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FAULT CURRENT CALCULATION IN INDUSTRIAL POWER SYSTEMS

Jae-Ryong Hwang

A MAJOR TECHNICAL REPORT

in the

Faculty of Engineering

Presented in partial fulfilment of the requirements for
the Degree of Master of Engineering at
Concordia University
Montreal, Canada

August, 1978

ABSTRACT

FAULT CURRENT CALCULATION IN INDUSTRIAL POWER SYSTEMS

Jae-Ryong Hwang

Two methods of constructing the bus impedance matrix (Z_{BUS}) are reviewed.

Also, basic formulae to be used for the calculation of fault current based on the Z_{BUS} are derived.

Practical fault current calculation methods recommended by two ANSI standards are described.

Finally, an efficient and convenient computer program, incorporating the theory described in this report and necessary recommendations of the ANSI standards, is developed and presented.

ACKNOWLEDGEMENT

The author wishes to acknowledge the technical guidance given by Prof. J. Lindsay of the Department of Electrical Engineering, Concordia University.

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1. INTRODUCTION

Nowadays most of the fault current studies are done with the bus impedance matrix (Z_{BUS}), or a driving point and transfer impedance matrix for a multi-terminal network.

Two methods of constructing Z_{BUS} are reviewed.

One is a basic topological method, which consists of formation of a bus admittance matrix (Y_{BUS}) and inversion of it to give Z_{BUS}.

The other is a method developed by Stagg, et. al. (1,2) which efficiently constructs Z_{BUS} directly from line information without any inversion operation of matrix.

Basic formulae to be used for the calculation of circuit values based on Z_{BUS}, incidence matrix, and primitive network matrix are, then, derived.

Simplified methods for considering the transient component of fault current and correction factors for machine impedances to take into account the change of them during transient period are described as recommended by ANSI C37.010-1972 and C37.13-1973.

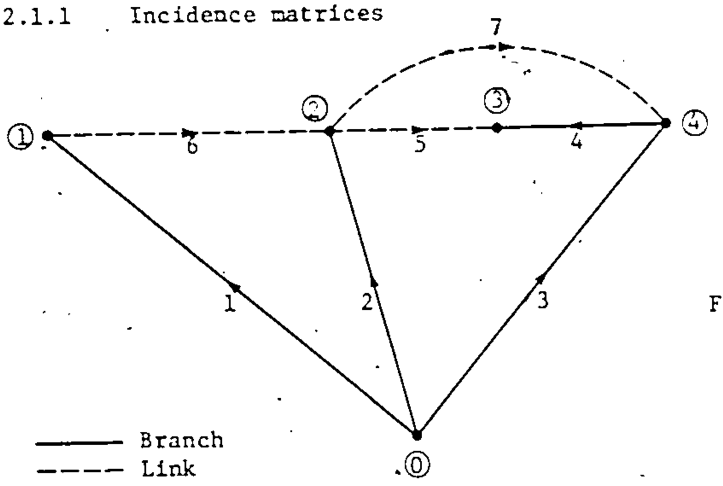
Finally a digital computer program using the algorithm developed by Stagg, et. al., incorporating all necessary requirements and recommendations of the ANSI standards, and equipped with a maximum degree of flexibility, efficiency, and abundant option features, is developed.

In the appendix, a User Manual for the use of the program, the whole copy of the program in Fortran version, and several sample runnings are included.

2. Z_{BUS} CONSTRUCTION

2.1 Singular Transformation

2.1.1 Incidence matrices



e = 7
n = 5
b = 4
L = 3

FIG. 1 Sample Graph

Element-node incidence matrix $\overset{+}{A}$

The incidence of elements to nodes in a connected graph is shown by the element-node incidence matrix. The elements of the matrix are as follows:

a_{ij} = 1 if the i th element is incident to and oriented away from the j th node

a_{ij} = -1 if the i th element is incident to and oriented toward the j th node

a_{ij} = 0 if the i th element is not incident to the j th node

The dimension of the matrix is e X n, where e is the number of elements and n is the number of nodes in the graph. The element-node incidence matrix for the graph shown in Fig. 1 is equation (1).

$$\overset{\dagger}{A} = \begin{array}{c|c|c|c|c|c|}
{}_{e}\diagdown^{n} & 0 & 1 & 2 & 3 & 4 \\
\hline
1 & 1 & -1 & & & \\
\hline
2 & 1 & & -1 & & \\
\hline
3 & 1 & & & & -1 \\
\hline
4 & & & & -1 & 1 \\
\hline
5 & & & 1 & -1 & \\
\hline
6 & & 1 & -1 & & \\
\hline
7 & & & 1 & & -1 \\
\hline
\end{array} \qquad (1)$$

Since

$$\sum_{j=o}^{4} a_{ij} = 0 \quad i = 1, 2, \ldots, e$$

the columns of $\overset{\dagger}{A}$ are linearly dependent. Hence, the rank of $\overset{\dagger}{A}$ $<n$.

Bus incidence matrix A

Any node of a connected graph can be selected as the reference node. Then, the variables of the other nodes, referred to as buses, can be measured with respect to the assigned reference. The matrix obtained

$$A = \begin{array}{c|c|c|c|c|}
{}_{e}\diagdown^{\text{bus}} & 1 & 2 & 3 & 4 \\
\hline
1 & -1 & & & \\
\hline
2 & & -1 & & \\
\hline
3 & & & & -1 \\
\hline
4 & & & -1 & 1 \\
\hline
5 & & 1 & -1 & \\
\hline
6 & 1 & -1 & & \\
\hline
7 & & 1 & & -1 \\
\hline
\end{array} \qquad (2)$$

[redacted]

from $\overset{+}{A}$ by deleting the column corresponding to the reference node is the element-bus incidence matrix A, which will be called the bus incidence matrix. The dimension of this matrix is e x (n - 1) and the rank is n - 1 = b, where b is the number of branches in the graph. Selecting node 0 as reference for the graph shown in Fig. 1, A is equation (2). This matrix is rectangular and therefore singular.

If the rows of A are arranged according to a particular tree, the matrix can be partitioned into submatrices A_b of dimension b x (n - 1) and A_L of dimension L x (n - 1), where the rows of A_b correspond to branches and the rows of A_L to links. The partitioned matrix for the graph shown in Fig. 1 is equation (3).

$$A = \begin{array}{c|cccc} e \diagdown \text{bus} & 1 & 2 & 3 & 4 \\ \hline 1 & -1 & & & \\ 2 & & -1 & & \\ 3 & & & & -1 \\ \hline 4 & & & -1 & 1 \\ 5 & & 1 & -1 & \\ 6 & 1 & -1 & & \\ 7 & & 1 & & -1 \end{array} = \begin{array}{c|c} e \diagdown \text{bus} & \text{Buses} \\ \hline & A_b \\ \hline & A_L \end{array} \tag{3}$$

A_L is a nonsingular square matrix with rank (n - 1).

Float network element-bus incidence matrix Af

If all the elements incident to bus o are eliminated, the remaining network constitutes a reduced or "float" network, for which the topology may be described by an element-bus incidence matrix.

This matrix, Af, is obtained by partitioning A provided the rows

[redacted]

and columns of A are arranged properly. A_f for the graph shown in Fig. 1 is shown in equation (4).

$$A = \begin{array}{c|cccc} e \backslash \text{bus} & 1 & 2 & 3 & 4 \\ \hline 1 & -1 & & & \\ 2 & & -1 & & \\ 3 & & & & -1 \\ \hline 4 & & & -1 & 1 \\ 5 & & 1 & -1 & \\ 6 & 1 & -1 & & \\ 7 & & 1 & & -1 \end{array} = \begin{array}{c|c} e \backslash \text{bus} & \text{buses} \\ \hline & \\ & \\ \hline & \\ & A_f \\ & \end{array} \qquad (4)$$

2.1.2 Primitive network

Network components represented both in impedance form and in admittance form are shown in Fig. 2. The performance of the components can be expressed using either form. The variables and parameters are:

v_{pq} is the voltage across the element p-q

e_{pq} is the source voltage in series with element p-q

i_{pq} is the current through element p-q

j_{pq} is the source current in parallel with element p-q

z_{pq} is the self-impedance of element p-q

y_{pq} is the self-admittance of element p-q

Each element has two variables, v_{pq} and i_{pq}. In the steady state these variables and the parameters of the elements z_{pq} and y_{pq} are real numbers for direct current circuits and complex numbers for alternating current circuits.

[redacted]

The performance equation of an element in impedance form is

$$v_{pq} + e_{pq} = z_{pq} i_{pq} \qquad (5)$$

or in admittance form is

$$i_{pq} + j_{pq} = y_{pq} v_{pq} \qquad (6)$$

The parallel source current in admittance form is related to the series source voltage in impedance form by

$$j_{pq} = -y_{pq} e_{pq} \qquad (7)$$

A set of unconnected elements is defined as a primitive network. The performance equations of a primitive network can be derived from (5) or (6) by expressing the variables as vectors and the parameters as matrices. The performance equation in impedance form is

$$\bar{v} + \bar{e} = (z) i \qquad (8)$$

or in admittance form is

$$\bar{i} + \bar{j} = (y) \bar{v} \qquad (9)$$

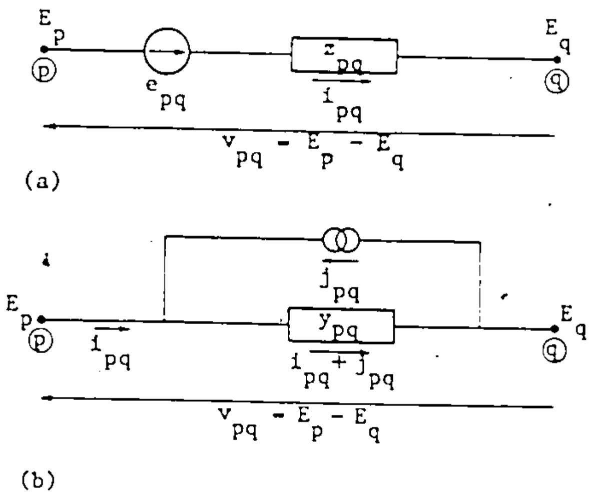


Fig. 2
Representations of a network component.
(a) Impedance form
(b) Admittance form

[redacted]

A diagonal element of the matrix $[z]$ or $[y]$ of the primitive network is the self-impedance $z_{pq,pq}$ or self-admittance $y_{pq,pq}$. An off-diagonal element is the mutual impedance $z_{pq,rs}$ or the mutual admittance $y_{pq,rs}$ between the elements p-q and r-s. The primitive admittance matrix $[y]$ can be obtained by inverting the primitive impedance matrix $[z]$. The matrices $[z]$ and $[y]$ are diagonal matrices if there is no mutual coupling between elements. In this case the self-impedances are equal to the reciprocals of the corresponding self-admittances.

The relationship between $\bar{e}$ and $\bar{j}$ in equations.(8) and (9) is

$$[z]\bar{j} = -\bar{e} \qquad (10)$$

2.1.3 Formation of network matrices by singular transformations

Network performance equations

A network is made up of an interconnected set of elements. In the bus frame of reference, the performance of an interconnected network is described by n - 1 independent nodal equations, where n is the number of nodes. In matrix notation, the performance equation in impedance form is

$$\bar{E}_{BUS} = Z_{BUS}\bar{I}_{BUS} \qquad (11)$$

or in admittance form is

$$\bar{I}_{BUS} = Y_{BUS}\bar{E}_{BUS} \qquad (12)$$

where $\bar{E}_{BUS}$ = vector of bus voltages measured with respect to the reference bus

$\bar{I}_{BUS}$ = vector of impressed bus currents

Z_{BUS} = bus impedance matrix whose elements are open circuit driving point and transfer impedances

Y_{BUS} = bus admittance matrix whose elements are short circuit driving point and transfer admittances

Bus admittance and bus impedance matrices

The bus admittance matrix Y_{BUS} can be obtained by using the bus incidence matrix A to relate the variables and parameters of the primitive network to bus quantities of the interconnected network. The performance equation of the primitive network

$$\bar{i} + \bar{j} = (y)\bar{v}$$

is premultiplied by A^t, the transpose of the bus incidence matrix, to obtain

$$A^t\bar{i} + A^t\bar{j} = A^t(y)\bar{v} \tag{13}$$

Since the matrix A shows the incidence of elements to buses, $A^t\bar{i}$ is a vector in which each element is the algebraic sum of the currents leaving the bus. In accordance with Kirchhoff's current law, the algebraic sum of the currents at a bus is zero. Then

$$A^t\bar{i} = 0 \tag{14}$$

Similarly, $A^t\bar{j}$ gives the algebraic sum of the source currents at each bus and equals the vector of impressed bus currents. Therefore

$$\bar{I}_{BUS} = A^t\bar{j} \tag{15}$$

Substituting from equations (14) and (15) into (13) yields

$$\bar{I}_{BUS} = A^t(y)\bar{v} \tag{16}$$

Power into the network is $(\bar{I}^*_{BUS})^t\bar{E}_{BUS}$ and the sum of the powers in the primitive network is $(\bar{j}^*)^t\bar{v}$. The power in the primitive and interconnected networks must be equal, that is, the transformation of variables must be power-invariant. Hence

$$(\bar{I}^*_{BUS})^t\bar{E}_{BUS} = (\bar{j}^*)^t\bar{v} \tag{17}$$

Taking the conjugate transpose of equation (15)

$$(\bar{I}^*_{BUS})^t = (\bar{j}^*)^tA^*$$

Since A is a real matrix

$$A^{*} = A$$

and

$$(\bar{I}^{*}_{BUS})^{t} = (\bar{j}^{*})^{t}A \qquad (18)$$

Substituting from equation (18) into (17)

$$(\bar{j}^{*})^{t}A\bar{E}_{BUS} = (\bar{j}^{*})^{t}\bar{v}$$

Since this equation is valid for all values of $\bar{j}$, it follows that

$$A\bar{E}_{BUS} = \bar{v} \qquad (19)$$

Substituting from equation (19) into (16)

$$\bar{I}_{BUS} = A^{t}(y)A\bar{E}_{BUS} \qquad (20)$$

Since the performance equation of the network is

$$\bar{I}_{BUS} = Y_{BUS}\bar{E}_{BUS} \qquad (21)$$

it follows from equations (20) and (21) that

$$Y_{BUS} = A^{t}(y)A$$

The bus incidence matrix A is singular and therefore $A^{t}(y)A$ is a singular transformation of (y).

The bus impedance matrix can be obtained from

$$Z_{BUS} = Y^{-1}_{BUS} = (A^{t}(y)A)^{-1} \qquad (22)$$

2.2 Direct Method

2.2.1 Introduction

The methods presented in the previous section require transformation and inversion of matrices to obtain network matrices. An alternative method based on an algorithm can be used to form the bus impedance matrix directly from system parameters and coded bus numbers. The underlying principle of the algorithm is the formation of the bus impedance matrix in steps, simulating the construction of the network by adding one element at a time.(1,2) A matrix is formed for the partial network represented after each element is connected to the network.

Most of the following description is direct quotation from Stagg's book.(2)

2.2.2 Algorithm for formation of bus impedance matrix

Performance equation of a partial network

Assume that the bus impedance matrix Z_{BUS} is known for a partial network of m buses and a reference node 0. The performance equation of this network, shown in Fig. 3, is

$$\bar{E}_{BUS} = Z_{BUS}\bar{I}_{BUS} \tag{23}$$

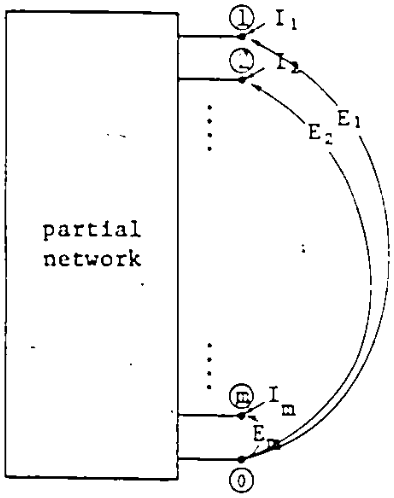


Fig. 3 Representation of a partial network.

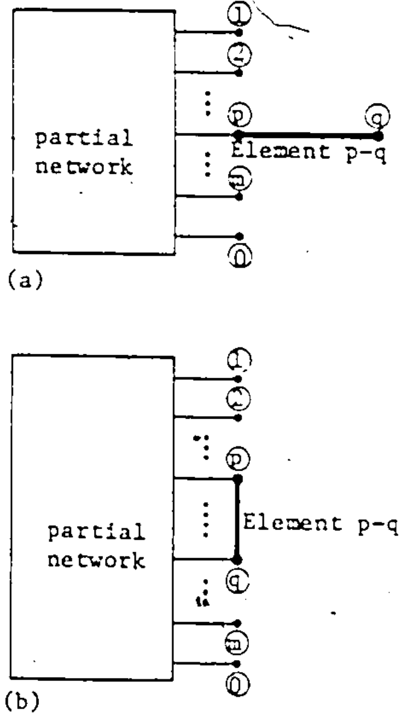


Fig. 4 Representations of a partial network with an added element.

(a) Addition of a branch
(b) Addition of a link.

where $\bar{E}_{BUS}$ = an m x 1 vector of bus voltages measured with respect to the reference node

$\bar{I}_{BUS}$ = an m x 1 vector of impressed bus currents

Where an element p-q is added to the partial network, it may be a branch or a link as shown in Fig. 4.

If p-q is a branch, a new bus q is added to the partial network and the resultant bus impedance matrix is of dimension (m + 1) x (m + 1). The new voltage and current vectors are of dimension (m + 1) x 1. To determine the new bus impedance matrix requires only the calculation of the elements in the new row and column.

If p-q is a link, no new bus is added to the partial network. In this case, the dimensions of the matrices in the performance equation are unchanged, but all the elements of the bus impedance matrix must be recalculated to include the effect of the added link.

Addition of a branch

The performance equation for the partial network with an added branch p-q is

$$\begin{bmatrix} E_1 \\ E_2 \\ \vdots \\ E_p \\ \vdots \\ E_m \\ E_q \end{bmatrix} = \begin{array}{c|ccccccc} & 1 & & & p & & m & q \\ \hline 1 & Z_{11} & Z_{12} & \cdots & Z_{1p} & \cdots & Z_{1m} & Z_{1q} \\ & Z_{21} & Z_{22} & \cdots & Z_{2p} & \cdots & Z_{2m} & Z_{2q} \\ & \vdots & \vdots & \ddots & \vdots & \iddots & \vdots & \vdots \\ p & Z_{p1} & Z_{p2} & \cdots & Z_{pp} & \cdots & Z_{pm} & Z_{pq} \\ & \vdots & \vdots & \iddots & \vdots & \ddots & \vdots & \vdots \\ m & Z_{m1} & Z_{m2} & \cdots & Z_{mp} & \cdots & Z_{mm} & Z_{mq} \\ q & Z_{q1} & Z_{q2} & \cdots & Z_{qp} & \cdots & Z_{qm} & Z_{qq} \end{array} \begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_p \\ \vdots \\ I_m \\ I_q \end{bmatrix} \qquad (24)$$

It is assumed that the network consists of bilateral passive elements. Hence $Z_{qi} = Z_{iq}$ where $i = 1, 2, \ldots, m$ and refers to the buses of the partial network, not including the new bus q. The added branch p-q is assumed to be mutually coupled with one or more elements of the partial network.

The elements Z_{qi} can be determined by injecting a current at the i th bus and calculating the voltage at the q th bus with respect to the reference node as shown in Fig. 5. Since all other bus currents equal zero, it follows from equation (24) that

$$\begin{aligned} E_1 &= Z_{1i}I_i \\ E_2 &= Z_{2i}I_i \\ &\vdots \\ E_p &= Z_{pi}I_i \\ &\vdots \end{aligned} \qquad (25)$$

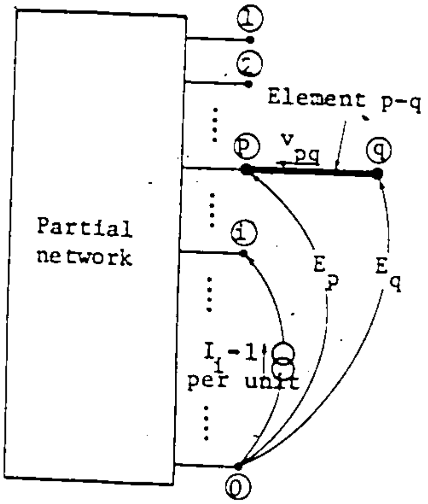


Fig. 5 Injected current and bus voltages for calculation of Z_{qi}

$$E_m = Z_{mi} I_i$$
$$E_q = Z_{qi} I_i$$

Letting $I_i = 1$ per unit in equations (25), Z_{qi} can be obtained directly by calculating E_q.

