01620	0.05300	.02720						100	100
99	100	1	.01120	0.03660	.01900						100	100
100	101	1	.06250	0.13200	.01280						100	100
100	38	1	.04300	0.14800	.01740						100	100
101	38	1	.03020	0.06410	.00600						100	100
38	102	1	.03500	0.12300	.01380						100	100
38	103	1	.02000	0.10200	.01380						100	100
38	40	1	.02390	0.17300	.02340						100	100
102	39	1	.02820	0.20740	.02220						100	100
103	40	1	.01390	0.07120	.00960						150	150
40	41	1	.01580	0.06530	.07940						200	200
40	43	1	.00790	0.03800	.04800						300	300
41	42	1	.02540	0.08360	.01060						100	100
42	43	1	.03870	0.12720	.01620						100	100
43	104	1	.02580	0.08460	.01080						100	100
43	105	1	.04810	0.15800	.02020						100	100
43	45	1	.06480	0.29500	.03860						100	100
43	111	1	.01230	0.05590	.00720						100	100
104	105	1	.02230	0.07320	.00940						100	100
105	106	1	.01320	0.04340	.00540						100	100
105	107	1	.02690	0.08690	.01140						100	100
105	45	1	.01780	0.05800	.03020						100	100
106	107	1	.01710	0.05470	.00740						100	100
107	108	1	.01730	0.08850	.01200						100	100
109	45	1	.03970	0.17900	.02380						100	100
44	45	1	.01800	0.08130	.01080						100	100

*** IEEE-118 BUS ***

BRANCH DATA

SENDING BUS	RECEIVING BUS	N	RESIST. P.U.	REACTANCE P.U.	TOTAL SUSC. P.U.	INITIAL TAP P.U.	LOWER TAP P.U.	INCR. P.U.	UPPER TAP P.U.	VOLTAGE SPECIFIED P.U.	TOLER.	POWER LIM 1 MVA	POWER LIM 2 MVA
45	110	1	.02770	0.12620	.01640							100	100
45	46	1	.01600	0.05250	.02680							150	150
45	47	1	.04510	0.20400	.02700							100	100
45	112	1	.06050	0.22900	.03100							100	100
110	111	1	.02460	0.11200	.01460							100	100
46	50	1	.03910	0.18130	.02300							100	100
46	47	1	.04660	0.15840	.02020							100	100
46	48	1	.05350	0.16250	.02040							100	100
47	48	1	.00990	0.03780	.00480							100	100
48	112	1	.01400	0.05470	.00720							100	100
48	49	1	.05300	0.18300	.02360							100	100
48	113	1	.02610	0.07030	.00920							100	100
112	49	1	.05300	0.18300	.02360							100	100
113	114	1	.01050	0.02880	.00380							100	100
114	50	1	.02780	0.07620	.01000							100	100
50	51	1	.02200	0.07550	.01000							100	100
50	52	1	.02470	0.06400	.03100							100	100
115	116	1	.00230	0.01040	.00140							100	100
4	57	1	.00000	0.02670	.00000	.9850						350	350
12	11	1	.00000	0.03820	.00000	.9600						250	250
71	64	1	.00000	0.03880	.00000	.9600						250	250
75	74	1	.00000	0.03750	.00000	.9380						250	250
90	25	1	.00000	0.03860	.00000	.9600						200	200
91	26	1	.00000	0.02680	.00000	.9850						100	100
28	29	1	.00000	0.03700	.00000	.9350						350	350
93	1	1	.00000	0.03700	.00000	.9350						300	300
98	37	1	.00000	0.03700	.00000	.9350						200	200
16				-7.14286									
20				-10.00000									
34				-8.33333									
48				-5.00000									
49				-16.66700									
50				-16.66700									
57				2.49377									
74				4.00000									
79				-10.00000									
80				-10.00000									
82				-6.66667									
97				-5.00000									
99				-5.00000									
100				-10.00000									