The bus voltages associated with the added element and the voltage across the element are related by

$$E_q = E_p - v_{pq} \tag{26}$$

The currents in the elements of the network in Fig. 5 are expressed in terms of the primitive admittances and the voltages across the elements by

$$\begin{bmatrix} i_{pq} \\ i_{rs} \end{bmatrix} = \begin{bmatrix} y_{pq,pq} & y_{pq,rs} \\ y_{rs,pq} & y_{rs,rs} \end{bmatrix} \begin{bmatrix} v_{pq} \\ v_{rs} \end{bmatrix} \tag{27}$$

In equation (27) pq is a fixed subscript and refers to the added element and rs is a variable subscript and refers to all other elements. Then,

i_{pq} and v_{pq}	are, respectively, current through and voltage across the added element
$\bar{i}_{rs}$ and $\bar{v}_{rs}$	are the current and voltage vectors of the elements of the partial network
$y_{pq,pq}$	is the self-admittance of the added element
$\bar{y}_{pq,rs}$	is the vector of mutual admittances between the added element p-q and the elements r-s of the partial network
$\bar{y}_{rs,pq}$	is the transpose of the vector $\bar{y}_{pq,rs}$
$\left[y_{rs,rs}\right]$	is the primitive admittance matrix of the partial network

The current in the added branch, shown in Fig. 5, is

$$i_{pq} = 0 \tag{28}$$

However v_{pq} is not equal to zero since the added branch is mutually coupled to one or more of the elements of the partial network. Moreover,

$$\bar{v}_{rs} = \bar{E}_r - \bar{E}_s \tag{29}$$

where $\bar{E}_r$ and $\bar{E}_s$ are the voltages at the buses in the partial network.

From equations (27 and 28),

$$i_{pq} = y_{pq,pq} v_{pq} + \bar{y}_{pq,rs} \bar{v}_{rs} = 0$$

and therefore,

$$v_{pq} = - \frac{\bar{y}_{pq,rs} \bar{v}_{rs}}{y_{pq,pq}} \tag{30}$$

Substituting for $\bar{v}_{rs}$ from equation (29),

$$v_{pq} = - \frac{\bar{y}_{pq,rs} (\bar{E}_r - \bar{E}_s)}{y_{pq,pq}} \tag{31}$$

Substituting for v_{pq} in equation (26) from (31),

$$E_q = E_p + \frac{\bar{y}_{pq,rs}(\bar{E}_r - \bar{E}_s)}{y_{pq,pq}}$$

Finally, substituting for E_q, E_p, $\bar{E}_r$ and $\bar{E}_s$ from equation (25) with $I_i = 1$,

$$Z_{qi} = Z_{pi} + \frac{\bar{y}_{pq,rs}(\bar{Z}_{ri} - \bar{Z}_{si})}{y_{pq,pq}} \qquad \begin{array}{l} i = 1, 2, \ldots, m \\ i \neq q \end{array} \tag{32}$$

The element Z_{qq} can be calculated by injecting a current at the q th bus and calculating the voltage at that bus. Since all other bus currents equal zero, it follows from equation (24) that

$$\begin{aligned} E_1 &= Z_{1q}I_q \\ E_2 &= Z_{2q}I_q \\ &\vdots \\ E_p &= Z_{pq}I_q \\ &\vdots \\ E_m &= Z_{mq}I_q \\ E_q &= Z_{qq}I_q \end{aligned} \tag{33}$$

Letting $I_q = 1$ per unit in equations (33), Z_{qq} can be obtained directly by calculating E_q.

The voltages at buses p and q are related by equation (26), and the current through the added element is

$$i_{pq} = -I_q = -1 \tag{34}$$

The voltages across the elements of the partial network are given by equation (29) and the currents through these elements by (27). From equations (27) and (34),

$$i_{pq} = y_{pq,pq}v_{pq} + \bar{y}_{pq,rs}\bar{v}_{rs} = -1$$

and therefore,

$$v_{pq} = -\frac{1 + \bar{y}_{pq,rs}\bar{v}_{rs}}{y_{pq,pq}}$$

Substituting for $\bar{v}_{rs}$ from equation (29),

$$v_{pq} = -\frac{1 + \bar{y}_{pq,rs}(\bar{E}_r - \bar{E}_s)}{y_{pq,pq}} \qquad (35)$$

Substituting for v_{pq} in equation (26) from (35),

$$E_q = E_p + \frac{1 + \bar{y}_{pq,rs}(\bar{E}_r - \bar{E}_s)}{y_{pq,pq}}$$

Finally, substituting for E_q, E_p, $\bar{E}_r$ and $\bar{E}_s$ from equation (33) with $I_q = 1$,

$$Z_{qq} = Z_{pq} + \frac{1 + \bar{y}_{pq,rs}(\bar{Z}_{rq} - \bar{Z}_{sq})}{y_{pq,pq}} \qquad (36)$$

If there is no mutual coupling between the added branch and other elements of the partial network, then the elements of $\bar{y}_{pq,rs}$ are zero and

$$z_{pq,pq} = \frac{1}{y_{pq,pq}} \qquad (37)$$

It follows from equation (32) that

$$Z_{qi} = Z_{pi} \qquad \begin{array}{l} i = 1, 2, \ldots, m \\ i \neq q \end{array} \qquad (38)$$

and from equation (36) that

$$Z_{qq} = Z_{pq} + z_{pq,pq} \qquad (39)$$

Furthermore, if there is no mutual coupling and p is the reference node,

$$Z_{pi} = 0 \qquad \begin{array}{l} i = 1, 2, \ldots, m \\ i \neq q \end{array} \qquad (40)$$

and

$$Z_{qi} = 0 \qquad \begin{array}{l} i = 1, 2, \ldots, m \\ i \neq q \end{array} \tag{41}$$

Also

$$Z_{pq} = 0 \tag{42}$$

and therefore,

$$Z_{qq} = z_{pq,pq} \tag{43}$$

Addition of a link

If the added element p-q is a link, the procedure for recalculating the elements of the bus impedance matrix is to connect in series with the added element a voltage source e_t as shown in Fig. 6. This creates a fictitious node t which will be eliminated later. The voltage source e_t is selected such that the current through the added link is zero.

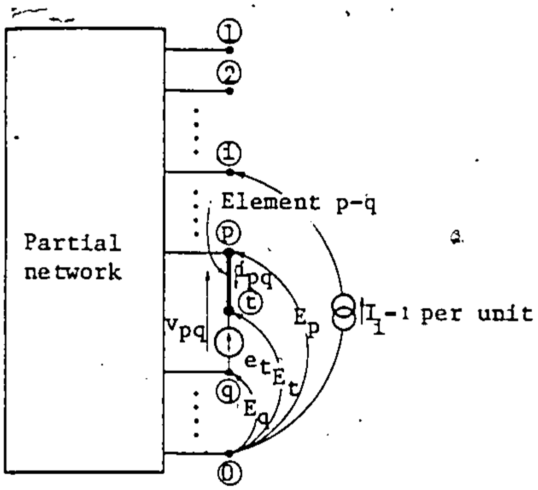


Fig. 6 Injected current voltage source in series with added link and bus voltages for calculation of Z_{ti}.

The performance equation for the partial network with the added element p-t and the series voltage source e_t is

$$\begin{array}{c} \\ E_1 \\ E_2 \\ \vdots \\ E_p \\ \vdots \\ E_m \\ e_t \end{array} = \begin{array}{c|ccccccc} & 1 & & & p & & m & t \\ \hline 1 & Z_{11} & Z_{12} & \cdots & Z_{1p} & \cdots & Z_{1m} & Z_{1t} \\ & Z_{21} & Z_{11} & \cdots & Z_{2p} & \cdots & Z_{2m} & Z_{2t} \\ & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \vdots \\ p & Z_{p1} & Z_{p2} & \cdots & Z_{pp} & \cdots & Z_{pm} & Z_{pt} \\ & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \vdots \\ m & Z_{m1} & Z_{m2} & \cdots & Z_{mp} & \cdots & Z_{mm} & Z_{mt} \\ t & Z_{t1} & Z_{t2} & \cdots & Z_{tp} & \cdots & Z_{tm} & Z_{tt} \end{array} \begin{array}{c} \\ I_1 \\ I_2 \\ \vdots \\ I_p \\ \vdots \\ I_m \\ I_t \end{array} \tag{44}$$

Since

$e_t = E_t - E_q$

the element Z_{ti} can be determined by injecting a current at the i th bus and calculating the voltage at the t th node with respect to bus q. Since all other bus currents equal zero, it follows from equation (44) that

$$\begin{aligned} E_k &= Z_{ki} I_i \qquad k = 1, 2, \ldots, m \\ e_t &= Z_{ti} I_i \end{aligned} \tag{45}$$

Letting $I_i = 1$ per unit in equations (45), Z_{ti} can be obtained directly by calculating e_t.

The series voltage source is

$$e_t = E_p - E_q - v_{pt} \tag{46}$$

Since the current through the added link is

$i_{pq} = 0$

the element p-t can be treated as a branch. The current in this element in terms of primitive admittances and the voltages across the elements is

$$i_{pt} = y_{pt,pt} v_{pt} + \bar{y}_{pt,rs} \bar{v}_{rs}$$

where

$$i_{pt} = i_{pq} = 0$$

Therefore

$$v_{pt} = - \frac{\bar{y}_{pt,rs} \bar{v}_{rs}}{y_{pt,pt}}$$

Since

$$\bar{y}_{pt,rs} = \bar{y}_{pq,rs} \quad \text{and} \quad y_{pt,pt} = y_{pq,pq}$$

then

$$v_{pt} = - \frac{\bar{y}_{pq,rs} \bar{v}_{rs}}{y_{pq,pq}} \tag{47}$$

Substituting in order from equations (47), (29), and (45) with $I_i = 1$ into equation (46) yields

$$Z_{ti} = Z_{pi} - Z_{qi} + \frac{\bar{y}_{pq,rs}(\bar{Z}_{ri} - \bar{Z}_{si})}{y_{pq,pq}} \qquad \begin{matrix} i = 1, 2, \ldots, m \\ i \neq t \end{matrix} \tag{48}$$

The element Z_{tt} can be calculated by injecting a current at the t th bus with bus q as reference and calculating the voltage at the t th bus with respect to bus q. Since all other bus currents equal zero, it follows from equation (44) that

$$E_k = Z_{kt} I_t \qquad k = 1, 2, \ldots, m$$

$$e_t = Z_{tt} I_t \tag{49}$$

Letting $I_t = 1$ per unit in equation (49), Z_{tt} can be obtained directly by calculating e_t.

The current in the element p-t is

$$i_{pt} = -I_t = -1$$

This current in terms of primitive admittances and the voltages across the elements is

$$i_{pt} = y_{pt,pt}v_{pt} + \bar{y}_{pt,rs}\bar{v}_{rs} = -1$$

Again, since

$$\bar{y}_{pt,rs} = \bar{y}_{pq,rs} \quad \text{and} \quad y_{pt,pt} = y_{pq,pq}$$

then

$$v_{pt} = -\frac{1 + \bar{y}_{pq,rs}\bar{v}_{rs}}{y_{pq,pq}} \tag{50}$$

Substituting in order from equations (50), (29), and (49) with $I_t = 1$ into (46) yields

$$Z_{tt} = Z_{pt} - Z_{qt} + \frac{1 + \bar{y}_{pq,rs}(\bar{Z}_{rt} - \bar{Z}_{st})}{y_{pq,pq}} \tag{51}$$

If there is no mutual coupling between the added element and other elements of the partial network, the elements of $\bar{y}_{pq,rs}$ are zero and

$$z_{pq,pr} = \frac{1}{y_{pq,pq}} \tag{52}$$

It follows from equation (48) that

$$Z_{ti} = Z_{pi} - Z_{qi} \qquad \begin{matrix} i = 1, 2, \ldots, m \\ i \neq t \end{matrix} \tag{53}$$

and from equation (51),

$$Z_{tt} = Z_{pt} - Z_{qt} + z_{pq,pq} \tag{54}$$

Furthermore, if there is no mutual coupling and p is the reference node,

$$Z_{pi} = 0 \qquad \begin{matrix} i = 1, 2, \ldots, m \\ i \neq t \end{matrix} \tag{55}$$

and

$$Z_{ti} = -Z_{qi} \qquad \begin{matrix} i = 1, 2, \ldots, m \\ i \neq t \end{matrix} \tag{56}$$

Also

$$Z_{pt} = 0 \tag{57}$$

and therefore,

$$Z_{tt} = -Z_{qt} + z_{pq,pq} \tag{58}$$

The elements in the t th row and column of the bus impedance matrix for the augmented partial network are found from equations (48) and (51). It remains to calculate the required bus impedance matrix to include the effect of the added link. This can be accomplished by modifying the elements Z_{ij}, where i, j = 1, 2, . . . , m, and eliminating the t th row and column corresponding to the fictitious node.

The fictitious node t is eliminated by short circuiting the series voltage source e_t. From equation (44),

$$\bar{E}_{BUS} = Z_{BUS}\bar{I}_{BUS} + \bar{Z}_{it}I_t \tag{59}$$

and

$$e_t = \bar{Z}_{tj}\bar{I}_{BUS} + Z_{tt}I_t = 0 \tag{60}$$

where i, j = 1, 2, . . . , m. Solving for I_t from equation (60) and substituting into (59)

$$\bar{E}_{BUS} = \left(Z_{BUS} - \frac{\bar{Z}_{it}\bar{Z}_{tj}}{Z_{tt}}\right)\bar{I}_{BUS} \tag{61}$$

which is the performance equation of the partial network including the link p-q. It follows that the required bus impedance matrix is

$$Z_{BUS(modified)} = Z_{BUS(before\ elimination)} - \frac{\bar{Z}_{it}\bar{Z}_{tj}}{Z_{tt}} \tag{62}$$

where any element of $Z_{BUS(modified)}$ is

$$Z_{ij(modified)} = Z_{ij(before\ elimination)} - \frac{Z_{it}Z_{tj}}{Z_{tt}} \quad (63)$$

A summary of the equations for the formation of the bus impedance matrix is given in Table 1.

Table 1 Summary of equations for formation of bus impedance matrix

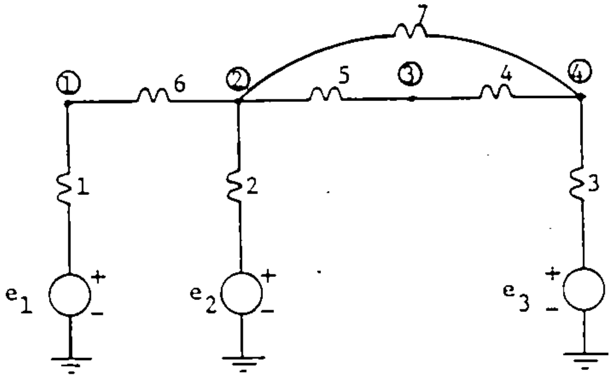
	Add p–q	p is not the reference bus	p is the reference bus
With mutual coupling	Branch	$z_{qi} = z_{pi} + \frac{\bar{y}_{pq,rs}(\bar{z}_{ri} - \bar{z}_{si})}{y_{pq,pq}}$ $i = 1, 2, \ldots, m$ $i \neq q$ $z_{qq} = z_{pq} + \frac{1 + \bar{y}_{pq,rs}(\bar{z}_{rq} - \bar{z}_{sq})}{y_{pq,pq}}$	$z_{qi} = \frac{\bar{y}_{pq,rs}(\bar{z}_{ri} - \bar{z}_{si})}{y_{pq,pq}}$ $i = 1, 2, \ldots, m$ $i \neq q$ $z_{qq} = \frac{1 + \bar{y}_{pq,rs}(\bar{z}_{rq} - \bar{z}_{sq})}{y_{pq,pq}}$
	Link	$z_{ti} = z_{pi} - z_{qi} + \frac{\bar{y}_{pq,rs}(\bar{z}_{ri} - \bar{z}_{si})}{y_{pq,pq}}$ $i = 1, 2, \ldots, m$ $i \neq t$ $z_{tt} = z_{pt} - z_{qt} + \frac{1 + \bar{y}_{pq,rs}(\bar{z}_{rt} - \bar{z}_{st})}{y_{pq,pq}}$	$z_{ti} = - z_{qi} + \frac{\bar{y}_{pq,rs}(\bar{z}_{ri} - \bar{z}_{si})}{y_{pq,pq}}$ $i = 1, 2, \ldots, m$ $i \neq t$ $z_{tt} = - z_{qt} + \frac{1 + \bar{y}_{pq,rs}(\bar{z}_{rt} - \bar{z}_{st})}{y_{pq,pq}}$
Without mutual coupling	Branch	$z_{qi} = z_{pi}$ $i = 1, 2, \ldots, m$ $i \neq q$ $z_{qq} = z_{pq} + z_{pq,pq}$	$z_{qi} = 0$ $i = 1, 2, \ldots, m$ $i \neq q$ $z_{qq} = z_{pq,pq}$
	Link	$z_{ti} = z_{pi} - z_{qi}$ $i = 1, 2, \ldots, m$ $i \neq t$ $z_{tt} = z_{pt} - z_{qt} + z_{pq,pq}$	$z_{ti} = -z_{qi}$ $i = 1, 2, \ldots, m$ $i \neq t$ $z_{tt} = -z_{qt} + z_{pq,pq}$

[redacted]

3. SHORT CIRCUIT NETWORK AND CIRCUIT VALUES

3.1 Short Circuit Network

An example of a short circuit network for 3-phase short circuit is shown in Fig. 7.



$e_1 = e_2 = e_3 = 1.0$ pu

Fig. 7 Short circuit network with constant voltage-sources

In this network all the circuit parameters are generally given in p.u. All the sources of fault current - generator, motor, utility system, etc. - are assumed to be in phase and represented by 1.0 pu constant voltage sources together with their appropriate transient or subtransient impedances.

To take advantage of Z_{BUS}, it is also worthwhile to convert voltage sources to constant current sources. Fig. 8 shows the resultant circuit with equivalent bus-current sources. Note that in the S.C. network, no link contains sources.

[redacted]

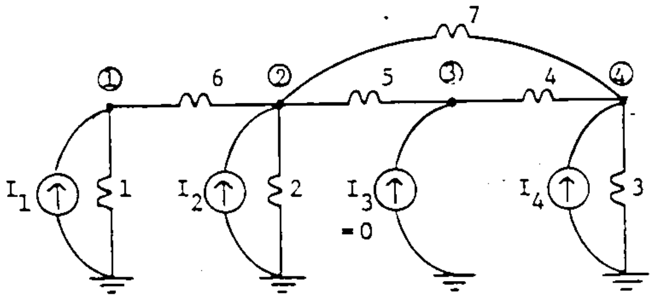


Fig. 8 Short circuit network with constant bus-current sources.

The values of bus-current sources may be obtained from primitive voltage-sources by

$$\bar{j} = -(z)^{-1}\bar{e}$$

$$\bar{I}_{BUS} = A^t\bar{j} \qquad (64)$$

Restricting the analysis only to actual electrical power system short circuit network, no source impedance has mutual coupling with any other network impedance. Thus,

$$\bar{I}_{BUS} = \begin{bmatrix} \frac{1.0}{z'_{1,0}} \\ \frac{1.0}{z'_{2,0}} \\ \vdots \\ \frac{1.0}{z'_{n,0}} \end{bmatrix} = \begin{bmatrix} y'_{1,0} \\ y'_{2,0} \\ \vdots \\ y'_{n,0} \end{bmatrix} \qquad (65)$$

where $z'_{1,0}$, for instance, is the total impedance of the sources connected to the bus 1 .

3.2 Circuit Values

Generally the following relationship stands.

$$\bar{E}_{BUS} = Z_{BUS}\ \bar{I}_{BUS}$$

or

$$\begin{bmatrix} E_1 \\ E_2 \\ \vdots \\ E_n \end{bmatrix} = \begin{bmatrix} Z_{11} & \cdots & Z_{1n} \\ \vdots & \ddots & \vdots \\ Z_{n1} & \cdots & Z_{nn} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_n \end{bmatrix}$$

By inspecting Fig. 7, it can be seen that, before fault,

$$\begin{bmatrix} E_1 \\ E_2 \\ \vdots \\ E_n \end{bmatrix} = \begin{bmatrix} 1.0 \\ 1.0 \\ \vdots \\ 1.0 \end{bmatrix} = \begin{bmatrix} Z_{11} & \cdots & Z_{1n} \\ \vdots & \ddots & \vdots \\ Z_{n1} & \cdots & Z_{n} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_n \end{bmatrix} \qquad (66)$$

If fault occurs at jth bus, the fault current can be obtained by Thevenin theorem:

$$I_F = \frac{1.0}{Z_{jj}}$$

Having a fault at this bus is identical to connecting a new current source I_F flowing from the jth bus to ground, as shown in Fig. 9.