*** IEEE-118 BUS ***

BRANCH DATA

SENDING BUS	RECEIVING BUS	N	RESIST. P.U.	REACTANCE P.U.	TOTAL SUSC. P.U.	INITIAL TAP P.U.	LOWER TAP P.U.	INCR. P.U.	UPPER TAP P.U.	VOLTAGE SPECIFIED P.U.	TOLER.	POWER LIM 1 MVA	POWER LIM 2 MVA
45	110	1	.02770	0.12620	.01640							100	100
45	46	1	.01600	0.05250	.02680							150	150
45	47	1	.04510	0.20400	.02700							100	100
45	112	1	.06050	0.22900	.03100							100	100
110	111	1	.02460	0.11200	.01460							100	100
46	50	1	.03910	0.18130	.02300							100	100
46	47	1	.04660	0.15840	.02020							100	100
46	48	1	.05350	0.16250	.02040							100	100
47	48	1	.00990	0.03780	.00480							100	100
48	112	1	.01400	0.05470	.00720							100	100
48	49	1	.05300	0.18300	.02360							100	100
48	113	1	.02610	0.07030	.00920							100	100
112	49	1	.05300	0.18300	.02360							100	100
113	114	1	.01050	0.02880	.00380							100	100
114	50	1	.02780	0.07620	.01000							100	100
50	51	1	.02200	0.07550	.01000							100	100
50	52	1	.02470	0.06400	.03100							100	100
115	116	1	.00230	0.01040	.00140							100	100
4	57	1	.00000	0.02670	.00000	.9850						350	350
12	11	1	.00000	0.03820	.00000	.9600						250	250
71	64	1	.00000	0.03880	.00000	.9600						250	250
75	74	1	.00000	0.03750	.00000	.9380						250	250
90	25	1	.00000	0.03860	.00000	.9600						200	200
91	26	1	.00000	0.02680	.00000	.9850						100	100
28	29	1	.00000	0.03700	.00000	.9350						350	350
93	1	1	.00000	0.03700	.00000	.9350						300	300
98	37	1	.00000	0.03700	.00000	.9350						200	200
16				-7.14286									
20				-10.00000									
34				-8.33333									
48				-5.00000									
49				-16.66700									
50				-16.66700									
57				2.49377									
74				4.00000									
79				-10.00000									
80				-10.00000									
82				-6.66667									
97				-5.00000									
99				-5.00000									
100				-10.00000									

BUSBAR LOADINGS

NAME	TYPE	VOLTAGE MAGNITUDE (P.U.)	VOLTAGE ANGLE (DEG)	GENERATION ACTIVE (MW)	GENERATION REACTIVE (MVAR)	LOAD ACTIVE (MW)	LOAD REACTIVE (MVAR)	SHUNT REACTIVE (MVAR)
1	REF.	1.0350	0.00	518.5	268.6	0.0	0.0	0.0
10	PV	0.9920	-9.06	-13.0	-4.1	0.0	0.0	0.0
100	PQ	0.9816	-1.91	0.0	0.0	20.0	10.0	9.6
101	PQ	0.9784	0.52	0.0	0.0	11.0	7.0	0.0
102	PQ	0.9847	0.34	0.0	0.0	21.0	10.0	0.0
103	PQ	0.9869	5.19	0.0	0.0	48.0	10.0	0.0
104	PQ	0.9839	0.49	0.0	0.0	12.0	7.0	0.0
105	PQ	0.9876	-1.66	0.0	0.0	30.0	16.0	0.0
106	PQ	0.9776	-2.62	0.0	0.0	42.0	31.0	0.0
107	PQ	0.9892	-2.77	0.0	0.0	38.0	15.0	0.0
108	PQ	1.0090	-2.39	0.0	0.0	15.0	9.0	0.0
109	PQ	1.0222	-2.88	0.0	0.0	34.0	8.0	0.0
11	PV	1.0500	-1.97	220.0	288.0	0.0	0.0	0.0
110	PQ	0.9900	-0.72	0.0	0.0	22.0	15.0	0.0
111	PQ	0.9883	1.98	0.0	0.0	5.0	3.0	0.0
112	PQ	0.9601	-9.97	0.0	0.0	43.0	16.0	0.0
113	PQ	0.9657	-10.92	0.0	0.0	2.0	1.0	0.0
114	PQ	0.9665	-11.37	0.0	0.0	8.0	3.0	0.0
115	PQ	0.9598	-15.47	0.0	0.0	8.0	3.0	0.0
116	PQ	0.9597	-15.47	0.0	0.0	22.0	7.0	0.0
117	PQ	0.9726	-19.14	0.0	0.0	20.0	8.0	0.0
118	PQ	0.9487	-8.18	0.0	0.0	33.0	15.0	0.0
12	PV	1.0150	-0.03	314.0	-220.0	0.0	0.0	0.0
13	PV	0.9680	-14.59	-9.0	10.9	62.0	13.0	0.0
14	PV	0.9670	-17.21	7.0	42.5	43.0	27.0	0.0
15	PV	0.9630	-15.14	0.0	-8.5	59.0	23.0	0.0
16	PV	0.9840	-18.76	0.0	100.2	59.0	26.0	13.6
17	PV	0.9800	-19.21	0.0	26.2	31.0	17.0	0.0
18	PV	0.9700	-22.81	-46.0	45.7	20.0	23.0	0.0
19	PV	0.9850	-21.59	-59.0	47.7	37.0	23.0	0.0
2	PV	0.9980	-14.47	-9.0	61.4	30.0	12.0	0.0
20	PV	1.0050	-11.59	19.0	1.7	28.0	10.0	10.1
21	PV	1.0250	-9.15	204.0	139.8	87.0	30.0	0.0
22	PV	0.9550	-14.84	48.0	12.0	113.0	32.0	0.0
23	PV	0.9520	-15.13	0.0	6.4	63.0	22.0	0.0
24	PV	0.9540	-14.94	0.0	4.5	84.0	18.0	0.0
25	PV	0.9850	-10.79	155.0	176.5	277.0	113.0	0.0
26	PV	0.9950	-6.07	160.0	-25.1	0.0	0.0	0.0
27	PV	0.9980	-6.69	0.0	5.0	77.0	14.0	0.0
28	PV	1.0050	-2.42	391.0	-469.5	0.0	0.0	0.0
29	PV	1.0500	-2.61	392.0	386.2	39.0	18.0	0.0
3	PV	0.9900	-16.78	0.0	27.6	52.0	22.0	0.0
30	PV	0.9550	-19.12	0.0	2.4	51.0	27.0	0.0
31	PV	0.9840	-7.45	0.0	17.2	66.0	20.0	0.0
32	PV	0.9800	-9.02	-12.0	-8.7	0.0	0.0	0.0
33	PV	0.9910	-8.08	-6.0	10.6	0.0	0.0	0.0
34	PV	0.9580	-8.43	0.0	-1.9	68.0	27.0	11.0
35	PV	0.9430	-8.37	0.0	7.6	68.0	36.0	0.0
36	PV	1.0060	-3.50	0.0	25.6	61.0	28.0	0.0
37	PV	1.0400	-1.32	477.0	350.6	130.0	26.0	0.0

BUSBAR LOADINGS

NAME	TYPE	VOLTAGE MAGNITUDE (P.U.)	VOLTAGE ANGLE (DEG)	GENERATION ACTIVE (MW)	GENERATION REACTIVE (MVAR)	LOAD ACTIVE (MW)	LOAD REACTIVE (MVAR)	SHUNT REACTIVE (MVAR)
38	PV	0.9850	2.00	0.0	3.9	24.0	15.0	0.0
39	PV	1.0150	0.10	0.0	13.7	0.0	0.0	0.0
4	PV	1.0150	-8.70	-28.0	-24.6	0.0	0.0	0.0
40	PV	1.0050	9.27	607.0	4.9	0.0	0.0	0.0
41	PV	0.9850	2.89	-85.0	62.1	78.0	42.0	0.0
42	PV	0.9800	2.92	-10.0	-11.8	0.0	0.0	0.0
43	PV	0.9900	3.48	0.0	-4.5	65.0	10.0	0.0
44	PV	1.0100	-3.28	-42.0	-15.6	0.0	0.0	0.0
45	PV	1.0170	-2.31	252.0	110.7	37.0	18.0	0.0
46	PV	1.0100	-6.05	40.0	80.0	23.0	16.0	0.0
47	PV	0.9710	-8.62	0.0	4.9	38.0	25.0	0.0
48	PV	0.9650	-9.73	0.0	-12.8	31.0	26.0	18.6
49	PV	0.9520	-12.79	-22.0	9.3	28.0	12.0	5.4
5	PV	1.0500	6.28	450.0	15.7	0.0	0.0	0.0
50	PV	0.9730	-12.22	0.0	4.4	39.0	30.0	5.7
51	PV	0.9800	-10.58	36.0	-1.4	0.0	0.0	0.0
52	PV	0.9750	-15.32	-43.0	43.0	25.0	13.0	0.0
53	PV	0.9930	-16.23	-6.0	45.8	0.0	0.0	0.0
54	PV	1.0050	-2.99	-184.0	-328.8	0.0	0.0	0.0
55	PQ	0.9710	-18.58	0.0	0.0	20.0	9.0	0.0
56	PQ	0.9658	-18.20	0.0	0.0	39.0	10.0	0.0
57	PQ	0.9961	-13.94	0.0	0.0	0.0	0.0	-39.8
58	PQ	0.9893	-17.24	0.0	0.0	19.0	2.0	0.0
59	PQ	1.0328	-1.33	0.0	0.0	0.0	0.0	0.0
6	PV	0.9900	-17.61	85.0	111.6	47.0	10.0	0.0
60	PQ	0.9836	-17.06	0.0	0.0	70.0	23.0	0.0
61	PQ	0.9660	-18.46	0.0	0.0	34.0	16.0	0.0
62	PQ	0.9827	-18.35	0.0	0.0	14.0	1.0	0.0
63	PQ	0.9793	-17.89	0.0	0.0	25.0	10.0	0.0
64	PQ	0.9837	-16.03	0.0	0.0	11.0	3.0	0.0
65	PQ	0.9538	-18.00	0.0	0.0	18.0	3.0	0.0
66	PQ	0.9535	-16.39	0.0	0.0	14.0	8.0	0.0
67	PQ	0.9646	-13.82	0.0	0.0	10.0	5.0	0.0
68	PQ	0.9973	-8.90	0.0	0.0	7.0	3.0	0.0
69	PQ	0.9609	-16.31	0.0	0.0	17.0	7.0	0.0
7	PV	0.9700	-18.76	0.0	43.7	90.0	30.0	0.0
70	PQ	0.9628	-17.32	0.0	0.0	24.0	4.0	0.0
71	PQ	1.0199	-10.74	0.0	0.0	0.0	0.0	0.0
72	PQ	0.9646	-19.30	0.0	0.0	23.0	9.0	0.0
73	PQ	0.9785	-19.18	0.0	0.0	33.0	9.0	0.0
74	PQ	0.9797	-18.13	0.0	0.0	0.0	0.0	-24.0
75	PQ	1.0258	-12.61	0.0	0.0	0.0	0.0	0.0
76	PQ	0.9655	-21.66	0.0	0.0	27.0	11.0	0.0
77	PQ	0.9664	-23.23	0.0	0.0	37.0	10.0	0.0
78	PQ	0.9723	-18.72	0.0	0.0	18.0	7.0	0.0
79	PQ	0.9791	-16.18	0.0	0.0	16.0	8.0	9.6
8	PV	0.9730	-18.45	0.0	51.2	60.0	34.0	0.0
80	PQ	0.9828	-14.35	0.0	0.0	53.0	22.0	9.7
81	PQ	1.0159	-9.33	0.0	0.0	34.0	0.0	0.0
82	PQ	1.0200	-10.14	0.0	0.0	20.0	11.0	15.6
83	PQ	1.0000	-11.17	0.0	0.0	17.0	4.0	0.0