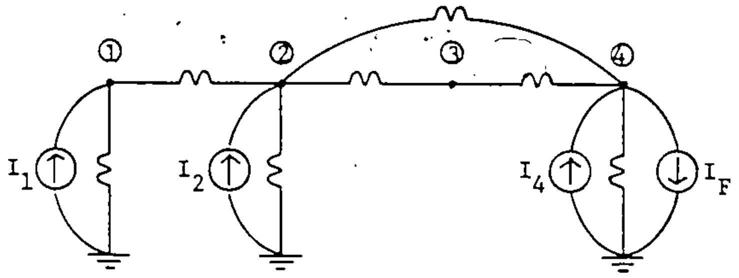


Fig. 9 New current source I_F simulating fault at bus 4.

Thus, after fault, the circuit is described by

$$\bar{E}'_{BUS} = \begin{bmatrix} E'_1 \\ \vdots \\ E'_j \\ \vdots \\ E'_n \end{bmatrix} = \begin{bmatrix} Z_{11} & \cdots & Z_{1n} \\ \vdots & \ddots & \vdots \\ Z_{n1} & \cdots & Z_{nn} \end{bmatrix} \begin{bmatrix} I_1 \\ \vdots \\ I_j - I_F \\ \vdots \\ I_n \end{bmatrix}$$

$$= \begin{bmatrix} 1.0 \\ \vdots \\ 1.0 \\ \vdots \\ 1.0 \end{bmatrix} - I_F \begin{bmatrix} Z_{1j} \\ \vdots \\ Z_{jj} \\ \vdots \\ Z_{nj} \end{bmatrix} \qquad (67)$$

Equation (67) gives the bus voltages during fault at bus j.

Line currents with fault at bus j are obtained in the following manner.

- For a line connecting 2 buses -

For the "float" network in which all lines connecting buses and ground (i.e. sources) are removed, the following stand. The subscript f denotes "float" network.

$$\bar{i}_f = (y_f)\bar{v}_f$$

$$(y_f) = (z_f)^{-1}$$

$$\bar{v}_f = A_f\bar{E}'_{BUS}$$

Thus line currents are

$$\bar{i}_f = (z_f)^{-1}A_f\bar{E}'_{BUS} \tag{68}$$

If a line has no mutual coupling,

$$i_{p,q} = \frac{E'_p - E'_q}{z_{p,q}} \qquad (p \neq 0,\ q \neq 0) \tag{69}$$

- For a line connecting a bus p and ground -

In this case the line current is simply

$$i_{o,p} = \frac{1.0 - E'_p}{z_{o,p}} \tag{70}$$

where it has been taken into account that in physical system, a fault current source, e.g. generator, etc., has no mutual coupling with other network elements.

4. ANSI METHODS FOR FAULT CURRENT CALCULATION

4.1 ANSI C37.010-1972

This standard recommends methods of calculating fault current to be used mainly for the application of high voltage circuit breakers.

4.1.1 Interrupting Duty

The standard introduces several methods, only one of which is most general and will be described here.

The basic philosophy of the method, called "E/X Method Corrected for AC and DC Decrements", is to find E/X and apply a correction factor to it.

The value obtained thus is compared with the circuit breaker interrupting rating with proper consideration of system operation voltage.

E/X implies the voltage at the fault point before fault divided by the Thevenin reactance ignoring all network resistances.

Table 2 Impedance correction factors for machines

Fault Current		X and R to be used	I.C.F.		
			C37.010-1972		C37.13-1973
			Int. Duty	Mom. Duty	Int. Duty
All turbo-generators, all hydro-generators with amortisseur windings, and all condensers		X''_d R	1.0	1.0	1.0
Hydro-generators without amortisseur windings		X'_d R	0.75	0.75	1.0
All synchronous motors		X''_d R	1.5	1.0	1.0
Induction Motors	Above 1000 HP at 1800 rpm, above 250 HP at 3600 rpm	X''_d R	1.5	1.0	1.0
	All others, 50 HP and above	X''_d R	3.0	1.2	1.0
	3-phase induction motors below 50 HP and all single-phase motors	X''_d R	∞	∞	1.0
Non-rotating equipment		X R	1.0	1.0	1.0
Utility supply		X R	1.0	1.0	1.0

For the calculation of X, network reactance data should be prepared in accordance with Table 2. The factors appearing in the table may be called "Impedance Correction Factors (ICF)".

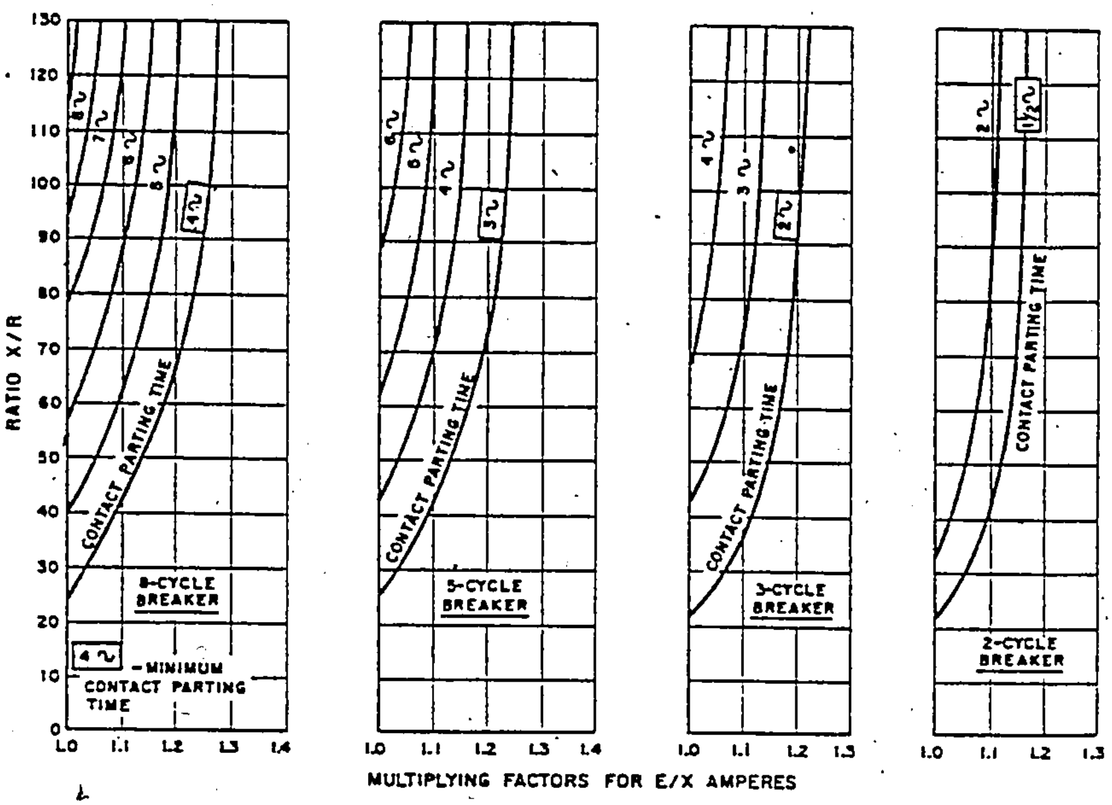


Fig. 10 Multiplying factors for three-phase faults fed predominantly from generators through not more than one transformation (From ANSI Standard C37.010-1972).

E/X is, in other words, the steady state component of fault current obtained assuming that machine reactances are constant at their corrected values.

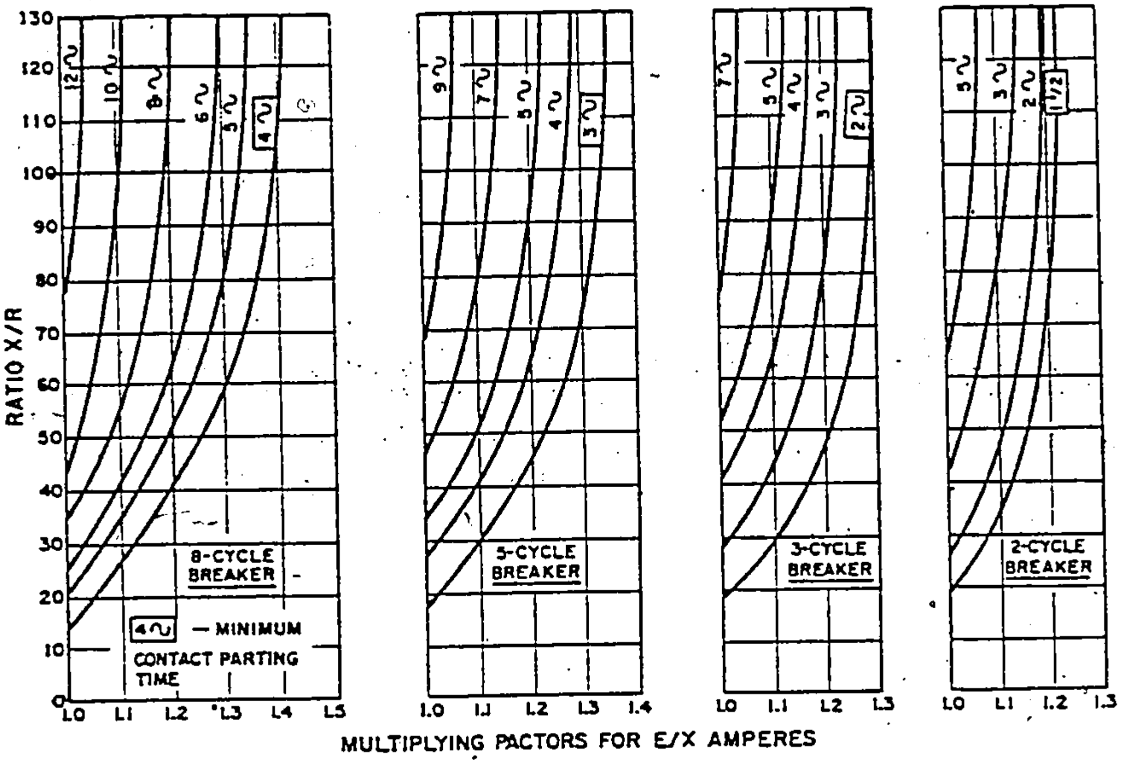


Fig. 11 Multiplying factors for line-to-ground faults fed predominantly from generators through not more than one transformation (From ANSI Standard C37.010-1972).

To take into account the DC and AC transient components of the fault current, a correction factor, "Current Correction Factor (CCF)", is applied to E/X.

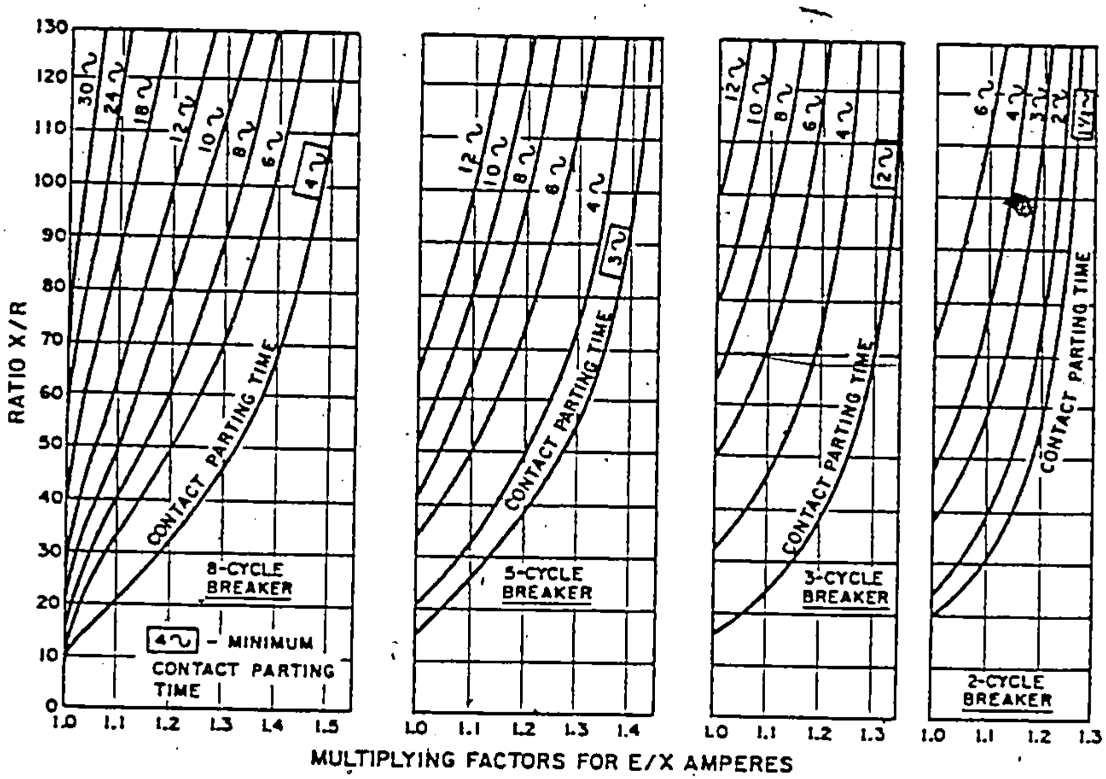


Fig. 12 Multiplying factors for three-phase and line-to-ground faults fed predominantly through two or more transformations (From ANSI C37.010-1972).

CCF depends on the rated interrupting time and contact parting time of the circuit breaker and on the X/R ratio of the network seen from the fault point. The R, which is necessary to find X/R, is also obtained with complete disregard for the reactances and with proper correction in accordance with Table 2, like X. Given these three pieces of information, CCF is obtained from Fig. 10, 11 and 12.*

* CCF = "Multiplying factors" of Fig. 10, 11 and 12

In utilizing Fig. 10, 11, and 12, there is a difficulty concerning number of transformations.

As noted from these curve titles, the Current Correction Factors are a function of the number of transformations the faulted bus is away from the generators. The standard does not define an impedance or transformer size to put a definite fix on what is considered an equivalent transformation. This procedure leaves doubt as to what to do in some cases. For example, why should a 20MVA transformer and a 1000kVA transformer each be considered a transformation, since the per unit impedances of each are greatly different? Can reactors or long lines be equivalent to a transformer, since the impedances may be of equal magnitude? How does one consider a bus with a generator on it and a generator two transformations away?

Those interpretations in Ref. 5 and 6 furnish answers to these questions. The answer is to measure the amount of fault current from the local generators and remote utility sources. The designated remote sources are always considered "remote", while local generators may have both a "local" and "remote" portion of fault current contribution depending on the fault location. As the fault location is removed away from the local generators terminals, the remote portion of the fault current increases. This interpretation provides a gradation between the "local" and "remote" extremes of AC decay provided in the standards. The local and remote portion of the fault current is determined from the expressions:

$$\text{Local portion} = \frac{\text{(Contribution of the gen. to faulted bus)}}{\text{(Contribution of the gen. if fault occurs at the gen. terminals)}} \times \text{(Contribution of the gen. to faulted bus)}$$

$$\text{Remote portion} = \text{(Contribution of the gen. to faulted bus)} - \text{(Local portion)}$$

[redacted]

If there are more than one local generators, remote portion for each generator should be calculated. A measure as to the closeness the generators are to the fault bus is determined by a No A.C. Decrement ratio.

$$\text{NACD ration} = \frac{\text{Sum of remote portions}}{\text{Total gen. contribution to fault current}}$$

If the ratio is 0, Fig. 10 or 11 would be used, while Fig. 12 would be used if the ratio is equal to 1. Fig. 13 gives some of the interpreted values between Fig. 10 or 11, and 12.

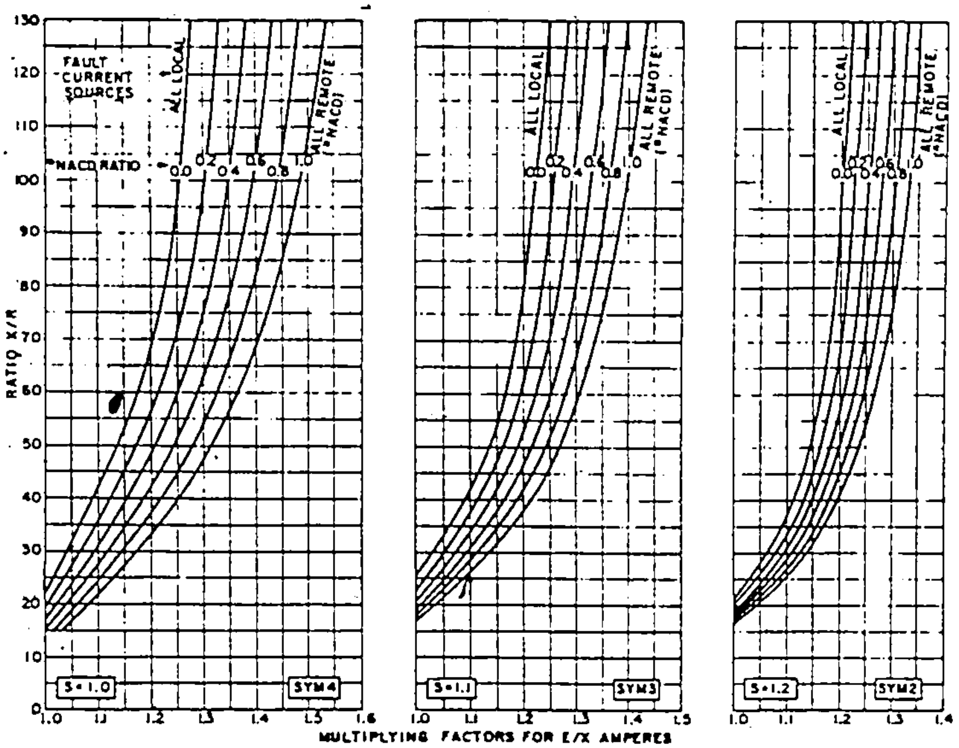


Fig. 13 Multiplying factors (symmetrical current rating basis) for three-phase faults fed from both local and remote generations.(5,6)

For 3-phase short circuit calculation, NACD ratio is determined by the above mentioned method. For 1L-G short circuit calculation, because of certain limitations of the program, exact value of NACD ratio is difficult to obtain. But as a good approximation, NACD ratio is obtained from the zero sequence network.

4.1.2 Momentary Duty

Momentary duty to be obtained by calculation is E/X where X is Thevenin reactance reduced from the network with corrected machine reactances in accordance with Table 2.

E/X obtained thus is compared with the momentary rating of circuit breaker with proper consideration of operating voltage of the system.

It is to be noted that the standard does not show which one of E/X and E/Z (Z: Thevenin impedance) should be used. To be more conservative, generally E/X is used.

4.2 ANSI C37.13-1973

This standard includes certain guides for the calculation of low voltage circuit breaker interrupting duty. Note that for low voltage circuit breaker, interrupting duty and momentary duty are not distinguished.

The recommended method is first to obtain E/X, where X is Thevenin reactance neglecting resistance of the network and then to apply a correction factor to it. The value obtained thus is compared with the interrupting rating of the circuit breaker.

For a low voltage network, E/Z, where Z is the Thevenin impedance, is frequently used. However, to be more conservative, E/X is nevertheless used especially when the network consists mainly of motors.

For the calculation of X, the network reactances are directly used without any correction as shown in Table 2.

The correction factor applied to E/X, say "Current Correction Factor (CCF)", is employed to take into account the effect of system resistances on the fault current. CCF depends on system X/R. But X/R is not as clearly defined in the standard as in C37.010-1972. Thus, in this report the same definition is used. With X/R given, CCF is obtained from Table 3.

Table 3 Current correction factors:
from ANSI C37.13-1973

X/R ratio	C.C.F.
6.6 or smaller	1.00
8.27	1.04
9.95	1.07
11.72	1.09
14.25	1.11
20.0 or bigger	1.15

5. COMPUTER PROGRAM - SHTCCT

The computer program (App. B) can be used primarily for the calculation of 3-phase short circuit current (also 1 line-to-ground short circuit current with some limitations) based on the recommendations of two ANSI standards, C37.010-1972 and C37.13-1973.

The method used is a driving point and transfer impedance matrix approach. In the program two separate matrices, R_{BUS} and X_{BUS}, are constructed instead of having one Z_{BUS} to go by ANSI recommendations.

To form R_{BUS} and X_{BUS}, the direct method described in section 2-2 is used. Since these matrices are symmetrical, only the lower half is stored for each of them to reduce storage requirement.

Based on these matrices, circuit values are calculated by the simple manipulations described in Chapter 3.

To give flexibility to the program, abundant options have been incorporated. For details of these flexibilities, User Manual (App. A) can be referred to.

To take into account the Current Correction Factors for H.V. circuit breakers, almost all of the related curves given in Figs. 10, 11, and 12 have been fitted into sixth order polynomials by least square fitting and put in a subroutine.

Also for C.C.F. for L.V. circuit breaker, Table 3 is fitted into a group of formulae which will give C.C.F. by linear interpolation.

To demonstrate the validity and efficiency in application of the program, studies of several sample systems are included in App. C.