*** IEEE-118 BUS ***

BUSBAR LOADINGS

NAME	TYPE	VOLTAGE MAGNITUDE (P.U.)	VOLTAGE ANGLE (DEG)	GENERATION ACTIVE (MW)	GENERATION REACTIVE (MVAR)	LOAD ACTIVE (MW)	LOAD REACTIVE (MVAR)	SHUNT REACTIVE (MVAR)
84	PQ	0.9644	-13.77	0.0	0.0	17.0	8.0	0.0
85	PQ	0.9538	-14.72	0.0	0.0	18.0	5.0	0.0
86	PQ	0.9435	-15.71	0.0	0.0	23.0	11.0	0.0
87	PQ	0.9693	-13.70	0.0	0.0	12.0	3.0	0.0
88	PQ	0.9572	-14.55	0.0	0.0	12.0	3.0	0.0
89	PQ	0.9930	-6.96	0.0	0.0	78.0	3.0	0.0
9	PV	0.9620	-18.92	0.0	-9.1	45.0	25.0	0.0
90	PQ	1.0137	-7.31	0.0	0.0	0.0	0.0	0.0
91	PQ	1.0105	-5.59	0.0	0.0	0.0	0.0	0.0
92	PQ	1.0189	-5.25	0.0	0.0	28.0	7.0	0.0
93	PQ	1.0185	-2.63	0.0	0.0	0.0	0.0	0.0
94	PQ	0.9866	-7.87	0.0	0.0	0.0	0.0	0.0
95	PQ	0.9662	-7.15	0.0	0.0	47.0	11.0	0.0
96	PQ	1.0033	-3.81	0.0	0.0	71.0	26.0	0.0
97	PQ	1.0090	-3.52	0.0	0.0	39.0	32.0	20.4
98	PQ	1.0522	-2.29	0.0	0.0	0.0	0.0	0.0
99	PQ	0.9855	-3.04	0.0	0.0	54.0	27.0	19.4
T O T A L				3801.5	1523.4	3668.0	1438.0	84.9