[redacted]

6. CONCLUSION

The methods of calculating short circuit duties are not new features. One of them has been simply reviewed in Chapter 2 of this report.

A newly defined "float" network element-bus incidence matrix A_f has been introduced (Eq. 4) and one of its convenient applications has been demonstrated (Eq. 68).

A computer program has been developed using part of this method for practical applications in line with current ANSI standards.

What is important in developing a program for digital computers to calculate short circuit currents are:

- how to manipulate the system
- how to apply the theory
- what to calculate
- how to consider standard recommendations

to achieve the purpose of minimum cost and maximum benefits, and it can be said that with this program much of the purpose has been achieved.

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2. G.W. Stagg and A.H. El-Abrad: Computer Methods in Power System Analysis, McGraw-Hill, New York, 1968.

3. American National Standard C37.010-1972: IEEE Standard Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

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5. W.C. Huening: Interpretation of New American National Standards for Power Circuit Breaker Applications, IEEE Trans. on Industry and General Applications, vol. IGA-5, no. 5, Sept/Oct 1969, pp. 501 - 523.

6. General Electric Energy Systems Operation: User Manual for Time-Sharing Computer Program for Calculating Three-Phase Short-Circuit Currents, May 1973, Schenectady, N.Y.

APPENDIX A

USER MANUAL
FOR PROGRAM
SHTCCT

MACHINE	CDC 172
COMPILER	FTN
LANGUAGE	FORTRAN IV

1. SINGLE LINE DIAGRAM

Draw a single line diagram showing all quantities in per unit on a common base. Then number the buses using only the numbers between 1 and 99. Even when more than 2 independent networks are to be analyzed by one running, no number can be used multiple times throughout the whole network.

For 3 phase short circuit study, one single line diagram, which represents the positive sequence network of the system, is enough.

For 1-line-to-ground short circuit study, a zero sequence single line diagram is also needed in addition to the positive sequence single line diagram. In the program it has been assumed that positive sequence network is identical to negative sequence network except in the latter there is no source.

An important note is that 1 L-G study should always be preceeded by 3 phase study since some values obtained in 3 phase study are used for the following 1 L-G study. In this case the "Case Connection Card" (explained later) between card deck for 3 phase study and that for 1 L-G study should read 2, which is same code as that for "NEW CASE". The same bus numbers should be used for both 3 phase and 1 L-G study.

In zero sequence network there will be usually several subnetworks which are independent from each other. Subnetworks which do not contain a line connecting a real bus and the ground should be completely removed. The program is written such that a subnetwork which is not connected to the ground results in an error message:

".EACH SUBNETWORK SHOULD CONTAIN ZERO-BUS"

and computation is terminated.

2. INPUT DATA CARDS

2.1 Case Bundles

Input data card deck consists of several case bundles. There are six card groups and a flag card, called "CASE CONNECTION CARD", in each case bundle.

There is no limitation on the number of case bundles.

The general structure of data deck is shown in Table A1.

Comments on Case-Connection Card

On this card 1, 2 or 0 (or blank) should be put in the first column.

1...A change case based on the present case follows.

2...A new case on 1 L-G study case follows.

0...No more case.

Comments on Change Case and New Case

When the next case is a new case, all information given so far is discarded.

When the next case is a change case, all the network topology which has been given cumulatively to the computer so far is retained. But other information than that is completely discarded.

When the next case is 1 L-G study case, all information given so far is discarded like a new case except Thevenin X and R obtained from the present case for all network buses.

For change cases, addition of lines and buses is accomplished simply by putting them in the 6th card group of the next case bundle.

Table A1 Structure of input card deck

Case bundle	Group	Identification
1st case bundle	1st group	"Job name"
	2nd group	"Base MVA, etc"
	3rd group	"Bus in question"
	4th group	"Remote monitoring"
	5th group	"Bus voltages"
	6th group	"Impedances"
	case connection card	"Case connection"
2nd case bundle	⋮	⋮
⋮	⋮	⋮

To remove existing lines, the negative of R and X of existing lines should be put in the 6th card group of the next case bundle. When there is more than one line connecting two buses, same number of negative line information should be given one by one to remove all of the existing lines. Removal of a bus is achieved by eliminating all lines incident to the bus.

2.2 Groups

Each case bundle consists of six card groups and one connection card. The six groups will be explained below one by one.

<u>1st Group</u>

- Job name and Description
- Only one card

This card contains any information which the user may want to show on the printout to identify project.

Use 1 - 40th columns for job name and 51-80th column for additional information.

(Example)

Input

1	41...
EXAMPLE...G.W. STAGG	NONE

Output

JOB NAME = EXAMPLE...G.W. STAGG

DESCRIPTION = NONE

2nd Group

- Base MVA, Fault type, Option code for R_{BUS} and X_{BUS} matrices printing.
- Only one card

Put the base MVA at any place in the first 10 columns with decimal point, the code 3 or 1 in the 11th column for type of fault, and the code 0 or 1 in the 12th column for option for R_{BUS} and X_{BUS} matrices printing.

(Example)

1	2	3	4	5	6	7	8	9	10	11	12
		2	5	0	.					3	1
A										B	C

A : Base MVA

B : Type of fault

3 = 3 phase short circuit

1 = 1 L-G short circuit

C : Option

0 - Don't print matrices

1 - Print them

3rd Group

- Buses in question,
  Duty classifications to be considered.
- As many cards as needed

This group should be one of the following two configurations.

(1) Only one card showing 111 in its first three columns.

Put this card when duty calculations for all buses are required. The card should be

1	2	3	...
1	1	1	

When this card is put, duty calculations are done, as follows, for all buses.

L.V. Bus = Int. duty

H.V. Bus = Mom. duty

Int. duty for the breakers:

2 cycle Int. time 1.5 cycle parting time

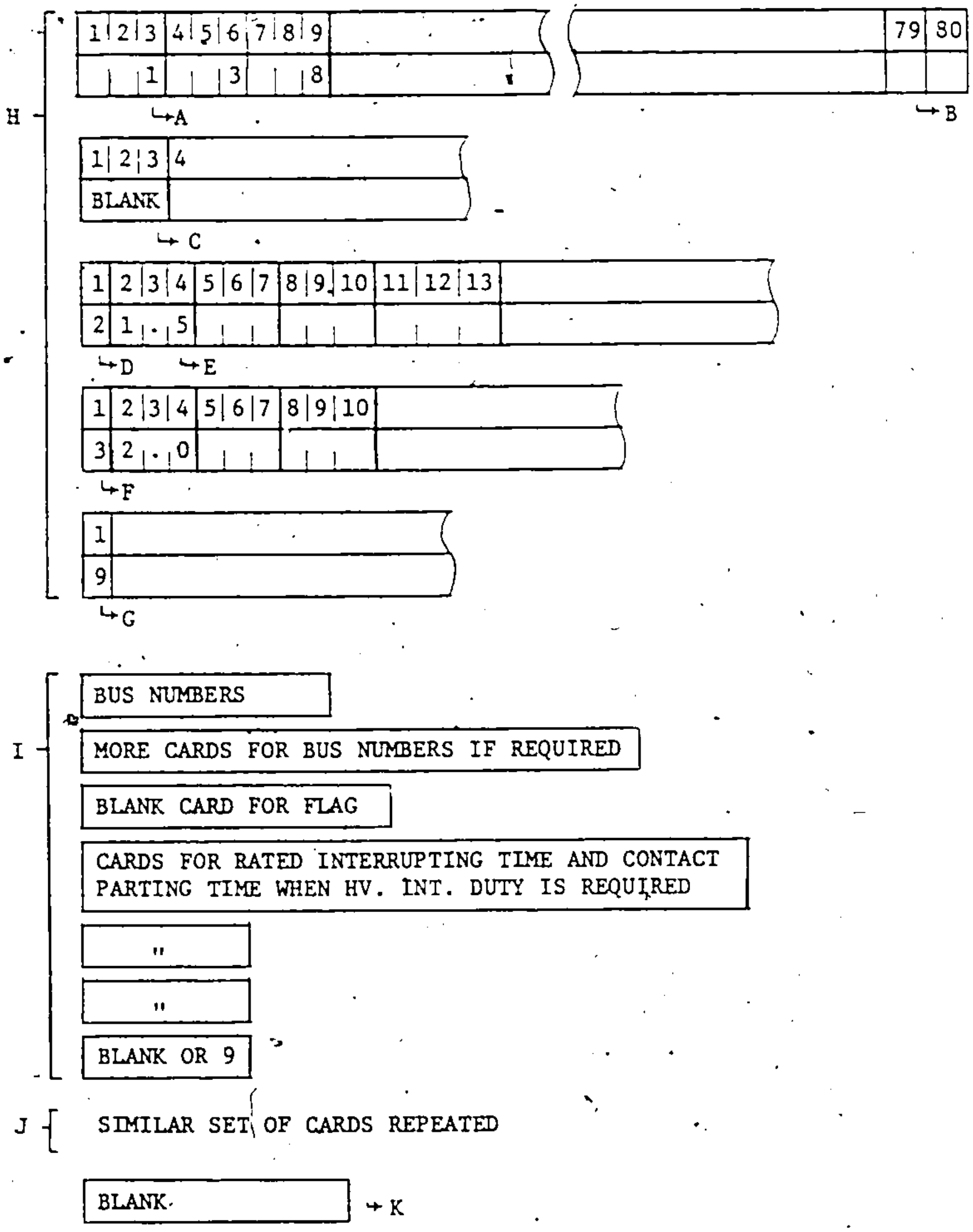
3 cycle Int. time 2.0 cycle parting time

5 cycle Int. time 3.0 cycle parting time

8 cycle Int. time 4.0 cycle parting time

(2) As many cards as required to specify the bus numbers and breakers rated interrupting time and contact parting time, etc., as illustrated below by examples.

(Example 1)

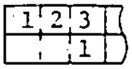

1 2 3 4 5 6 7 8 9
79 80
1 3 8
A
B
H
1 2 3 4
BLANK
C
1 2 3 4 5 6 7 8 9 10 11 12 13
2 1 . 5
D
E
1 2 3 4 5 6 7 8 9 10
3 2 . 0
F
1
9
G
I
BUS NUMBERS
MORE CARDS FOR BUS NUMBERS IF REQUIRED
BLANK CARD FOR FLAG
CARDS FOR RATED INTERRUPTING TIME AND CONTACT PARTING TIME WHEN HV. INT. DUTY IS REQUIRED
"
"
BLANK OR 9
J
SIMILAR SET OF CARDS REPEATED
BLANK
K

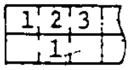
Explanation

A : Put bus numbers carefully.

Each bus number occupies 3 columns.

Note the difference between



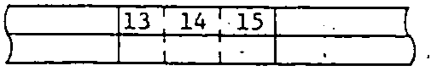
and


. The former is 1 while the latter is 10.

One card may contain 26 bus numbers.

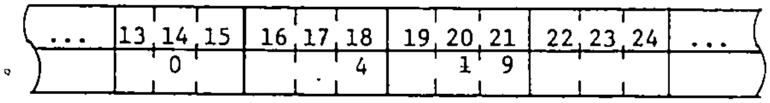
Note that the biggest bus number possible is 99.

If a card contains zero, like:



then the zero is ignored but the subsequent information is respected.

For example, with a card like



bus numbers 4 and 19 are respected.

B : Any information in 79 and 80th columns is ignored.

C : This is a flag to end cards for bus numbers.

D : Rated interrupting time should be put in the first column, if required.

E : Contact parting times, correcponding to the rated interrupting time put in the first column, should be put in three columns.

If one more contact parting time is to be examined it can be put in the next three columns.

Contact parting time must be REAL number (i.e. it must include decimal point).

F : If another rated interrupting time is to be examined, use another card and put the rated interrupting time in the first column and the corresponding contact parting times in the subsequent blocks of three columns.

G : This is a flag to end the first "subgroup".

This flag should be either 9 or zero.

9 : first cycle duty required

0 (or blank) : first cycle duty - not required

H : This is the first "subgroup" of the 3rd Card Group.

For this particular example, duty calculations will be done as follows:

For bus 1 (assume this bus is H.V.)

- Interrupting duty calculation
  - : for 2 cycle R. I. time, 1.5 cycle C.P. time
  - : for 3 cycle R. I. time, 2.0 cycle C.P. time

    *See note on the next page.
- Momentary duty (first cycle duty) calculation will be done.

For buses 3 and 8 (assume these are L.V.)

- Interrupting duty (first cycle duty) calculation will be done.

I : Put another "subgroup" if wanted.

If buses included in this subgroup are all L.V. buses, cards for R.I. time and C.P. time are not required.

J : Put another subgroup if wanted.

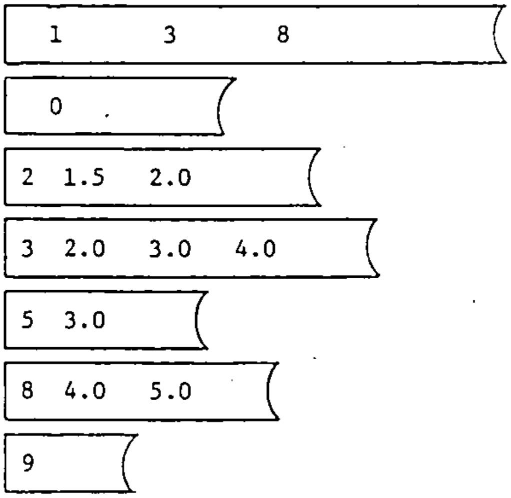
K : This is flag to end the 3rd Card Group.

The number of "subgroups" in this 3rd Card Group is unlimited.

*NOTE

(1) The maximum number of cases for H.V. Int. duty calculation per "subgroup" cannot exceed 7.

e.g.



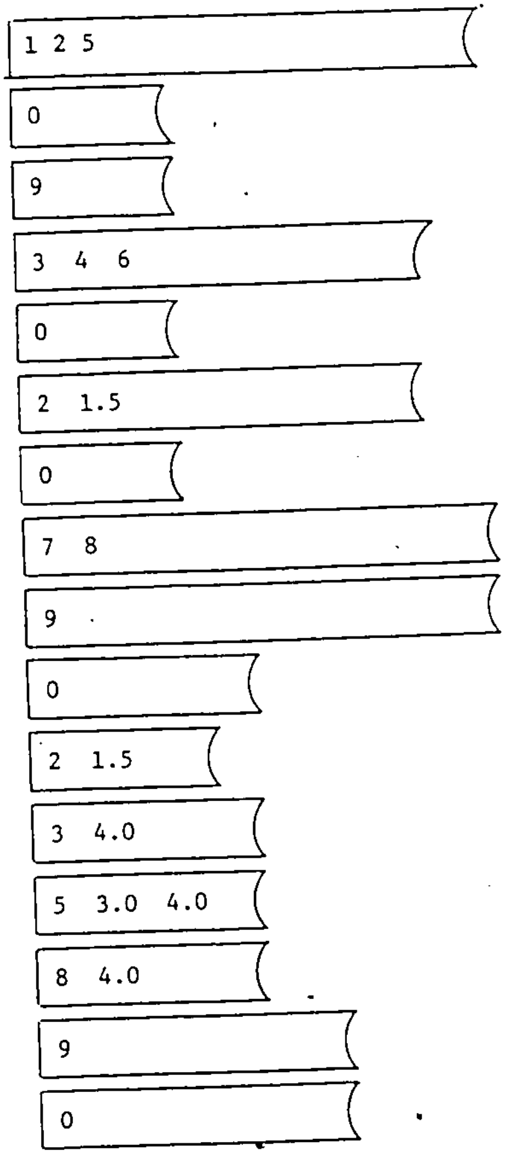
The above is invalid because 8 cases are requested. Actually this makes a big error. No diagnosis is provided.

(2) Permitted combintations are as follows:

R.I. Time	C.P. Time
2	1.5 , 2.0
3	2.0 , 3.0 , 4.0
5	3.0 , 4.0 , 5.0 , 6.0
8	4.0 , 5.0 , 6.0 , 7.0 , 8.0

Thus, for example, request for "2 cycle R.I. time and 3.0 cycle C.P. Time" duty calculation is invalid. Error message is provided.

(Example 2)



```
1 2 5
0
9
3  4  6
0
2  1.5
0
7  8
9
0
2  1.5
3  4.0
5  3.0  4.0
8  4.0
9
0
```

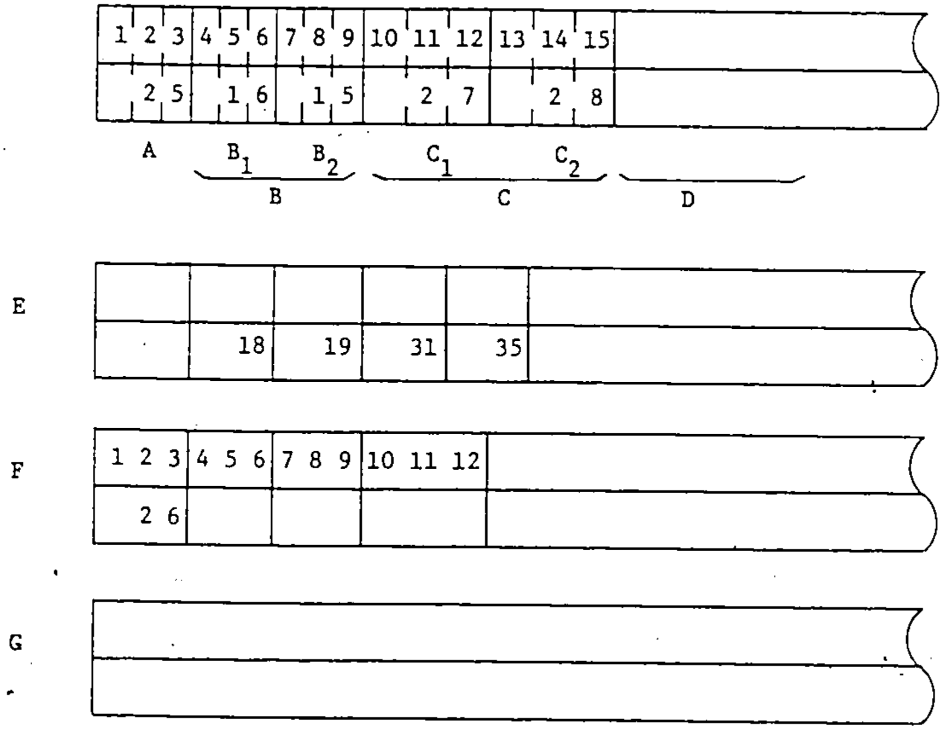
Explanation will not be given for this additional example.

4th Group

- Remote monitoring
- As many cards as required

By giving the identifications of lines, the current through the lines and the bus voltages at both ends of the lines can be obtained corresponding to a particular faulted bus.

(Example)



Explanation

A : Faulted Bus number.

B : Line identification

B_1 : From-bus

B_2 : To-bus

C, D : same as B

*If there is more than one line between bus B_1 and B_2, current through each individual line is printed.

*If the whole card is empty except the columns for faulted bus (position A), then monitoring for all lines is performed for that faulted bus.

E : If one more card is needed to accommodate all monitored line identifications corresponding to the faulted bus, the first three columns of the continuing card should be left empty and the rest of it can be used for bus pairs.

F : For monitoring corresponding to another faulted bus, another set of information similar to A~E should be given.

G : The 4th Card Group is terminated by this blank card.

*If no remote monitoring is wanted, one blank card should be put in the 4th Card Group position.

*The number of cases of "remote monitoring" should be compared with the value of MAXMON (See DATA statement of the program SHTCCT).

If, e.g., the whole 4th Card Group is like this,

1 5	2 2	2 3	2 3	3 1	
1 8	2 0	2 2			
	3 2	2 0	2 2	2 5	
BLANK					

then the number of "remote monitoring cases" is 5.

And faulted buses appearing in this card group is 2.

Then MAXMON should not be smaller than 7 (=5 + 2).

5th Group

- Bus voltages
- As many cards as needed

For all buses listed in the 3rd card group ("BUS IN QUESTION") the bus voltages should be given.

Excess information is not used, i.e. any bus voltage specification for a bus which is not listed in "BUS IN QUESTION" is ignored.

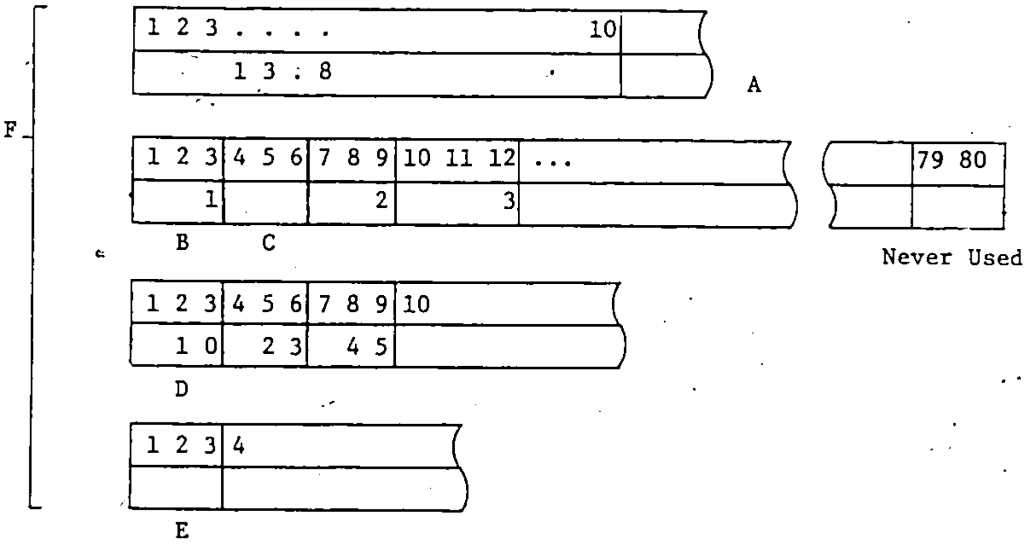
This group consists of as many subgroups as the number of voltage levels.

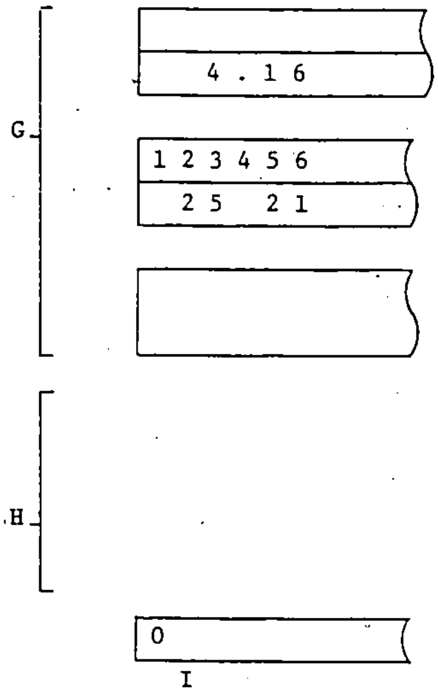
Each subgroup consists of one card for voltage (kV), as many cards as needed for the buses of that voltage level, and one card for flag.

This 5th Card Group should end with a flag which is blank or zero.

An example is given below.

(Example)





Explanation

A : Bus voltage should be put somewhere in the first 10 columns.
It must have decimal point.

B : One card can contain 26 buses. Each bus number occupies 3 columns.
The first 3 columns should contain nonzero bus number.
*Note: the biggest bus number = 99.

C : Zero bus number is ignored but subsequent nonzero bus numbers are respected.

D : If one card is not enough to accommodate all the buses at this voltage level, use another or more cards as required.

E : This is flag to end the "subgroup" for this voltage (here, 13.8 kV).

F,G,H : Put as many subgroups as the number of voltage levels.

I : This card is flag to end the "BUS-VOLTAGES" section.

6th Group

- Bus pair, R and X, Identification.
- As many ~~cards~~ as needed

This group contains network information. The two bus numbers at both ends of the line, line resistance and reactance, line identification code are contained in each card.

No special sequence is required for cards in this group.

If the branch identification codes are properly put in, the consideration of "Impedance Correction Factor" and "Current Correction Factor" is automatically achieved by the program.

The "Impedance Correction Factor" and the identification (or classification) code is tabulized in Table A2.

This group must end with a flag which is a blank (or zero) card.

Table A2 Impedance Correction Factors and Line Identification Codes

* I.C.F. has been stored in the program.

Iden. Code	Low Voltage Int. Duty (=First Cycle)	High Voltage Int. Duty	High Voltage Mom. Duty (=First Cycle)
1	1.0	1.0	1.0
2	1.0	0.75	0.75
3	1.0	1.5	1.0
4	1.0	1.5	1.0
5	1.0	3.0	1.2
6	1.0	(=100000.0)	(=100000.0)
7	1.0	1.0	1.0
8	1.0	1.0	1.0

Iden. Code

1 - - - All turbo-generators, all hydro generators with amortisseur windings, and all condensers.

Put X''_d on data card.

2 - - - Hydro-generators without amortisseur windings.

Put X'_d on data card.

3 - - - All synchronous motors

Put X''_d on data card.

4 - - - Induction motors above 1000 HP at 1800 r/min, above 250HP at 3600 r/min.

Put X''_d on data card.

5 - - - Induction motors other than the above but equal or greater than 50 HP.

Put X''_d on data card.

6 - - - Induction motors less than 50 HP

Put X''_d on data card.

7 - - - Non-rotating equipment (Cable, reactor, transformer, etc.)

Put X on data card.

8 - - - Utility System, Outside Source, etc.

Put X on data card

Information should be put in the following manner.

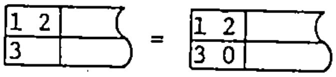
1 2	3 4	5 . . . 14	15 24	25	
A	B	C	D	E	

Explanation

A : Bus number

B : Bus number

* Note



C : Resistance R

Decimal point must always appear and can be put anywhere in the range.

If an R is zero, all resistances are ignored. And for L.V. duty calculations, two results will be shown:

(1) E/X

(2) E/X multiplied by 1.15 as per ANSI C37.13-1973, 9.1.4.3.

If R is zero and H.V. interrupting duty calculation is required, program stops with an error message.

D : Reactance X

Decimal point must always appear and can be put anywhere in the range.

X cannot be zero.

If an X is zero, program stops with an error message.

E : Line identification code

One of eight identification codes defined in Table A1 should be put here.

If it is left empty, that line is assumed to be a non-rotating equipment (Iden. Code = 7).

* Comment on R and X

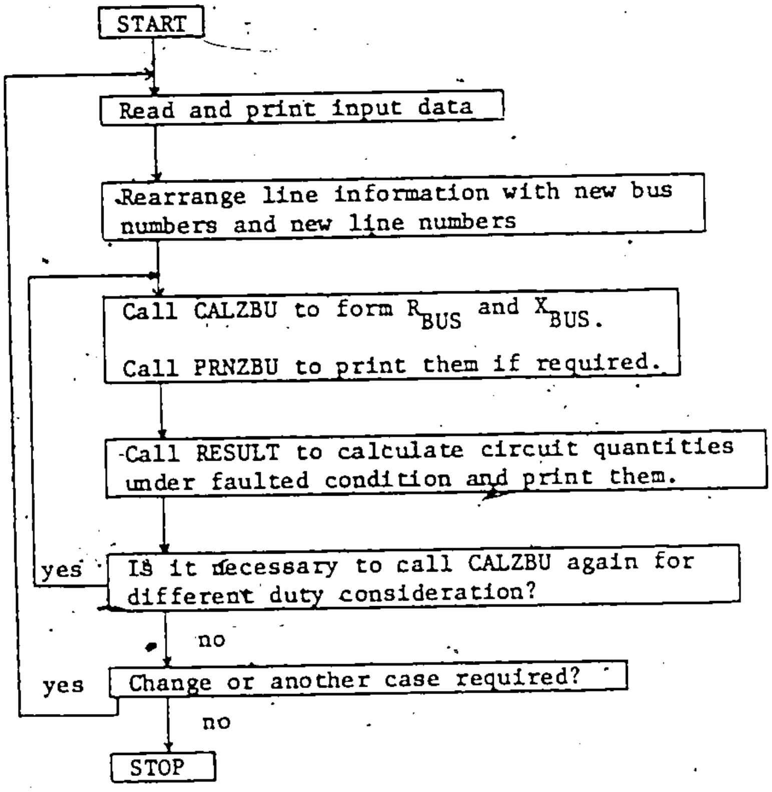
R and X can be negative only when a previously existing line is to be eliminated.

It is important that the absolute values of these negative R and X be exactly equal to those of the line to be eliminated. Otherwise program will stop with an error message.

APPENDIX B

COMPUTER PROGRAMS

1. FLOW CHART FOR PROGRAM SHTCCT



2. USAGE OF IMPORTANT VARIABLES

2.1 Single variables

The following integers should be defined in DATA statement in SHTCCT.

N9 : Should not be smaller than the maximum number of network buses.
Cannot be bigger than 99,

N30 : Should not be smaller than the total number of network lines.
Cannot be bigger than 999.

N495 : Should not be smaller than N9*(N9+1)/2

N10 : N10 = N9+1

MAXMON : Should not be samller than the number of remote monitoring cases plus the number of faulted buses appearing in 4th card group in any one case bundle.

2.2 Arrays

ENQUIR(---): Dimension should not be smaller than N9.

If ENQUIR(5) = 99920399152., the duty calculation for bus 5 is done in the following manner.

9	99	20	3	99	15	2
A	B	C	D	E	F	G

(1) If bus 5 is H.V.

G,F --- Do interrupting duty calculation for 2 cycle rated interrupting time and 1.5 cycle contact parting time.

E --- Partition

D,C --- Do interrupting duty calculation for 3 cycle rated interrupting time and 2.0 cycle contact parting time.

B --- Partition

A --- Do momentary duty calculation

* If A is 0, mom. duty calculation is not done.

(2) If bus 5 is L.V.

B, - G --- All ignored

A --- Do int. duty calculation for bus 5.

* If A is 0, no duty calculation is done.

MONTOR(--) : Dimension should not be smaller than MAXMON. Information related to remote monitoring is stored here.

IOLNWB(--) : Dimension should not be smaller than N9. If IOLNWB(5) = 9, 5 is user-given bus number while 9 is program-given bus number.

INCDEN(--) : Dimension should not be smaller than N30. If INCDEN(5) = 72031008, the 5th line information for a given case corresponds to the line connecting buses 20 and 31, the iden. code is 7, and program given rank is 008 after new arrangement.

VOLBUS(--) : Dimension should not be smaller than N9. This is bus voltage.

ROLBRN(--),XOLBRN(--) : Dimension should not be smaller than N30. These are line R and X.

RBUS(--), XBUS(--) : Dimensions should not be smaller than N495. These are R_{BUS} and X_{BUS}.

AUXRBU(--), AUXXBU(--) : Dimension should not be smaller than N10. These are used to form R_{BUS} and X_{BUS}.

3. PROGRAM LISTING

```
                 * C O N C O R D I A   U N I V E R S I T Y   C O M P U T E R   C E N T E R *

                                      JOB ORIGIN = REMOTE.

           NOS 1.2-446       DATE = 78/05/06.    TIME-ON =    15.41.41.    TIME-OFF =    15.47.28.

HWANG2      HH        HH  WW        WW   AAAAAAAAAA   NN        NN  BBBBBBBBBBB    AAAAAAAAAA   ZZZZZZZZZZZZ      HWANG2
HWANG2      HH        HH  WW        WW  AAAAAAAAAAAA  NNN       NN  BBBBBBBBBBBB  AAAAAAAAAAAA  ZZZZZZZZZZZZ      HWANG2
HWANG2      HH        HH  WW        WW  AA        AA  NNNN      NN  BB        BB  AA        AA  Z         ZZ      HWANG2
HWANG2      HH        HH  WW        WW  AA        AA  NN NN     NN  BB        BB  AA        AA           ZZ       HWANG2
HWANG2      HH        HH  WW        WW  AA        AA  NN  NN    NN  BB        BB  AA        AA          ZZ        HWANG2
HWANG2      HH        HH  WW        WW  AA        AA  NN   NN   NN  BB        BB  AA        AA         ZZ         HWANG2
HWANG2      HH        HH  WW   WW   WW  AA        AA  NN    NN  NN  BB        BB  AA        AA        ZZ          HWANG2
HWANG2      HHHHHHHHHHHH  WW   WW   WW  AA        AA  NN     NN NN  BBBBBBBBBBBB  AA        AA    ZZZZZZZZ        HWANG2
HWANG2      HHHHHHHHHHHH  WW  WWWW  WW  AAAAAAAAAAAA  NN      NNNN  BBBBBBBBBBB   AAAAAAAAAAAA       ZZ           HWANG2
HWANG2      HH        HH  WW W    W WW  AAAAAAAAAAAA  NN       NNN  BB        BB  AAAAAAAAAAAA      ZZ            HWANG2
HWANG2      HH        HH  WW WW  WW WW  AA        AA  NN        NN  BB        BB  AA        AA     ZZ             HWANG2
HWANG2      HH        HH  WW W    W WW  AA        AA  NN        NN  BB        BB  AA        AA    ZZ              HWANG2
HWANG2      HH        HH  WWWW    WWWW  AA        AA  NN        NN  BB        BB  AA        AA   ZZ               HWANG2
HWANG2      HH        HH  WWW      WWW  AA        AA  NN        NN  BB        BB  AA        AA  ZZ         Z      HWANG2
HWANG2      HH        HH  WWW      WWW  AA        AA  NN        NN  BBBBBBBBBBBB  AA        AA  ZZZZZZZZZZZZ      HWANG2
HWANG2      HH        HH  WW        WW  AA        AA  NN        NN  BBBBBBBBBBB   AA        AA  ZZZZZZZZZZZZ      HWANG2
```

(POOR PRINT)

```
      PROGRAM SHTCCT      73/172  OPT=1                FTN 4.6+446       78/05/06. 15.45.54       PAGE    1

            PROGRAM SHTCCT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
            DOUBLE ENQUIR(55),ENFO,DENOM
            DIMENSION  MONTOR(100),           INOBUS(26),PTIM(10),
           -PNSEQR(55),PNSEQX(55),
           -VOLBUS(55),FACTOR(8,3),IOLNWB(55),INCDEN(120), NORMAL(100),
           -ROLBRN(120),XOLBRN(120),
           -RBUS(1540),XBUS(1540),AUXRBU(56 ),AUXXBU(56 )
            DATA ROLBRN/120*0./,XOLBRN/120*0./,INCDEN/120*0/,
           -FACTOR/9*1,0,0,75,2*1,5,3,0,100000,0,3*1,0,0,75,2*1,0,1,2,
           -100000,0,2*1.0/,
           -N9/55/,N30/120/,N495/1540/,N10/56 /,MAXMON/100 /
      C
      C****       SHTCCT IS A SHORT CIRCUIT CURRENT CALCULATION PROGRAM.    *******
      C
            IFCHAN=2
            PRINT 1000
      1000  FORMAT(1H1,30X,*SHORT CIRCUIT STUDY*)
            IF(N495-N9*(N9+1)/2)2,8,8
      2     PRINT 1002
      1002  FORMAT(1H ,*ERROR...N495 MUST NOT BE SMALLER THAN */
           -1H ,*N9(N9+1)/2*)
            STOP
      8     ENFO=0.0D0$DENOM=0.0D0
            JLV=-1$JHI=-1$JHF=-1
            NB=8$N3=3$NUMB=0$MAXBUS=0
            IKK=1
      C
            DO 605 K9=1,N9
            ENQUIR(K9)=0.0D0
            IOLNWB(K9)=0
      605   VOLBUS(K9)=0
            DO 610 K495=1,N495
            RBUS(K495)=0
      610   XBUS(K495)=0
            DO 615 KMON=1,MAXMON
      615   MONTOR(KMON)=0
            DO 620 IDDL=1,IBRN
      620   INCDEN(IDDL)=INCDEN(IDDL)/1000*1000
      C
      3     READ(5,1)(NORMAL(I),I=1,8)
      1     FORMAT(8A10)
            WRITE(6,5)(NORMAL(I),I=1,8)
      5     FORMAT(1H1////1H ,*JOB NAME=*,4A10//1H ,*DESCRIPTION=*,4A10)
            READ(5,7)BMVA,ITYPE,IFZBU
      7     FORMAT(F10.2,I1,I1)
            WRITE(6,10)BMVA
      10    FORMAT(1H ,*BASE MVA=*,F10.2)
            IF(ITYPE-3)20,15,20
      15    WRITE(6,16)
      16    FORMAT(1H ,*TYPE OF FAULT=3PHASE SHORT CIRCUIT*)
            GO TO 35
      20    IF(ITYPE-1)30,25,30
      25    WRITE(6,26)
      26    FORMAT(1H ,*TYPE OF FAULT=1LINE TO GROUND SHORT CIRCUIT*)
            GO TO 35
      30    WRITE(6,31)
      31    FORMAT(1H ,*ERROR IN INPUT...11TH COLUMN OF 2ND*
```

POOR PRINT

```
     -/1H ,*DATA CARD SHOULD BE EITHER 3 OR 1*)
      STOP
35    READ(5,40)(INOBUS(I),I=1,26)
40    FORMAT(26I3)
      IF(INOBUS(1)-1))45,180,45
180   ALLBUS=1.
      WRITE(6,186)
186   FORMAT(1H ,*FOR ALL BUSES OF HIGH VOLTAGE,CHECKS FOR*
     -/1H ,*2-1.5,3-2.0,5-3.0,8-4.0 BREAKER"S INT.*
     -*DUTY AND CHECKS FOR*/1H ,*FIRST CYCLE DUTY*
     -*WILL BE DONE.*/1H ,*FOR ALL BUSES OF LOW*
     -*VOLTAGE, CHECKS FOR FIRST CYCLE DUTY WILL BE DONE.*)
      GO TO 190
45    ALLBUS=-1.
      WRITE(6,46)
46    FORMAT(///* DUTY CALCULATIONS TO BE DONE BY THIS STUDY ARE...*
     -/1H ,*(IF H.V. INT.DUTY CAL. IS REQUIRED,*
     -/1H ,*RATED INT.TIME AND CONT.PARTING TIME IN CYCLES*
     -/1H ,*OF THE C.B. TO BE CHECKED ARE AS SHOWN.)*)
      IF(INOBUS(1))55,50,55
50    WRITE(6,51)
51    FORMAT(1H ,*ERROR IN INPUT...*,* THE FIRST BUS IN*
     -*QUESTION CAN NOT BE ZERO.*)
      STOP
55    PRINT 1055
1055  FORMAT(1H //1H ,*AT BUSES*)
      LIMI=0
      DO 60 I1=1,26
      ICHECK=INOBUS(I1)/100
      IF(ICHECK)70,65,70
70    WRITE(6,71)INOBUS(I1)
71    FORMAT(1H ,*ERROR IN INPUT...CHECK"BUS IN QUESTION."*
     -*BUS NUMBER CAN NOT BE*,I3)
      STOP
65    IF(INOBUS(I1))67,60,67
67    LIMI=LIMI+1
      NORMAL(LIMI)=INOBUS(I1)
60    CONTINUE
85    READ(5,86)(INOBUS(I),I=1,26)
86    FORMAT(26I3)
      IF(INOBUS(1))90,120,90
90    DO 105 I2=1,26
      ICHECK=INOBUS(I2)/100
      IF(ICHECK)100,93,100
100   WRITE(6,71)INOBUS(I2)
      STOP
93    IF(INOBUS(I2))94,105,94
94    LIMI=LIMI+1
      NORMAL(LIMI)=INOBUS(I2)
105   CONTINUE
      GO TO 85
120   I=1
      NUMB=NUMB+LIMI
119   IF(MOD(I,10)-1)122,123,122
123   PRINT 1123,NORMAL(I)
1123  FORMAT(1H ,I4)
```

(POOR PRINT)

```
PROGRAM SHTCCT      73/172  OPT=1                    FTN 4.6+446        78/05/06. 15.45.54        PAGE    3

               GO TO 124
        8122   IPLU=I+8
        8124   PRINT 1122,(NORMAL(K),K=1,IPLU )
        1122   FORMAT(1H ,4X,9(*,*,I4))
               I=IPLU
        124    I=I+1
               IF(I-LIM)119,119,125
        122    IF(I+8-LIM)8122,8123,8123
        8123   IPLU=LIM
               GO TO 8124
        125    ENFO=0.00
               IPOINT=0
        127    READ(5,126)INTIM,(PTIM(I),I=1,10)
        126    FORMAT(I1,10F3.1)
               IF(INTIM)130,150,130
        130    IF(INTIM-9)132,160,132
        132    DO 133 I=1,10
               K=I-1
               IF(PTIM(I))133,131,133
        133    CONTINUE
        131    IF(INTIM-2)9133,8133
        9133   IF(INTIM-3)9134,8134
        9134   IF(INTIM-5)9135,8135
        9135   IF(INTIM-8)9136,8136
        9136   PRINT 19136,INTIM
        19136  FORMAT(1H ,*ERROR IN INPUT*/1H ,
              -*RATED INT.TIME SHOULD BE 2,3,5,OR 8.*/
              -1H ,*IT CAN NOT BE *,I3,*.*)
               STOP
        8133   DO 28133 I=1,K
               IF(PTIM(I)-1.5)7133,28133
        7133   IF(PTIM(I)-2.0)6133,28133
        28133  CONTINUE
               GO TO 99131
        8134   DO 28134 I=1,K
               IF(PTIM(I)-2.0)7134,28134
        7134   IF(PTIM(I)-3.0)6134,28134
        6134   IF(PTIM(I)-4.0)6133,28134
        28134  CONTINUE
               GO TO 99131
        8135   DO 28135 I=1,K
               IF(PTIM(I)-3.0)7135,28135
        7135   IF(PTIM(I)-4.0)6135,28135
        6135   IF(PTIM(I)-5.0)5135,28135
        5135   IF(PTIM(I)-6.0)6133,28135
        28135  CONTINUE
               GO TO 99131
        8136   DO 28136 I=1,K
               IF(PTIM(I)-4.0)7136,28136
        7136   IF(PTIM(I)-5.0)6136,28136
        6136   IF(PTIM(I)-6.0)5136,28136
        5136   IF(PTIM(I)-7.0)4136,28136
        4136   IF(PTIM(I)-8.0)6133,28136
        28136  CONTINUE
               GO TO 99131
        6133   PRINT 16133,PTIM(I),INTIM
        16133  FORMAT(1H ,*ERROR IN INPUT...*/
```