*** IEEE-118 BUS ***

BRANCH LOADINGS

SENDING BUS	RECEIVING BUS	N.	POWER SENT ACTIVE (MW)	POWER SENT REACTIV (MVAR)	POWER RECEIVED ACTIVE (MW)	POWER RECEIVED REACTIV (MVAR)	LINE LOSSES ACTIVE (MW)	LINE LOSSES REACT. (MVAR)	LINE LOSSES PERCE-NTAGE	ACTUAL MVA	MVA LIM1 MVA	MVA LIM2 MVA	OVER-LOAD	TAP SETT-ING (P.U.)
101	100	1	24.5	-13.9	24.0	-13.7	0.51	-0.16		28	100	100		
104	105	1	44.3	-18.1	43.8	-18.9	0.52	0.81		47	100	100		
105	106	1	40.6	10.6	40.4	10.3	0.24	0.26		41	100	100		
105	107	1	19.5	-8.2	19.4	-7.5	0.12	-0.72		21	100	100		
107	106	1	1.7	20.2	1.6	20.7	0.07	-0.48		20	100	100		
108	107	1	11.5	19.7	11.4	20.5	0.09	-0.72		23	100	100		
111	110	1	39.1	-9.9	38.7	-10.3	0.41	0.43		40	100	100		
113	114	1	21.8	-10.7	21.7	-10.5	0.07	-0.17		24	100	100		
115	116	1	1.3	0.4	1.3	0.5	0.00	-0.13		1	100	100		
12	11	1	90.8	-191.3	90.8	-209.3	0.00	18.04		228	250	250		1: 0.9600
11	13	1	144.0	34.9	137.5	10.9	6.43	23.99		148	150	150		
13	116	1	20.8	6.0	20.7	6.5	0.08	-0.54		21	100	100		
15	115	1	9.3	2.7	9.3	3.4	0.01	-0.68		9	100	100		
13	15	1	12.7	2.2	12.7	2.9	0.04	-0.76		13	100	100		
15	14	1	30.4	-13.1	30.0	-13.1	0.35	-0.01		33	100	100		
16	17	1	29.8	5.0	29.7	5.0	0.08	-0.02		30	100	100		
19	18	1	12.5	3.3	12.4	5.2	0.10	-1.89		13	100	100		
1	21	1	49.7	-10.0	47.4	-13.2	2.33	3.26		50	100	100		
21	19	1	137.2	5.2	130.8	-15.2	6.45	20.32		137	150	150		
21	22	1	75.7	28.2	73.2	26.0	2.56	2.13		80	100	100		
22	23	1	7.1	1.9	7.1	2.8	0.01	-0.87		7	100	100		
22	24	1	18.4	4.7	18.4	5.0	0.01	-0.29		19	100	100		
24	23	1	21.8	5.7	21.7	5.8	0.03	-0.08		22	100	100		
25	22	1	30.6	5.8	30.0	6.2	0.51	-0.48		31	100	100		
25	23	1	34.8	7.3	34.2	7.1	0.63	0.22		35	100	100		
25	24	1	59.2	4.7	57.7	5.5	1.49	-0.79		59	100	100		
26	25	1	53.1	-3.7	52.1	-6.1	0.94	2.38		53	100	100		
26	27	1	25.4	-13.6	25.3	-13.4	0.07	-0.16		28	100	100		
29	21	1	270.5	18.0	264.5	-10.0	6.01	27.96		271	300	300		
29	27	1	38.1	16.3	37.3	15.8	0.77	0.47		41	100	100		
28	29	1	8.9	-280.2	8.9	-313.1	0.00	32.93		313	350	350		1: 0.9350
1	31	1	109.3	19.2	105.8	10.7	3.49	8.54		110	150	150		
31	10	1	5.9	-5.7	5.8	-1.0	0.05	-4.79		8	100	100		
10	32	1	1.0	4.6	1.0	6.9	0.02	-2.30		6	100	100		
31	34	1	16.6	13.6	16.4	14.5	0.20	-0.93		21	100	100		
118	35	1	7.7	7.3	7.7	7.8	0.02	-0.54		10	100	100		
1	36	1	66.3	8.6	65.0	9.7	1.31	-1.12		66	100	100		
36	35	1	62.3	25.5	60.3	20.5	2.01	4.96		67	100	100		
37	107	1	19.3	24.1	18.9	24.9	0.33	-0.82		31	100	100		
37	108	1	26.7	28.8	26.5	28.7	0.27	0.04		39	100	100		
37	109	1	29.3	10.3	29.1	10.8	0.22	-0.53		31	100	100		
37	36	1	140.7	61.3	138.3	57.7	2.38	3.62		153	200	200		
38	100	1	42.0	-9.3	41.2	-10.4	0.81	1.12		43	100	100		
38	101	1	35.9	-6.6	35.5	-6.9	0.41	0.30		36	100	100		
38	102	1	21.2	-6.2	21.1	-5.4	0.17	-0.73		22	100	100		
103	38	1	51.7	-7.5	51.1	-9.0	0.56	1.50		52	100	100		
39	102	1	0.0	13.7	-0.1	15.4	0.06	-1.78	HIGH	15	100	100		
40	103	1	101.1	8.8	99.7	2.5	1.42	6.31		101	150	150		
40	38	1	73.3	4.9	72.0	-2.0	1.28	6.95		73	100	100		
40	41	1	168.5	-4.6	164.1	-15.1	4.44	10.50		168	200	200		
41	42	1	1.1	5.1	1.1	6.0	0.01	-1.00		6	100	100		

*** IEEE-118 BUS ***

BRANCH LOADINGS

SENDING BUS	RECEIVING BUS	N.	POWER SENT ACTIVE (MW)	POWER SENT REACTIV (MVAR)	POWER RECEIVED ACTIVE (MW)	POWER RECEIVED REACTIV (MVAR)	LINE LOSSES ACTIVE (MW)	LINE LOSSES REACT. (MVAR)	LINE LOSSES PERCE-NTAGE	MVA ACTUAL MVA	MVA LIM1 MVA	MVA LIM2 MVA	OVER-LOAD	TAP SETT-ING (P.U.)
43	104	1	57.2	-9.2	56.3	-11.1	0.88	1.84		57	100	100		
43	105	1	51.8	-12.8	50.4	-15.4	1.38	2.57		53	100	100		
43	111	1	44.4	-6.5	44.1	-6.9	0.25	0.44		44	100	100		
40	43	1	264.1	-4.3	258.6	-25.7	5.46	21.46		264	300	300		
43	42	1	9.0	4.3	8.9	5.7	0.04	-1.43		10	100	100		
37	44	1	19.9	9.6	19.7	11.5	0.22	-1.87		22	100	100		
105	45	1	4.1	-52.6	3.6	-51.2	0.48	-1.47	HIGH	52	100	100		
45	109	1	4.9	-5.2	4.9	-2.8	0.02	-2.40		7	100	100		
110	45	1	16.7	-25.3	16.5	-24.8	0.25	-0.52		30	100	100		
45	112	1	60.3	11.5	58.1	6.1	2.23	5.41		61	100	100		
43	45	1	31.3	-16.1	30.5	-15.8	0.78	-0.33		35	100	100		
45	44	1	22.4	3.4	22.3	4.1	0.09	-0.70		22	100	100		
45	46	1	121.8	-20.8	119.4	-25.7	2.35	4.96		123	150	150		
45	47	1	56.2	12.0	54.7	8.1	1.46	3.92		57	100	100		
46	47	1	32.5	14.9	31.9	14.9	0.60	0.05		35	100	100		
48	112	1	8.9	6.1	8.9	6.7	0.02	-0.60		11	100	100		
48	113	1	23.9	-10.0	23.8	-9.7	0.19	-0.35		25	100	100		
46	48	1	43.4	13.9	42.3	12.5	1.10	1.36		45	100	100		
47	48	1	48.6	2.9	48.3	2.4	0.25	0.50		48	100	100		
112	49	1	24.0	-3.2	23.6	-2.2	0.33	-1.01		24	100	100		
48	49	1	26.8	-1.3	26.4	-0.5	0.41	-0.76		26	100	100		
114	50	1	13.7	-13.5	13.6	-12.9	0.11	-0.65		19	100	100		
46	50	1	60.6	9.5	59.1	5.0	1.45	4.47		61	100	100		
51	50	1	36.0	-1.4	35.7	-1.4	0.30	0.07		36	100	100		
50	52	1	69.4	-29.1	67.9	-30.0	1.46	0.83		75	100	100		
15	53	1	4.3	-16.6	4.1	-14.7	0.17	-1.91		17	100	100		
55	30	1	12.4	11.3	12.3	12.1	0.09	-0.86		17	100	100		
56	30	1	38.9	12.7	38.7	12.5	0.23	0.27		40	100	100		
57	2	1	104.5	-46.4	104.3	-47.4	0.24	0.96		114	150	150		
57	3	1	89.3	-6.5	88.3	-10.1	0.96	3.67		89	100	100		
4	57	1	340.8	29.3	340.8	-2.0	0.00	31.25		342	350	350		1: 0.9850
57	56	1	69.5	14.2	68.3	10.1	1.23	4.13		70	100	100		
3	58	1	36.3	-4.5	36.2	-4.5	0.06	0.03		36	100	100		
59	4	1	•445.2	22.5	440.6	25.9	4.52	-3.42		445	450	450		
5	59	1	450.0	15.7	445.2	22.5	4.83	-6.84		450	500	500		
6	117	1	20.2	7.0	20.0	8.0	0.16	-1.05		21	100	100		
6	55	1	32.7	20.4	32.4	20.3	0.29	0.19		38	100	100		
6	56	1	9.8	11.1	9.7	12.6	0.12	-1.54		15	100	100		
58	6	1	17.2	-6.5	17.2	-6.2	0.03	-0.29		18	100	100		
2	60	1	65.3	2.0	64.4	-0.1	0.90	2.10		65	100	100		
57	60	1	77.5	-3.1	76.2	-6.4	1.23	3.29		77	100	100		
60	6	1	34.9	-42.3	34.7	-42.6	0.18	0.37		55	100	100		
60	61	1	35.7	12.8	35.4	12.6	0.33	0.20		37	100	100		
6	62	1	19.1	4.1	19.0	4.7	0.08	-0.60		19	100	100		
6	63	1	8.3	10.1	8.2	11.0	0.04	-0.87		13	100	100		
64	14	1	14.4	5.3	14.3	6.8	0.12	-1.50		15	100	100		
64	53	1	2.0	-31.2	1.9	-31.1	0.09	-0.07		31	100	100		
64	63	1	16.9	-2.7	16.8	-1.0	0.14	-1.70		17	100	100		
66	65	1	28.8	-6.7	28.6	-6.5	0.17	-0.17		29	100	100		
67	66	1	43.2	2.1	42.8	1.3	0.42	0.83		43	100	100		
68	10	1	8.2	7.3	8.2	9.7	0.02	-2.38		12	100	100		