(POOR PRINT)

```
      PROGRAM SHYCCT     73/172  OPT=1                 FTN 4.6+446        78/05/06. 15.45.54        PAGE     4

           -1H ,* CONT.PART.TIME CAN NOT BE*,F5.1,*FOR INT.TIME=*,I3,*.*/
           -1H ,*CHECK "BUS IN QUESTION."*)
            STOP
      99131 WRITE(6,134)INTIM,(PTIM(I),I=1,K)
      134   FORMAT(1H ,10X,*INT.TIME=*,I3,*,  PARTING TIME=*,9(F3.1,*, *))
      135   ENFO=ENFO+INTIM*10.D0**IPOINT
            IPOINT=IPOINT+1
            DO 138 I3=1,K
      138   ENFO=ENFO+10.D0*PTIM(I3)*10.D0**(2*(I3-1)+IPOINT)
      140   IPOINT=IPOINT+2*K
            ENFO=ENFO+99.D0*10.D0**IPOINT
            IPOINT=IPOINT+2
            GO TO 127
      160   ENFO=ENFO+9.D0*10.D0**IPOINT
            WRITE(6,161)
      161   FORMAT(1H ,10X,*FIRST CYCLE DUTY WANTED*)
            GO TO 152
      150   WRITE(6,151)
      151   FORMAT(1H ,10X,*FIRST CYCLE DUTY NOT WANTED*)
      152   DO 155 I4=1,LIMI
            IF(ENQUIR(NORMAL(I4)))154,155
      154   PRINT 1154,NORMAL(I4)
      1154  FORMAT(1H ,*ERROR IN INPUT,,,BUS NUMBER*,I3,
           -*DUPLICATED. CHECK "BUS IN QUESTION".*)
            STOP
      155   ENQUIR(NORMAL(I4))=ENFO
            READ(5,40)(INOBUS(I),I=1,26)
            IF(INOBUS(I))55,190,55
      190   IF(NUMB-N9)2000,2000,9194
      9194  PRINT 19194
      19194 FORMAT(1H ,*ERROR...N9 MUST NOT BE SMALLER THAN */
           -1H ,*TOTAL NUMBER OF BUSES LISTED IN "BUS IN QUESTION"."*)
            STOP
      C
      C
      2000  PRINT 12000
      12000 FORMAT(1H1///1H ,*REMOTE MONITORING*/1H ,T5,
           -*FAULTED BUS///MONITORED BRANCH(FROM BUS/TO BUS)*)
            MONDO=0
            MONO=1
      2100  READ(5,2010)(NORMAL(MON),MON=1,25)
      2010  FORMAT(25I3)
            DO 2120 JE=1,25
            IF(NORMAL(JE)-N9)2120,2120,2110
      2110  PRINT 12110,NORMAL(JE)
      12110 FORMAT(1H ,*INPUT ERROR...CHECK"REMOTE MONITORING"*/
           -1H ,*BUS NUMBER*,I8,* IS BIGGER THAN N9*)
            STOP
      2120  CONTINUE
            IF(NORMAL(1))2017,2015
      2017  IF(ENQUIR(NORMAL(1)))2018,2020
      2020  IF(ALLBUS-1.)2019,2018
      2019  PRINT 12019,NORMAL(1)
      12019 FORMAT(1H ,*INPUT ERROR...IN"REMOTE MONITORING",*/1H ,
           -*BUS*,I4,*DOES NOT APPEAR IN "BUS IN QUESTION".*)
            STOP
      2018  NEM=0
```

POOR PRINT

```
             MONDO=1
             MONTOR(MONO)=NORMAL(1)*(1+1000)
             MONO=MONO+1
      2200   DO 2040 JMN=2,24,2
             IF(NORMAL(JMN)+NORMAL(JMN+1))2050,2040
      2050   IF(NORMAL(JMN)-NORMAL(JMN+1))2170,2060
      2060   PRINT 12060,NORMAL(JMN),NORMAL(JMN+1)
      12060  FORMAT(1H ,*INPUT ERROR...CHECK"REMOTE MONITORING."*/
            -1H ,*MONITORED BRANCH SHOULD CONNECT TWO DIFFERENT BUSES.*/
            -1H ,*CHECK FROM BUS*,I4,* TO BUS*,I4)
             STOP
      2170   NFB=1
             MONTOR(MONO)=NORMAL(JMN)*1000+NORMAL(JMN+1)
             MONO=MONO+1
      2040   CONTINUE
             IF(NFB)2100,2030
      2030   MONTOR(MONO)=0
             MONO=MONO+1
             GO TO 2100
      2015   ISUM=0
             DO 2250 IADD=2,26
      2250   ISUM=ISUM+NORMAL(IADD)
             IF(ISUM)2200,2210
      2210   IF(MONDO)2300,2220
      2220   PRINT 12220
      12220  FORMAT(1H ,T5,*NO REMOTE MONITORING*)
             GO TO 2500
      2300   MN=1
             MNP=0
             FLAG=0
      2350   MONTB=MOD(MONTOR(MN),1000)
             MONFB=(MONTOR(MN)-MONTB)/1000
             IF(MONTB-MONFB)2320,2400
      2310   IF(MONTB)2340,2330
      2340   PRINT 12340,MONTB
      12340  FORMAT(1H ,T5,I3)
             MN=MN+1
             FLAG=1
             GO TO 2350
      2330   IF(FLAG-1)2500,2360
      2360   PRINT 12360
      12360  FORMAT(1H ,T15,*ALL BRANCHES*)
             FLAG=0
             MN=MN+1
             GO TO 2350
      2320   FLAG=0
             MNP=MNP+2
             INOBUS(MNP-1)=MONFB
             INOBUS(MNP)=MONTB
             IF(MNP-10)2380,2370
      2370   PRINT 12370,(INOBUS(IK),IK=1,10)
      12370  FORMAT(1H ,T15,5(I4,*/*,I4,*,*))
             MNP=0
      2380   MN=MN+1
             GO TO 2350
      2400   IF(MNP)2410,2310
      2410   PRINT 12370,(INOBUS(IK),IK=1,MNP)
```

POOR PRINT

```
            MNP=0
            GO TO 2310
      2500  CONTINUE
            IF(ITYPE-1)2530,2510
      2510  IF(MONDO)2520,2530
      2520  PRINT 12520
      12520 FORMAT(1H ,*REMOTE MONITORING REQUEST*/
           -1H ,*IS IGNORED SINCE FAULT TYPE IS IL-G S.C.*)
            MONDO=0
      2530  CONTINUE
      C
      9193  WRITE(6,194)
      194   FORMAT(1H1//1H ,*BUS VOLTAGES*)
            NBUCHK=0
      195   READ(5,196)VOLT
      196   FORMAT(F10.2)
            IF(VOLT)198,199,198
      199   IF(NBUCHK-NUMB  )215,220,220
      19A   WRITE(6,197)VOLT
      197   FORMAT(1H ,10X,*BUSES AT*,F10.2,*KV*)
            NUMVOL=0
      9200  NIREAD=0
      200   READ(5,201)(INOBUS(I),I=1,26)
      201   FORMAT(26I3)
            IF(INOBUS(1))203,204,203
      203   DO 208 ICOL=1,26
            ICHECK=INOBUS(ICOL)/100
            IF(ICHECK)6203,206 ,6203
      6203  PRINT 16203,INOBUS(ICOL)
      16203 FORMAT(1H ,*ERROR IN INPUT...*/
           -1H ,*CHECK "BUS VOLTAGES". BUS NUMBER CAN NOT BE*,I3)
            STOP
      206   IF(INOBUS(ICOL))205,208,205
      205   NUMVOL=NUMVOL+1
            NIREAD=NIREAD+1
            NORMAL(NIREAD)=INOBUS(ICOL)
            IF(VOLBUS(INOBUS(ICOL)))6207,6205
      6207  PRINT 16207,INOBUS(ICOL)
      16207 FORMAT(1H ,*ERROR IN INPUT...BUS NUMBER*,I3,
           -*DUPLICATED. CHECK"BUS VOLTAGES."*)
            STOP
      6205  VOLBUS(INOBUS(ICOL))=VOLT
      208   CONTINUE
            GO TO 200
      204   I=1
      9210  IF(MOD(I,10)-1)9212,9213,9212
      9213  PRINT 19213,NORMAL(I)
      19213 FORMAT(1H ,20X,I2)
            GO TO 9214
      9212  IF(I+8-NIREAD)9215,9216,9216
      9216  IPLU=NIREAD
            GO TO 9217
      9215  IPLU=I+8
      9217  PRINT 19208,(NORMAL(K),   K=I,IPLU)
      19208 FORMAT(1H+,22X,9(*,*,I2))
            I=IPLU
      9214  I=I+1
```

POOR PRINT

```
      IF(I-NIREAD)9210,9210,210
210   WRITE(6,211)NUMVOL
211   FORMAT(1H ,20X,*AT LEAST*,I4,*BUSES AT THIS VOLTAGE.*)
      NBUCHK=NBUCHK+NUMVOL
      GO TO 195
215   WRITE(6,216)
216   FORMAT(1H ,*ERROR IN DATA CARD...TOTAL NUMBER OF BUSES*/
     -1H ,*LISTED IN "BUS IN QUESTION " *,
     -*CAN NOT BE BIGGER*/1H ,
     -*THAN THAT    OF BUSES GIVEN IN "BUS VOLTAGES"SECTION.*)
      STOP
220   CONTINUE
      J=1$K=1
4227  IF(K-NUMB)4223,4223,4226
4223  IF(ENQUIR(J))4220,4221
4221  J=J+1
      IF(J-100)4223,4228,4228
4228  PRINT 14228
14228 FORMAT(1H ,*ERROR IN INPUT...C HECK "BUS IN QUESTION".*)
      STOP
4220  IF(VOLBUS(J))4224,4225
4224  K=K+1$J=J+1
      GO TO 4227
4225  PRINT 14225,J
14225 FORMAT(1H ,*ERROR IN INPUT...*/
     -1H ,*BUS VOLTAGE FOR BUS*,I3,*SHOULD BE GIVEN.*)
      STOP
C
4226  CONTINUE
C     DETERMINATION OF JLV,JHI,JHF
      IF(ALLBUS-1.)270,252,270
252   DO 258 I=1,MAXBUS
      IF(VOLBUS(I))258,258,253
253   IF(VOLBUS(I)-1.0)254,256,256
254   JLV=1
      GO TO 257
256   JHI=1
      JHF=1
257   IF(JLV+JHI+JHF-3)258,289,289
258   CONTINUE
C
270   DO 285 I=1,100
      IF(VOLBUS(I))278,285,278
278   IF(ENQUIR(I))271,285,271
271   ENFO=ENQUIR(I)
      IF(IKK-NUMB)6280,6280,289
6280  IKK=IKK+1
280   K=1
276   DENOM=10.D0**K
      TIM=DMOD(ENFO,DENOM)
      IF(K-1)274,274,279
274   IF(TIM)272,275,272
272   IF(TIM-9.)273,277,273
273   ENFO=(ENFO-TIM)/DENOM
      K=2
      GO TO 276
279   ENFO=(ENFO-TIM)/DENOM
```

POOR PRINT

```
      PROGRAM SHTCCT      73/172  OPT=1                        FTN 4.6+446       78/05/06. 15.46.54        PAGE    8

            IF(TIM)286,281,286
     281    PRINT 1281
     1281   FORMAT(1H ,*INPUT ERROR...CHECK INT.TIME AND PARTING TIME.*)
            STOP
     286    CONTINUE
            IF(TIM-99.)276,280,276
     275    IF(VOLBUS(I)-1.0)285,283,283
     283    JHI=1
     288    IF(JLV+JHI+JHF-3)285,289,289
     277    IF(VOLBUS(I)-1.0)282,284,284
     282    JLV=1
            GO TO 288
     284    JHF=1
            GO TO 283
     285    CONTINUE
     289    CONTINUE
     C      BRANCH IMPEDANCES
            PRINT 7221
     7221   FORMAT(1H ,*IDENTIFICATION CODE FOR BRANCH IMPEDANCES*///
           -1H ,*  ID CODE1=A T/G,H/G WITH AMOR.WINDING,OR CONDENSER.*/
           -1H ,*  ID CODE2=AN H/G WITHOUT AMOR.WINDING.*/
           -1H ,*  ID CODE3=A SYNCH.MOTOR.*/
           -1H ,*  ID CODE4=AN IND.MTR.ABV 1000HP AT 1800RPM,OR*/
           -1H ,10X,*ABV 250HP AT 3600RPM.*/
           -1H ,*  ID CODE5=AN IND.MTR.50HP AND ABV...NOT BIGGER THAN*/
           -1H ,10X,*1000HP AT 1800 RPM OR 250HP AT 3600RPM.*/
           -1H ,*  ID CODE6=AN IND.MTR.SMALLER THAN 50HP.*/
           -1H ,*  ID CODE7=A STATIC ELEMENT...CABLE,BUSDUCT,TRF,RXTR,ETC.*/
           -1H ,*  ID CODE8=UTILITY SYSTEM,OFFSITE SOURCE,ETC.*)
            LINE=0
            WRITE(6,221)
     221    FORMAT(1H1,*IMPEDANCES*/1H , 5X,*FROM BUS*,T20,
           -*TO BUS*,T33,*R*,T43,*X*,T50,*IDEN.CODE*)
            IF(IFCHAN-2)530,500
     500    DO 510 K30=1,N30
            ROLBRN(K30)=XOLBRN(K30)=INCOEN(K30)=0
     510    CONTINUE
            GO TO 520
     530    IF(IFCHAN-1)535,223
     535    PRINT 1535
     1535   FORMAT(1H ,*INPUT ERROR...CHECK THE FLAG CARD FOR*/
           -*  CHANGE OR NEW CASES.*/
           -*  THE FIRST COLUMN OF THAT CARD SHOULD BE 0,1,OR 2.*)
            STOP
     520    IBRN=0
            NOOR=1
     223    READ(5,224)IFROMB,ITOB,BRANR,BRANX,ICODMG
     224    FORMAT(2I2,2F10.5,I1)
            IF(IFROMB+ITOB)222,250,222
     222    IBRN=IBRN+1
            IF(IFROMB-ITOB)8226,8227
     8[illegible]7   IF(ICODMG)8229,8228
     8229   IF(ICODMG-7)8226,8228
     8228   IF(ITYPE-1)8230,8226
     8230   PRINT 18228,IFROMB,ITOB
     18228  FORMAT(1H ,*INPUT ERROR...*/1H ,
```

POOR PRINT

```
           -*CHECK IDEN CODE OF THE BRANCH*/1H ,
           -*WHICH CONNECTS F,BUS*,I4,*T,BUS*,I4)
            STOP
      8226  IF(MAXBUS-IFROMB)8223,8222,8222
      8223  MAXBUS=IFROMB
      8222  IF(MAXBUS-ITOB)8224,8225,8225
      8224  MAXBUS=ITOB
      8225  IF(IBRN-N30)7222,7222,230
      230   PRINT 231
      231   FORMAT(1H ,*ERROR...N30 MUST NOT BE SMALLER THAN */
           -1H ,*TOTAL NUMBER OF BRANCHES.*)
            STOP
      7222  IF(BRANX)5223,5225,5224
      5223  IF(IFCHAN-1)15223,5224
      15223 PRINT 25223,BRANX
      25223 FORMAT(1H ,*INPUT ERROR...BRANCH X CANNOT BE NEGATIVE EXCEPT*/
           -*  CHANGE CASES.*/
           -*  CHECK WHERE BRANCH X IS *,F15.5)
            STOP
      5225  PRINT 15225,IBRN
      15225 FORMAT(1H ,*ERROR IN INPUT...X CAN NOT BE ZERO.*/
           -1H ,*CHECK*,I4,*TH BRANCH IMPEDANCE.*)
            STOP
      5224  IF(BRANR)6223,6224,66223
      6223  IF(BRANX)16223,5225,46223
      46223 PRINT 56223,BRANR,BRANX
      56223 FORMAT(1H ,*INPUT ERROR...R AND X*/
           -1H ,*SHOULD HAVE SAME POLARITY EXCEPT WHEN R=0.*)
            STOP
      66223 IF(BRANX)46223,5225,6222
      36223 IF(IFCHAN-1)16223,6222
      16223 PRINT 26223,BRANR
      26223 FORMAT(1H ,*INPUT ERROR...BRANCH R CANNOT BE NEGATIVE EXCEPT*/
           -*  CHANGE CASES.*/
           -*  CHECK WHERE BRANCH R IS *,F15.5,*.*)
            STOP
      6224  IF(OLV-1)6222,6227,6222
      6227  NOOR=0
      6222  CONTINUE
            IF(ICODMG)225,226,225
      226   ICODMG=7
      225   IF(LINE-55)9225,9226,9226
      9226  PRINT 19226
      19226 FORMAT(1H1,*IMPEDANCES...CONT'D*/
           -1H ,5X,*FROM BUS*,T20,*TO BUS*,T31,*R*,T43,*X*,
           -T59,*IDEN.CODE*)
            LINE=1
            GO TO 9227
      9225  LINE=LINE+1
      9227  WRITE(6,228)IFROMB,ITOB,BRANR,BRANX,ICODMG
      228   FORMAT(1H ,I10,I4,T20,I4,T30,F8.4,T40,F8.4,I5)
            CALL MGIMP(ICODMG)
            IF(IBRN-1)4360,4360,43501
      43501 IF(BRANX)4350,5225,4360
      C
      4350  NFTR=IFROMB*100+ITOB
            NTFR=ITOB*100+IFROMB
```

|POOR PRINT|

```
                KLIM=IBRN-1
                DO 4399 K=1,KLIM
                INTERM=INCDEN(K)/1000
                LFTB=MOD(INTERM,10000)
                LCODMG=INTERM/10000
                IF(LFTB-NFTB)4395,4390
          4395  IF(LFTB-NTFB)4399,4390
          4390  IF(ICODMG-LCODMG)4399,300
          300   IF(BRANR)330,305
          330   IF(ROLBRN(K))335,305
          335   IF(ROLBRN(K)+BRANR)4362,320,345
          345   ROLBRN(K)=ROLBRN(K)*BRANR/(ROLBRN(K)+BRANR)
          305   IF(XOLBRN(K)+BRANX)4362,320,325
          325   XOLBRN(K)=XOLBRN(K)*BRANX/(XOLBRN(K)+BRANX)
                IBRN=IBRN-1
                GO TO 223
          320   IF(K-KLIM)355,380
          355   IKREP=K+1
                LKREP=IBRN-1
                DO 370 KREP=IKREP,LKREP
                INCDEN(KREP-1)=INCDEN(KREP)
                ROLBRN(KREP-1)=ROLBRN(KREP)
          370   XOLBRN(KREP-1)=XOLBRN(KREP)
          380   IBRN =IBRN-1
                INCDEN(KLIM)=ROLBRN(KLIM)=XOLBRN(KLIM)=0
                GO TO 223
          4399  CONTINUE
          C
                IF(BRANX)4362,5225,4360
          4362  PRINT 14362,IFROMB,ITOB
          14362 FORMAT(1H ,*INPUT ERROR...PREVIOUSLY THERE WAS */
               -* NO BRANCH CONNECTING BUS*,I3,* AND BUS*,I3,*.*/
               -* IN THIS CASE NEGATIVE R AND X ARE MEANINGLESS,*/
               -* OR NEGATIVE R AND/OR X IS BIGGER THAN PREVIOUS R AND/OR X*/
               -* IN MAGNITUDE,*/
               -* OR BRANCH IDEN CODE IS INCORRECT.*)
                STOP
          4360  INCDEN(IBRN)=ICODMG*10**7+IFROMB*10**5+ITOB*10**3
                ROLBRN(IBRN)=BRANR
                XOLBRN(IBRN)=BRANX
                GO TO 223
          250   CONTINUE
                IF(NOOR)6230,6231,6230
          6231  PRINT 16231
          16231  FORMAT(1H ,10X,*ALL RESISTANCES WILL BE IGNORED FOR LV INT *,
               -*DUTY CALCULATION*/1H ,
               -*SINCE(AT LEAST)ONE VALUE OF INPUT RESISTANCES IS ZERO.*)
          6230  CONTINUE
                IF(JHI-1)6238,6232
          6232  DO 6234 I=1,IBRN
                IF(ROLBRN(I))6234,6236
          6234  CONTINUE
                GO TO 6238
          6236  PRINT 16236,I
          16236 FORMAT(1H ,*ERROR IN INPUT...*/1H ,
               -*HV INT.DUTY REQUIRES NON ZERO RESISTANCES.*/1H ,
               -*CHECK*,I4,*TH BRANCH IMPEDANCE.*)
```

[POOR PRINT]

```
      STOP
 6238 CONTINUE
C
C     NEW BRANCH NUMBERS AND NEW BUS NUMBERS
      NEWBRN=0
      NEWBUS=0
      LNBRN=0
 7300 I=0
 7240 I=I+1
      IF(I-IBRN)7342,7342,7244
 7342 IF(MOD(INCDEN(I),1000))7240,7242
 7242 INTERM=INCDEN(I)/1000
      ITOB=MOD(INTERM,100)
      INTERM=INTERM/100
      IFROMB=MOD(INTERM,100)
      IF(ITOB*IFROMB)7240,7241
 7244 PRINT 17244
17244 FORMAT(1H ,*ERR IN BRANCH IMPEDANCES...*/1H ,
     -*SOURCE BRANCH SHOULD CONTAIN ZERO BUS,*/
     -1H ,*ALSO EACH SUBNETWORK SHOULD CONTAIN ZERO BUS.*)
      STOP
 7241 INCDEN(I)=INCDEN(I)+NEWBRN+1
      NEWBRN=1+NEWBRN
      NEWBUS=1+NEWBUS
      IF(IFROMB)9241,9240,9241
 9240 IOLNWB(ITOB)=NEWBUS
      GO TO 9247
 9241 IOLNWB(IFROMB)=NEWBUS
      INCDEN(I)=INCDEN(I)-(IFROMB*100+ITOB)*1000+(ITOB*100+IFROMB)*1000
 9247 CONTINUE
 9248 DO 9280 I=1,IBRN
      IF(MOD(INCDEN(I),1000))9280,9250,9280
 9250 INTERM=INCDEN(I)/1000
      ITOB=MOD(INTERM,100)
      INTERM=INTERM/100
      IFROMB=MOD(INTERM,100)
      IF(ITOB)9251,9259
 9259 IF(IOLNWB(IFROMB))9262,9280
 9262 INCDEN(I)=INCDEN(I)-(IFROMB*100+ITOB)*1000+(ITOB*100+IFROMB)*1000
      GO TO 7271
 9251 IF(IOLNWB(ITOB))9252,9253,9252
 9253 IF(IFROMB)9255,9280
 9255 IF(IOLNWB(IFROMB))9256,9280,9256
 9256 NEWBUS=NEWBUS+1
      NEWBRN=NEWBRN+1
      IOLNWB(ITOB)=NEWBUS
      INCDEN(I)=NEWBRN+INCDEN(I)
      GO TO 9280
 9252 IF(IFROMB)9258,9260,9258
 9258 IF(IOLNWB(IFROMB))9270,9264,9270
 9264 NEWBUS=NEWBUS+1
      NEWBRN=NEWBRN+1
      INCDEN(I)=INCDEN(I)-(IFROMB*100+ITOB)*1000+(ITOB*100+IFROMB)*1000
      IOLNWB(IFROMB)=NEWBUS
      INCDEN(I)=NEWBRN+INCDEN(I)
      GO TO 9280
 9260 GO TO 7272
```

```
9270   IF(IOLNWB(ITOB)-IOLNWB(IFROMB))7270,7272,7272
7270   INCDEN(I)=INCDEN(I)-(IFROMB*100+ITOB)*1000+(ITOB*100+IFROMB)*1000
7273   NBIGB=IOLNWB(IFROMB)
       GO TO 7275
7272   NBIGB=IOLNWB(ITOB)
7275   DO 7290 J=1,NEWBRN
       K=NEWBRN-J+1
       DO 7280 L=1,IBRN
       LL=MOD(INCDEN(L),1000)
       IF(LL        -K)7280,7279,7280
7279   JOLBRN=L
       GO TO 7282
7280   CONTINUE
7282   INTERM=INCDEN(JOLBRN)/1000
       ITBCHK=MOD(INTERM,100)
       NTBCHK=IOLNWB(ITBCHK)
       IF(NTBCHK-NBIGB)7292,7292,7285
7285   INCDEN(JOLBRN)=K+1+INCDEN(JOLBRN)/1000*1000
7290   CONTINUE
       PRINT 17290
17290 FORMAT(1H ,*SOMETHING WRONG NEAR STATMNT LABL 7290*)
       STOP
7292   INCDEN(I)=K+1+INCDEN(I)
       NEWBRN=NEWBRN+1
       GO TO 9280
9280   CONTINUE
       IF(LNBRN-NEWBRN)7387,7385,7388
7387   LNBRN=NEWBRN
       GO TO 9240
7388   PRINT 97388
97388 FORMAT(1H ,*97388,..IN SHTCCT,*)
       STOP
7385   IF(NEWBRN-IBRN)7300,9281,9282
9282   PRINT 19282,NEWBRN,IBRN
19282 FORMAT(1H ,*NEWBRN(=*,I4,*) CAN NOT BE BIGGER THAN IBRN(=*,I4,*)*)
       STOP
9281   NTTLBU=NEWBUS
C      DUTY CALCULATION
       PRINT 1300
1300   FORMAT(1H1///1H ,*SHORT CIRCUIT DUTIES*/1H ,*-----------------*
      -*-----*)
       IF(JLV-1)405,400,405
405    IF(JHI-1)415,410,415
415    JCDVIF=3
       GO TO 402
400    JCDVIF=1
       GO TO 402
410    JCDVIF=2
402    CONTINUE
       CALL CALZAU(        IBRN,INCDEN,IOLNWB,RBUS,XBUS,AUXRBU,
      -AUXXBU,JCDVIF,NTTLBU,FACTOR,NOOR,ROLBRN,XOLBRN,
      -N90,N9,N8,N3,N495,N10)
       IF(IFZBU)422,423
422    CALL PRNZAU(RBUS,XBUS,NTTLBU,JCDVIF,NOOR,N9,MAXBUS,IOLNWB)
423    CALL RESULT(ALLBUS,MAXBUS,IOLNWB,VOLBUS,RBUS,XBUS,JCDVIF,
      -INCDEN,ITYPE,
      -MONTOR,MAXMON,MONDO,
```

POOR PRINT

```
         PROGRAM SHTCCT      73/172  OPT=1                          FTN 4.6+446       78/05/06. 15.45.54       PAGE    13


   685                 -PNSEQR,PNSEQX,
                       -                             ENQUIR,ENFO,DENOM,BMVA,IBRN,FACTOR,
                       -BOLBRN,IOLBRN,
                       -N30,N9,N8,V3,N495,N10,NOOR)
                403     IF(JCOVIF-1)420,405,420
   690          420     IF(JCOVIF-2)430,425,430
                425     IF(JHF-1)430,415,430
                430     READ(5,1435)IFCHAN
               1435     FORMAT(I1)
                        IF(IFCHAN)0,435
   695          435     PRINT 1430
               1430     FORMAT(1H1////*         THANK YOU,BYE-BYE.*)
                        STOP
                        END
```

POOR PRINT

```
      SUBROUTINE MBIMP      73/172  OPT=1                    FTN 4.6+446       78/05/06. 15.45.54       PAGE    1

            SUBROUTINE MBIMP(ICODMG)
            IF(ICODMG-1)1,19
    1       IF(ICODMG-2)2,19
    2       IF(ICODMG-3)3,19
    3       IF(ICODMG-4)4,19
    4       IF(ICODMG-5)5,19
    5       IF(ICODMG-6)6,19
    6       IF(ICODMG-7)7,19
    7       IF(ICODMG-8)17,19
    17      WRITE(6,170)
    170     FORMAT(1H+,T50,*CODE ERORR AT THIS BRANCH.*)
            STOP
    19      RETURN
            END
```

POOR PRINT

```
SUBROUTINE LOCATN     737172  OPT=1                    FTN 4.6+446     78/05/06. 15.45.54     PAGE    1

                SUBROUTINE LOCATN(KROW,KCOL,LCTN)
                IF(KROW-KCOL)1,2,2
          1     KBIG=KCOL
                KSMALL=KROW
                GO TO 3
          2     KBIG=KROW
                KSMALL=KCOL
          3     LCTN=KBIG*(KBIG-1)/2+KSMALL
                RETURN
                END
```

POOR PRINT

```
      SUBROUTINE CALZBU      73/172  OPT=1                 FTN 4.6+446        78/05/06. 15.46.56        PAGE    1

      SUBROUTINE CALZBU(       IBRN,INCDEN,IOLNWB,RBUS,
     -XBUS,AUXRBU,AUXXBU,JCDVIF,NIILBU,FACTOR,NOOR,ROLBRN,XOLBRN,
     -N30,N9,N8,N3,N495,N10)
      DIMENSION
     -INCDEN(N30),ROLBRN(N30),XOLBRN(N30),
     -IOLNWB(N9),
     -FACTOR(N8,N3),
     -RBUS(N495),
     -XBUS(N495),
     -AUXRBU(N10),
     -AUXXBU(N10)
      NROLD=NOOR
      NTWXR=1
      KRWCOL=1
      IF(JCDVIF-2)3,1,2
    2 NOOR=0
      GO TO 3
    1 NOOR=1
    3 DO 999 NEWBRN=1,IBRN
      DO 30 I=1,IBRN
      IF(MOD(INCDEN(I),1000)-NEWBRN)30,34,30
   34 IOLBRN=I
      GO TO 35
   30 CONTINUE
      PRINT 31
   31 FORMAT(1H ,*MACHINE ERROR...PLEASE RUN AGAIN.*)
      STOP
   35 BRANX=XOLBRN(IOLBRN)
      BRANR=ROLBRN(IOLBRN)
      INTERM=INCDEN(IOLBRN)/1000
      ITOB=MOD(INTERM,100)
      IF( ITOB)71,70
   70 PRINT 20,INCDEN(IOLBRN)
   20 FORMAT(1H ,*WRONG...ITOB CANNOT BE ZERO..20 IN CALZBU,*)
      STOP
   71 NTOB=IOLNWB(ITOB)
   72 INTERM=INTERM/100
      IFROMB=MOD(INTERM,100)
      IF(IFROMB)81,80
   80 NFROMB=0
      GO TO 82
   81 NFROMB=IOLNWB(IFROMB)
   82  ICODMO=INTERM/100
      IF(NTOB-NFROMB)10,10,11
   10 PRINT 1110
 1110 FORMAT(1H ,*SOMETHING WRONG...NTOB IS SMALLER THAN NFROMB.* /
     -/1H ,*10 IN CALZBU*)
      STOP
   11 CONTINUE
      IF(NFROMB)50,40,50
   40 IF(NTOB-KRWCOL)44,42,60
   42 LTYPE=1
      NTWKR=NTOB
      GO TO 100
   44 LTYPE=2
      GO TO 400
```

|POOR PRINT|

```
      50    IF(NTOB-KRWCOL)54,52,60
      52    LTYPE=3
            GO TO 300
      54    LTYPE=4
            GO TO 400
      60    CONTINUE
            PRINT 1060
    1060    FORMAT(1H ,*SOMETHING WRONG NE AR STAT LABL 60 IN CALZBU*)
            STOP
     100    KROW=KCOL=NTOB
            CALL LOCATN(KROW,KCOL,LCTN)
            XBUS(LCTN)=BRANX*FACTOR(ICODHG,JCOVIF)
            RBUS(LCTN)=NOOR*BRANR*FACTOR(ICODHG,JCOVIF)
            GO TO 500
     400    KRWCOL=KRWCOL-1
            DO 420 ITMS8=NTWKB,KRWCOL
            KCOL=ITMS8
            IF(NFROMB)405,410
     405    KROW=NFROMB
            CALL LOCATN(KROW,KCOL,LCTN)
            RFMROW=RBUS(LCTN)
            XFMROW=XBUS(LCTN)
            GO TO 415
     410    RFMROW=0.
            XFMROW=0.
     415    KROW=NTOB
            CALL LOCATN(KROW,KCOL,LCTN)
            RTOROW=RBUS(LCTN)
            XTOROW=XBUS(LCTN)
            AUXRBU(ITMS8)=RFMROW-RTOROW
            AUXXBU(ITMS8)=XFMROW-XTOROW
     420    CONTINUE
            IF(NFROMB)425,430
     425    KROW=NFROMB
            KCOL=NFROMB
            CALL LOCATN(KROW,KCOL,LCTN)
            RFMDGL=RBUS(LCTN)
            XFMDGL=XBUS(LCTN)
            GO TO 435
     430    RFMDGL=0.
            XFMDGL=0.
     435    KROW=NTOB
            KCOL=NTOB
            CALL LOCATN(KROW,KCOL,LCTN)
            RTODGL=RBUS(LCTN)
            XTODGL=XBUS(LCTN)
            IF(NFROMB)436,437
     436    KROW=NTOB
            KCOL=NFROMB
            CALL LOCATN(KROW,KCOL,LCTN)
            RMUTUL=RBUS(LCTN)
            XMUTUL=XBUS(LCTN)
            GO TO 439
     437    RMUTUL= 0.
            XMUTUL=0.
     439    AUXRBU(KRWCOL+1)=RFMDGL+RTODGL-2*RMUTUL+NOOR*BRANR*FACTOR
           -(ICODHG,JCOVIF)
```

POOR PRINT

```
      SUBROUTINE CALZBU      73/172  OPT=1                FTN 4.6+446        78/05/06. 15.46.54        PAGE     3

            AUXXBU(KRWCOL+1)=XFMOGL+XTODGL-2*XMUTUL+BRANX*FACTOR
           -(ICODMG,JCDVIF)
            DO 440 KROW=NTWKB,KRWCOL
            DO 440 KCOL=NTWKB,KROW
            CALL LOCATN(KROW,KCOL,LCTN)
            IF(NOOR)443,445
      443   RBUS(LCTN)=RBUS(LCTN)-AUXRBU(KROW)*AUXRBU(KCOL)/AUXRBU(KRWCOL+1)
      445   XBUS(LCTN)=XBUS(LCTN)-AUXXBU(KROW)*AUXXBU(KCOL)/AUXXBU(KRWCOL+1)
      440   CONTINUE
            GO TO 500
      300   LIMIT=NTOB-1
            DO 340 KCOL=NTWKB,LIMIT
            KROW=NFROMB
            CALL LOCATN(KROW,KCOL,LCTN)
            RFMROW=RBUS(LCTN)$XFMROW=XBUS(LCTN)
            KROW=NTOB
            CALL LOCATN(KROW,KCOL,LCTN)
            RBUS(LCTN)=RFMROW$XBUS(LCTN)=XFMROW
      340   CONTINUE
            KROW=KCOL=NFROMB
            CALL LOCATN(KROW,KCOL,LCTN)
            RFMOGL=RBUS(LCTN)$XFMOGL=XBUS(LCTN)
            KROW=KCOL=NTOB
            CALL LOCATN(KROW,KCOL,LCTN)
            RBUS(LCTN)=RFMOGL+NOOR*BRANR*FACTOR(ICODMG,JCDVIF)
            XBUS(LCTN)=XFMOGL+BRANX*FACTOR(ICODMG,JCDVIF)
            GO TO 500
      500   KRWCOL=KRWCOL+1
      999   CONTINUE
            IF(KRWCOL-NTTLBU-1)605,600
      605   PRINT 1605,KRWCOL,NTTLBU
      1605  FORMAT(1H ,*SOMETHING WRONG NEAR 605 IN CALZBU*/
           -1H ,*KRWCOL=*,I4,5X,*NTTLBU=*,I4,*KRWCOL-1*
           -*SHOULD BE EQUAL TO NTTLBU.*)
            STOP
      600   CONTINUE
            NOOR=NROLD
            RETURN
            END
```

POOR PRINT

```
      SUBROUTINE PANZBU      73/172  OPT=1                         FTN 4.6.446       78/05/06. 15.45.54        PAGE    1

              SUBROUTINE PANZBU(RBUS,XBUS,NTTLBU,JCOVIF,NOOR,N9,MAXBUS,IOLNWB)
              DIMENSION RBUS(N9),XBUS(N9),IOLNWB(N9)
              PRINT 1000
        1000  FORMAT(1H1,*RBUS AND XBUS MATRICES FOR*)
              IF(JCOVIF-2)11,13,12
        11    PRINT 1011
        1011  FORMAT(1H ,*L.V. INT.DUTY STUDY*)
              GO TO 20
        12    PRINT 1012
        1012  FORMAT(1H ,*H.V.MOM.(FIRST CYCLE) DUTY STUDY*)
              GO TO 20
        13    PRINT 1013
        1013  FORMAT(1H ,*H.V.INT.DUTY STUDY*)
              GO TO 20
        20    IF(NOOR)50,40
        40    PRINT1040
        1040  FORMAT(1H ///1H ,*FOR RBUS MATRIX ,FOR THIS CASE,*/1H ,
             -*ALL ELEMENTS ARE ZERO.*)
              MAXLCN=NTTLBU*(NTTLBU+1)/2
              DO 45 ICHK=1,MAXLCN
              IF(RBUS(ICHK))44,45
        45    CONTINUE
              GO TO 46
        44    PRINT 1045
        1045  FORMAT(1H ,*SOMETHING WRONG.THE ABOVE STATEMENT IS INCORRECT.*)
        46    CONTINUE
              LINE=7
        50    NPRNTD=0
        52    PRINT 1052
        1052  FORMAT(1H //1H ,*RBUS AND XBUS MATRICES ...(BUS,BUS)*)
              LINE =5
              DO 60 KRAW=1,MAXBUS
              IF(IOLNWB(KRAW))1053,60
        1053  DO 61 KCCL=1,KRAW
              IF(IOLNWB(KCCL))1054,61
        1054  KROW=IOLNWB(KRAW)
              KCOL=IOLNWB(KCCL)
              NPRNTD=NPRNTD+1
              CALL LOCATN(KROW,KCOL,LCTN)
              PRINT 1055,KRAW,KCCL,RBUS(LCTN),KRAW,KCCL,XBUS(LCTN)
        1055  FORMAT(1H ,10X,*RBUS(*,I3,*,*,I3,*)=*,F20.10,10X,*XBUS(*,
             -I3,*,*,I3,*)=*,F20.10)
              LINE=LINE+1
              IF(NPRNTD-NTTLBU)53,61,61
        53    IF(LINE-45)61,56,56
        56    PRINT 1056
        1056  FORMAT(1H1,*RBUS AND XBUS MATRICES...CONT"D*)
              LINE=1
        61    CONTINUE
        60    CONTINUE
              RETURN
              END
```

POOR PRINT

```
      SUBROUTINE HVMF(RHACD,XOVR,ITYPE,CBITIM,CPTIM,RHVMF)
      DIMENSION IMPMF(2)
      X=XOVR
      IF(CPTIM-1.5)10,5,10
5     CPTIM=1
10    DO 600 IBMCL=1,2
      IDEN=ITYPE*10+IBMCL
      IF(IDEN-12)15,20,15
20    IDEN=32
15    IDEN=IDEN*100+CBITIM*10+CPTIM
      IF(IDEN-1121)101,1121
101   IF(IDEN-1122)102,1122
102   IF(IDEN-1132)103,1132
103   IF(IDEN-1133)104,1133
104   IF(IDEN-1134)105,1134
105   IF(IDEN-1153)106,1153
106   IF(IDEN-1154)107,1154
107   IF(IDEN-1155)108,1155
108   IF(IDEN-1156)109,1156
109   IF(IDEN-1184)110,1184
110   IF(IDEN-1185)111,1185
111   IF(IDEN-1186)112,1186
112   IF(IDEN-1187)113,1187
113   IF(IDEN-1188)200,1188
200   IF(IDEN-3121)201,3121
201   IF(IDEN-3122)202,3122
202   IF(IDEN-3132)203,3132
203   IF(IDEN-3133)204,3133
204   IF(IDEN-3134)205,3134
205   IF(IDEN-3153)206,3153
206   IF(IDEN-3154)207,3154
207   IF(IDEN-3155)208,3155
208   IF(IDEN-3156)209,3156
209   IF(IDEN-3184)210,3184
210   IF(IDEN-3185)211,3185
211   IF(IDEN-3186)212,3186
212   IF(IDEN-3187)213,3187
213   IF(IDEN-3188)300,3188
300   IF(IDEN-3221)301,3221
301   IF(IDEN-3222)302,3222
302   IF(IDEN-3232)303,3232
303   IF(IDEN-3233)304,3233
304   IF(IDEN-3234)305,3234
305   IF(IDEN-3253)306,3253
306   IF(IDEN-3254)307,3254
307   IF(IDEN-3255)308,3255
308   IF(IDEN-3256)309,3256
309   IF(IDEN-3284)310,3284
310   IF(IDEN-3285)311,3285
311   IF(IDEN-3286)312,3286
312   IF(IDEN-3287)313,3287
313   IF(IDEN-3288)400,3288
C
400   PRINT 4400
4400  FORMAT(1H ,*INPUT ERROR...*/1H ,
     -*IF H.V.INT.DUTY REQUIRED, C.B. INT.TIME AND CONT PART,TIME */
```