*** IEEE-118 BUS ***

BRANCH LOADINGS

SENDING BUS	RECEIVING BUS	N.	POWER SENT ACTIVE (MW)	POWER SENT REACTIV (MVAR)	POWER RECEIVED ACTIVE (MW)	POWER RECEIVED REACTIV (MVAR)	LINE LOSSES ACTIVE (MW)	LINE LOSSES REACT. (MVAR)	LINE LOSSES PERCE-NTAGE	ACTUAL MVA	MVA LIM1 MVA	MVA LIM2 MVA	OVER-LOAD	TAP SETT-ING (P.U.)
11	68	1	166.8	43.8	162.6	26.6	4.24	17.21		172	200	200		
68	15	1	93.1	6.1	90.3	1.6	2.79	4.51		93	100	100		
68	67	1	54.3	10.1	53.2	7.1	1.06	2.96		55	100	100		
13	69	1	33.0	0.7	32.8	0.6	0.22	0.05		32	100	100		
61	7	1	1.4	-3.4	1.4	-0.5	0.00	-2.91		3	100	100		
62	7	1	5.0	3.7	5.0	6.0	0.03	-2.28		7	100	100		
64	7	1	104.4	0.7	102.9	-2.1	1.49	2.80		104	150	150		
14	70	1	8.3	9.2	8.3	9.5	0.02	-0.32		12	100	100		
69	70	1	15.8	-6.4	15.7	-5.5	0.07	-0.80		17	100	100		
12	71	1	223.2	-28.7	219.4	-23.3	3.82	-5.38		225	250	250		
4	71	1	71.9	-27.9	71.6	-4.0	0.22	-23.97		77	100	100		
71	64	1	229.1	-1.0	229.1	-22.2	0.00	21.24		230	250	250		1: 0.9600
7	72	1	7.7	1.1	7.7	2.5	0.03	-1.41		8	100	100		
73	17	1	1.3	-14.3	1.3	-14.2	0.00	-0.09		14	100	100		
74	16	1	93.9	-70.2	93.5	-71.1	0.37	0.88		117	150	150		
74	18	1	43.4	-8.8	42.2	-10.2	1.20	1.41		44	100	100		
74	72	1	15.4	5.2	15.3	6.5	0.12	-1.31		16	100	100		
74	73	1	34.4	-5.3	34.3	-5.3	0.14	-0.01		34	100	100		
28	75	1	182.9	-47.8	179.9	-27.0	3.02	-20.81		189	200	200		
71	75	1	61.9	-26.3	61.7	-6.3	0.18	-19.96		67	100	100		
75	74	1	241.7	-33.3	241.7	-57.5	0.00	24.11		248	250	250		1: 0.9380
76	18	1	26.5	-15.3	26.3	-15.2	0.18	-0.11		30	100	100		
74	76	1	54.5	-2.3	53.5	-4.3	0.99	2.01		54	100	100		
18	77	1	14.9	2.5	14.9	2.9	0.04	-0.44		15	100	100		
19	77	1	22.3	6.2	22.1	7.1	0.23	-0.87		23	100	100		
16	78	1	1.3	5.5	1.2	7.4	0.02	-1.93		7	100	100		
79	78	1	16.9	-2.6	16.8	-0.4	0.18	-2.14		17	100	100		
64	8	1	80.5	2.6	79.6	-0.2	0.82	2.77		80	100	100		
20	80	1	37.0	5.6	36.4	5.3	0.56	0.25		37	100	100		
21	80	1	51.5	5.4	49.8	2.8	1.76	2.54		51	100	100		
80	79	1	33.2	-4.2	32.9	-4.2	0.26	-0.04		33	100	100		
1	81	1	59.5	-7.9	56.7	-13.4	2.82	5.56		60	100	100		
81	20	1	31.6	-0.9	31.3	-0.6	0.37	-0.38		31	100	100		
21	81	1	9.0	11.8	8.9	12.5	0.04	-0.70		15	100	100		
82	20	1	14.9	2.3	14.7	4.3	0.13	-2.00		15	100	100		
21	82	1	35.1	-2.3	34.9	-2.3	0.21	-0.06		35	100	100		
21	83	1	53.7	15.4	52.9	14.1	0.80	1.30		55	100	100		
21	84	1	66.7	23.1	64.3	18.3	2.32	4.86		70	100	100		
84	85	1	28.6	7.5	28.4	7.6	0.19	-0.09		29	100	100		
22	86	1	12.7	5.7	12.6	6.8	0.06	-1.12		14	100	100		
85	86	1	10.4	2.6	10.4	4.2	0.05	-1.60		11	100	100		
87	24	1	23.2	6.8	23.0	7.3	0.22	-0.50		24	100	100		
83	87	1	35.9	10.1	35.2	9.8	0.67	0.28		37	100	100		
88	24	1	6.6	0.3	6.6	1.3	0.02	-1.05		6	100	100		
84	88	1	18.7	2.8	18.6	3.3	0.10	-0.53		18	100	100		
89	25	1	44.4	-3.6	43.7	-4.7	0.64	1.07		44	100	100		
26	89	1	112.7	-6.6	112.3	-7.6	0.33	1.03		112	150	150		
27	89	1	10.0	6.3	10.0	7.0	0.02	-0.63		12	100	100		
16	9	1	3.4	6.2	3.4	9.0	0.06	-2.81		9	100	100		
65	9	1	10.6	-9.5	10.6	-8.4	0.05	-1.11		14	100	100		
7	9	1	11.5	16.0	11.5	16.3	0.05	-0.30		19	100	100		

*** IEEE-118 BUS ***

BRANCH LOADINGS

SENDING BUS	RECEIVING BUS	N.	POWER SENT ACTIVE (MW)	POWER SENT REACTIV (MVAR)	POWER RECEIVED ACTIVE (MW)	POWER RECEIVED REACTIV (MVAR)	LINE LOSSES ACTIVE (MW)	LINE LOSSES REACT. (MVAR)	LINE LOSSES PERCE-NTAGE	MVA ACTUAL MVA	MVA LIM1 MVA	MVA LIM2 MVA	OVER-LOAD	TAP SETT-ING (P.U.)
8	9	1	19.6	17.1	19.6	17.3	0.08	-0.17		26	100	100		
90	25	1	150.7	-25.4	150.7	-34.9	0.00	9.52		154	200	200		1: 0.9600
91	26	1	31.1	1.6	31.1	1.3	0.00	0.26		31	100	100		1: 0.9850
28	91	1	183.2	-39.3	182.2	-30.3	0.92	-9.00		187	200	200		
91	90	1	151.1	-31.8	150.7	-25.4	0.39	-6.46		154	200	200		
92	27	1	24.6	12.2	24.4	12.9	0.19	-0.69		27	100	100		
29	92	1	53.3	20.8	52.6	19.2	0.67	1.61		57	400	400		
1	93	1	122.4	234.2	122.4	210.1	0.00	24.11		264	300	300		0.9350:1
28	93	1	16.0	-102.2	15.9	-70.8	0.11	-31.44		103	150	150		
93	54	1	184.4	326.0	184.0	328.8	0.41	-2.88		376	400	400		
31	94	1	17.1	-11.4	17.0	-11.2	0.04	-0.25		20	100	100		
94	32	1	11.0	-0.1	11.0	1.8	0.06	-1.92		11	100	100		
94	33	1	6.0	-11.1	6.0	-10.6	0.01	-0.50		12	100	100		
1	95	1	111.3	24.5	106.3	15.7	4.98	8.78		113	150	150		
95	118	1	41.0	22.9	40.7	22.3	0.34	0.61		46	100	100		
31	95	1	0.3	11.5	0.2	13.0	0.07	-1.49	HIGH	12	100	100		
95	34	1	52.0	4.1	51.6	3.4	0.36	0.72		52	100	100		
36	95	1	34.2	9.5	33.5	9.3	0.76	0.13		35	100	100		
36	96	1	46.4	7.6	46.3	7.9	0.08	-0.35		47	100	100		
37	97	1	64.5	32.1	63.7	29.6	0.75	2.43		71	100	100		
97	96	1	24.7	18.0	24.7	18.1	0.05	-0.10		30	100	100		
37	98	1	46.6	158.5	46.6	149.1	0.00	9.33		165	200	200		0.9350:1
98	93	1	46.6	149.1	46.1	186.7	0.49	-37.55		192	400	400		
100	99	1	45.2	-24.5	44.9	-23.7	0.30	-0.85		51	100	100		
107	99	1	10.0	2.7	10.0	5.3	0.02	-2.59		11	100	100		
99	36	1	0.8	-26.0	0.7	-22.4	0.18	-3.54	HIGH	25	100	100		

SYSTEM LOSSES

	ACTIVE MW	REACTIVE MVAR
SERIES	133.61	852.59
SHUNT		-682.29
TOTAL	133.61	170.30

REFERENCES

(1) Zollenkopf, K., Large sparse sets of linear equations in Bifactorization - basic computational algorithms and programming techniques (book) edited by J.K. Reid, Ed., New York 1970, Academic Press 1979.

(2) El- Marsafaury, M.M. and Mathur, R.M., An Improved method for outage studies , paper A 79 062-1 IEEE winter power meeting, New York, Feb. 1979.

(3) B. Stott and O. Alsac, Fast decoupled load flow technique , IEEE Trans., Vol. PAS-93, 1974, pp. 859 - 869.

(4) Yaacov, G.Z. Ben, Data base approach to system analysis studies , PAS-81, pp. 2643 - 2649.

(5) Walker, Leuris N., Hybrid simulator, faster-than-real time performance evaluation, PAS-78, pp. 1795-1804.

(6) Granirlley, Ott., Hybrid simulator for studying long term dynamics , PAS-77 pp. 907 - 915.

(7) Keyhani, Ali, Interactive simulator for power system research , PAS-84, pp. 516 - 521.

(8) Elder, L., Real-time simulation of major disturbances for use in operator training , PAS-82, pp. 334 - 339.

(9) Diane M., Special purpose numerical hard ware for power system applications , PAS-82, pp. 265 - 270.

(10) Pai, M.A., Computer techniques in power system analysis , Tata Mc Graw-Hill, New Delhi, pp. 110 - 136.

(11) Stagg and El - Abiad, Computer methods in power system analysis , Mc Grow-Hill , International student Edition, pp. 257 - 342.

(12) Debs, A.S. and Benon, A.R. , Security assessment of power system, Conference on System Engineering for Power, Status and Prospect , August 1975 pp. 144-172.