POOR PRINT

```
      SUBROUTINE MVHF        73/172  OPT=1                    FTN 4.6+446       78/05/06. 15.45.54      PAGE    2

                   -1H ,*SHOULD BE GIVEN.*)
                    STOP
             1121   P1=.749971820732540095 38
                    P2=.0180805604230377 3504
                    P3=-.000324474692132821 49
                    P4=.0000032466702365 0314
                    P5=-.00000001695086261596
                    P6=.00000000003540022869
                    GO TO 499
             1122   P1=.646814435323625235 70
                    P2=.021820437860651908 93
                    P3=-.000428612900636662 56
                    P4=.000004693176167945 69
                    P5=-.000000026323812060 72
                    P6=.000000000058107840 21
                    GO TO 499
             1132   P1=.70201473267869118899
                    P2=.02147246794034030071
                    P3=-.00036827382773689735
                    P4=.00000342787487644389
                    P5=-.00000001817314150747
                    P6=.00000000000412264731 8
                    GO TO 499
             1133   P1=.52941607023906200080
                    P2=.02762765786206977658
                    P3=-.00057245960024251831
                    P4=.00000550610860300372
                    P5=-.00000003411689095816
                    P6=.00000000000650326599 7
                    GO TO 499
             1134   P1=.32311639274242942577
                    P2=.03277039162101158531
                    P3=-.00058591176339764351
                    P5=-.00000002809710529117
                    P6=.00000000000550491530 7
                    GO TO 499
             1153   P1=.87316162742219916026
                    P2=.00583543725163163107
                    P3=.00013312095007507520
                    P4=-.00000321086606926253
                    P5=.00000002332852774303
                    P6=-.000000000657639397
                    GO TO 499
             1156   P1=.66719188744730217877
                    P2=.01626011154278630199
                    P3=-.00016495298970704681
                    P4=.00000057637094887258
                    P5=.0000000016922201935
                    P6=-.00000000001251413
                    GO TO 499
             1155   P1=.228422830481328276
                    P2=.04314825576372960183
                    P3=-.00088107506832335244
                    P4=.00000970212255225664
                    P5=-.00000005420793696613
                    P6=.00000000011966760365
                    GO TO 499
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```
         1156  P1=.25422843992677179870
               P2=.03436296513247660833
               P3=-.00055055312809759018
               P4=.00000445138870420670
               P5=-.00000001602402601686
               P6=.000000000002149960137
               GO TO 499
         1184  P1=.00246002093439557257
               P2=.00776653054789552821
               P3=.000055822256093412490
               P4=-.00000188964479063385
               P5=.00000001420260584807
               GO TO 499
         1185  P1=.85785163557439858550
               P6=-.000000000003573573543
               P2=.00580909096810553200
               P3=.00000211648774915469
               P4=-.00000182110077036918
               P5=.00000001121321750898
               P6=-.00000000002295612669
               GO TO 499
         1186  P1=.29892531730963955283
               P2=.04955142062355854660
               P3=-.00119460829080148684
               P4=.00001515393591302157
               P5=-.00000009471776881537
               P6=.00000000022937616497
               GO TO 499
         1187  P1=.87197078376624759244
               P2=-.00151513407935608552
               P3=.00032579919245624527
               P4=-.00000577384651549321
               P5=.00000004029684454638
               P6=-.00000000010112803788
               GO TO 499
         1188  P1=.56784695443144528326
               P2=.01838424722863429839
               P3=-.00020541136875006256
               P4=.00000877944740456633
               P5=.00000000253018484556
               P6=-.00000000001877647847
               GO TO 499
         3121  P1=.70970930878761606664
               P2=.01987779571032122217
               P3=-.00038926087616941545
               P4=.00000411207826709091
               P5=-.00000002260015633085
               P6=.00000000000503265252
               GO TO 499
         3122  P1=.48762646234230899722
               P2=.03157406115150673820
               P3=-.00072701087658772617
               P4=.00000871245884654134
               P5=-.00000005212600874677
               P6=.00000000121518865937
               GO TO 499
         3132  P1=.55784532613780005985
```

POOR PRINT

```
            P2=.03221778263479979643
            P3=-.00072384831489990339
            P4=.00000049267555999682
            P5=-.00000004971649767039
            P6=.00000000011451110954
            GO TO 499
      3133  P1=-.36347354275875431995
            P2=.07766315154862590830
            P3=-.00173995704114136840
            P4=.00002004776275217948
            P5=-.00000011546341646100
            P6=.00000000026248549216
            GO TO 499
      3134  P1=-5.66329957092054314671
            P2=.32845620237631756311
            P3=-.00644169487983012323
            P4=.00006282596809328725
            P5=-.00000830331775833538
            P6=.00000000057904625251
            GO TO 499
      3152  P1=.63210958450459619753
            P2=.02367096550425288671
            P3=-.00050779100553417084
            P4=.00000656840032120355
            P5=-.00000004409852203173
            P6=.00000000011531254742
            GO TO 499
      3154  P1=2.07230137450764573259
            P2=-.08246840413175560158
            P3=.00227983213746071889
            P4=-.00002831077356531633
            P5=.00000016538986350699
            P6=-.00000000003705089850
            GO TO 499
      3155  P1=1.89330272437380306918
            P2=-.06924562275063461669
            P3=.00181309672522030063
            P4=-.00002148263134311794
            P5=.00000012197074643669
            P6=-.00000000026429808992
            GO TO 499
      3156  P1=-55.71193707246948179090
            P2=2.47786252402175932730
            P3=-.04308349167241432021
            P4=.00037242154836755574
            P5=-.00000159901152719503
            P6=.00000000272680572303
            GO TO 499
      3184  P1=.95114945901132585959
            P2=-.00319302813668471351
            P3=.00031690345474973125
            P4=-.00000499162221544440
            P5=.00000003211953458934
            P6=-.00000000007605448135
            GO TO 499
      3185  P1=.70417959452043632496
            P2=.01006290383595476179
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POOR PRINT

```
                  P3=-.00008451033979865524
                  P4=.00000063655722135781
                  P5=-.00000000476835521066
                  P6=.00000000001575153902
                  GO TO 499
            3186  P1=.29552720189357195579
                  P2=.03053982256259291095
                  P3=-.00057398556454743566
                  P4=.00000619920118590596
                  P5=-.00000034296305009721
                  P6=.00000000007441465675
            3187  P1=-9.91239512584564863573
                  P2=.51609190625921099809
                  P3=-.00909645356053914238
                  P4=.00009539061702989409
                  P5=-.00000045973166735727
                  P6=.00000000000346085902
                  GO TO 499
            3188  P1=-96.96489229497765471833
                  P2=4.27480883448910745756
                  P3=-.07446937794639030272
                  P4=.00064694416844348485
                  P5=-.00000280083069825697
                  P6=.00000000483252921621
                  GO TO 499
            3221  P1=.63310866092675510686
                  P2=.02717753961575064547
                  P3=-.00054774778194605772
                  P4=.00000593573595041797
                  P5=-.00000003260948220358
                  P6=.00000000007106151226
                  GO TO 499
            3222  P1=.62907840573090112457
                  P2=.02419762830658545028
                  P3=-.00047703438899671796
                  P4=.00000532987205333201
                  P5=-.00000003100926075367
                  P6=.00000000007228475151
                  GO TO 499
            3232  P1=.66519557768500447992
                  P2=.02906046224930658450
                  P3=-.00068736127391201183
                  P4=.00000708943585192074
                  P5=-.00000004275189923548
                  P6=.00000000010252952400
                  GO TO 499
            3233  P1=.56539040763255954403
                  P2=.02529579146196880846
                  P3=-.00037368372492451764
                  P4=.00000273252746725476
                  P5=-.00000000878205245350
                  P6=.00000000000745740793
                  GO TO 499
            3234  P1=.47034350823392045982
                  P2=.02657289914543670140
                  P3=-.00041809639817123878
                  P4=.00000367015828109327
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POOR PRINT

```
      P5=-.00000001695331205125
      P6=.00000000003191640124
      GO TO 499
3253  P1=.87924856344900703675
      P2=.00619409057261458007
      P3=.00017778689203266050
      P4=-.00000436086163403725
      P5=.00000003415868610413
      P6=-.00000000009246572129
      GO TO 499
3254  P1=.67305246552711750496
      P2=.02064511424472015300
      P3=-.00031710860358991240
      P4=.000003113879459867543
      P5=-.00000001784197287822
      P6=.000000000004291202582
      GO TO 499
3255  P1=.49088993964208249565
      P2=.03115152674391730159
      P3=-.00064951891469979331
      P4=.00000196065956321396
      P5=-.00000004977248593639
      P6=.000000000012153712964
      GO TO 499
3256  P1=.60701039508800747058
      P2=.01530365784642723215
      P3=-.00011181433713454599
      P4=-.00000302942415036449
      P5=.00000009070944235561
      P6=-.00000000003533300755
      GO TO 499
3284  P1=.95545676256571709928
      P2=.00278429729936037965
      P3=.00029961525932728841
      P4=-.00000623569206147896
      P5=.00000004780464079655
      P6=-.000000000012952532736
      GO TO 499
3285  P1=.98168706271155419811
      P2=-.00092806926433811748
      P3=.00034125246249002913
      P4=-.00000610426733862150
      P5=.00000004381534500693
      P6=-.000000000011430052737
      GO TO 499
3286  P1=1.02671776200233390909
      P2=-.00634015473843496657
      P3=.00043740414466942983
      P4=-.00000676867798758305
      P5=.00000004522015954114
      P6=-.000000000011203936598
      GO TO 499
3287  P1=1.02503222193890763947
      P2=-.00602395019969201306
      P3=.00039211349609643989 1
      P4=-.00000592856463345459
      P5=.00000001912877316929
```

POOR PRINT

```
      SUBROUTINE MVHF        737172  OPT=1                   FTN 4.6+446        78/05/06. 15.45.54       PAGE    7

               P6=-.00000000009694870375
               GO TO 499
         3288  P1=1.02011547708851236193
               P2=-.00611661974980370893
               P3=.00035939914767901988
               P4=-.00000526496090664586
               P5=.00000003419907936028
               P6=-.000000000008395258873
               GO TO 499
          499  TMPMF(IRMCL)=P1+P2*X**1+P3*X**2+P4*X**3+P5*X**4+P6*X**5
               IF(TMPMF(IRMCL)-1.)495,500,500
          495  TMPMF(IRMCL)=1.
          500  CONTINUE
               RHVMF=TMPMF(1)+(TMPMF(2)-TMPMF(1))*RNACO
               IF(CPTIM-1.)502,501
          501  CPTIM=1.5
          502  RETURN
               END
```

POOR PRINT

```
      SUBROUTINE LVHF        737172  OPT=1                    FTN 4.6+446      78/05/06. 15.45.54      PAGE    1

                SUBROUTINE LVHF(XOVR,RLVHF)
                IF(XOVR-20.0)20,10,10
         20     IF(XOVR-14.25)40,30,30
         40     IF(XOVR-11.72)60,50,50
         60     IF(XOVR-9.95)80,70,70
         80     IF(XOVR-8.27)100,90,90
         100    IF(XOVR-6.6)120,110,110
         10     RLVHF=1.15
                RETURN
         30     RLVHF=1.11+(1.15-1.11)*(XOVR-14.25)/(20.0-14.25)
                RETURN
         50     RLVHF=1.09+(1.11-1.09)*(XOVR-11.72)/(14.25-11.72)
                RETURN
         70     RLVHF=1.07+(1.09-1.07)*(XOVR-9.95)/(11.72-9.95)
                RETURN
         90     RLVHF=1.04+(1.07-1.04)*(XOVR-8.27)/(9.95-8.27)
                RETURN
         110    RLVHF=1.0+(1.04-1.0)*(XOVR-6.6)/(8.27-6.6)
                RETURN
         120    RLVHF=1.0
                RETURN
                END
```

POOR PRINT

```
     SUBROUTINE DTL         73/172  OPT=1                                   FTN 4.6+446       78/05/06. 15.45.54        PAGE    1

                  SUBROUTINE DTL(JCDVIF)
                  IF(JCDVIF-2)11,13,12
            11    PRINT 1011
            1011  FORMAT(1H1,*LOW VOLTAGE INT,DUTY(=FIRST CYCLE DUTY)*)
                  GO TO 30
            12    PRINT 1012
            1012  FORMAT(1H1,*HIGH VOLTAGE NOM,DUTY(=FIRST CYCLE DUTY)*)
                  GO TO 30
            13    PRINT 1013
            1013  FORMAT(1H1,*HIGH VOLTAGE INT,DUTY*)
                  GO TO 30
            30    RETURN
                  END
```

POOR PRINT

```
      SUBROUTINE RESULT(ALLBUS,MAXBUS,IOLNWB,VOLBUS,
     -RBUS,XBUS,JCDVIF,INCDEN,ITYPE,MONIOR,MAXMON,MONOQ,
     -PNSEQR,PNSEQX,
     -ENQUIR,ENFO,DENOM,BMVA,IBRN,FACTOR,ROLBRN,XOLBRN,
     -N30,N9,N8,N3,N495,N10,NOOR)
      DOUBLE ENQUIR(N9),ENFO,DENOM
      DIMENSION IOLNWB(N9),VOLBUS(N9),RBUS(N495),XBUS(N495),
     =INCDEN(N30),ROLBRN(N30),XOLBRN(N30), MONIOR(MAXMON),
     -PNSEQR(N9),PNSEQX(N9),
     -FACTOR(N8,N3)
      IF(ITYPE-1)10,28
 10   DO 20 LQ=1,N9
      PNSEQR(LQ)=PNSEQX(LQ)=0.
      KROW=KCOL=IOLNWB(LQ)
      IF(KROW)15,28
 15   CALL LOCATN(KROW,KCOL,LCTN)
      PNSEQR(LQ)=RBUS(LCTN)
      PNSEQX(LQ)=XBUS(LCTN)
 20   CONTINUE
 28   IOBQ=0
      LINE=0
      CALL DTL(JCDVIF)
C     THIS SECTION IS TO FIND "BUS NUMBER" REQUIRED SEQUENTIALLY .
 30   CONTINUE
 32   IOBQ=IOBQ+1
      IF(IOBQ-MAXBUS)36,36,37
 37   RETURN
 36   IF(VOLBUS(IOBQ))31,32
 31   IF(JCDVIF-2)35,50,50
 35   IF(VOLBUS(IOBQ)-1.0)40,32,32
 50   IF(VOLBUS(IOBQ)-1.0)32,40,40
 40   IF(ALLBUS)42,300,300
 42   IF(ENQUIR(IOBQ))271,32
 271  ENFO=ENQUIR(IOBQ)
 280  K=1
 276  DENOM=10.D0**K
      TIM=DMOD(ENFO,DENOM)
      IF(K-1)274,274,279
 274  IF(TIM)272,275,272
 272  IF(TIM-9.)273,277,273
 273  ENFO=(ENFO-TIM)/DENOM
      K=2
      GO TO 276
 279  ENFO=(ENFO-TIM)/DENOM
      IF(TIM)286,281,286
 281  PRINT 1281
 1281 FORMAT(1H ,*WRONG...STAT LABL 281 IN RESULT*)
      STOP
 286  CONTINUE
      IF(TIM-99.)276,280
 275  IF(JCDVIF-2)32,285
 277  GO TO 285
 285  ENFO=ENQUIR(IOBQ)
      GO TO 400
 300  ENFO=99940899305992039915 2.D0
C     F/E AND CONTRIBUTION
```

POOR PRINT

```
      400   IF(LINE-40)401,402,402
      402   LINE=0
            CALL DTL(JCOVIF)
            PRINT 1403
      1403  FORMAT(1H+,43X,*CONT"D*)
      401   PRINT 1400,IOBQ
      1400  FORMAT(1H //1H ,T10,*AT BUS*,I4)
            PRINT 1420,VOLBUS(IOBQ)
      1420  FORMAT(1H ,T20,*BUS    VOLTAGE=*,F12.4,*(KV)*)
            BASCUR=BMVA/(VOLBUS(IOBQ)*SQRT(3.))
            KROW=KCOL=NWBQ=IOLNWB(IOBQ)
            CALL LOCATN(KROW,KCOL,LCTN)
            BUX=XBUS(LCTN)$BUR=RBUS(LCTN)
            IF(ITYPE-1)1425,1422
      1422  IF(PNSEQR(IOBQ)+PNSEQX(IOBQ))1423,1424
      1423  BUX=(BUX+2.*PNSEQX(IOBQ))/3.
            BUR=(BUR+2.*PNSEQR(IOBQ))/3.
            GO TO 1425
      1424  PRINT 11424
      11424 FORMAT(* INPUT ERROR...3PHASE DUTY CALCULATION*/
           -* SHOULD BE DONE BEFORE 1 L-G DUTY CALCULATION.*)
            STOP
      1425  EOVXPU=1.0/BUX
            EOVXMP=BASCUR/BUX
            PRINT 1430,EOVXMP,EOVXPU
      1430  FORMAT(1H ,T20,*CALCULATED E/X=*,F12.4,*(SYM,KA)=*,F10.4,*(P.U.)*)
            IF(ITYPE-1)1435,1100
      1435  PRINT 1440
      1440  FORMAT(1H ,T25,*-CONTRIBUTIONS FROM ADJACENT BUSES-*)
            LINE=LINE+6
            DO 480 NRBU=1,IBRN
            BRANX=XOLBRN(NRBU)
            BRANB=BOLBRN(NRBU)
            INTERM=INCDEN(NRBU)/1000
            ITOR=MOD(INTERM,100)
            INTERM=INTERM/100
            IFROMB=MOD(INTERM,100)
            ICODMG=INTERM/100
            IF(IFROMB-IOBQ)445,450,445
      445   IF(ITOR-IOBQ)480,460,480
      450   NEARB=ITOR$GO TO 465
      460   NEARB=IFROMB
      465   IF(NEARB)467,468
      468   CURADB=1.0/BRANX*BASCUR
            CRABPU=CURADB/BASCUR
            GO TO 469
      467   KROW=IOLNWB(NEARB)
            KCOL=NWBQ
            CALL LOCATN(KROW,KCOL,LCTN)
            BNEARX=XBUS(LCTN)
            CURADB=(1.0-BNEARX/BUX)*BASCUR/(BRANX*FACTOR(ICODMG,JCOVIF))
            CRABPU=CURADB/BASCUR
      469   IF(LINE-50)471,472,472
      472   LINE=0
            CALL DTL(JCOVIF)
            PRINT 1403
            PRINT 1400,IOBQ
```

POOR PRINT

```
           PRINT 1472
     1472  FORMAT(1H+,22X,*CONT"D*)
      471  LINE=LINE+1
      470  PRINT 1470,NEARB,CURADB,CRABPU
     1470  FORMAT(1H ,T25,*FROM BUS *,I4,***,F15.5,*(SYM,KA)=*,F10.5,
          -*(P.U.)*)
      480 CONTINUE
     C
           IF(MONDO)905,1100
      905  IDIO=IOBQ*(I+1000)
           DO 910 MN=1,MAXMON
           IF(MONTOR(MN)-IOIO)910,915
      910  CONTINUE
           GO TO 1100
      915  PRINT 1915
     1915  FORMAT(1H ,T25,*-REMOTE MONITORING-*/
          -1H ,T25,*/CURRENT/*,T55,*/BUS VOLT/*)
           IF(MONTOR(MN+1))980,920
      920  DO 970 IBR=1,IBRN
           INTERM=INCDEN(IBR)/1000
           ITOB=MOD(INTERM,100)
           INTERM=INTERM/100
           IFROMB=MOD(INTERM,100)
           ICODMG=INTERM/100
           IF(ITOB-IOBQ)921,970
      921  IF(IFROMB-IOBQ)922,970
      922  IF(IFROMB)945,925
      925  KROW=IOLNWB(ITOB)
           KCOL=NWBQ
           CALL LOCATN(KROW,KCOL,LCTN)
           XTQ=XBUS(LCTN)
           IF(XTQ)930,970
      930  CMNPU=XTQ/BUX/XOLBRN(IBR)/FACTOR(ICODMG,JCOVIF)
           VOLFB=0
           VOLTB=(BUX-XTQ)/BUX
           GO TO 960
      945  KROW=IOLNWB(IFROMB)
           KCOL=NWBQ
           CALL LOCATN(KROW,KCOL,LCTN)
           XFQ=XBUS(LCTN)
           IF(XFQ)947,970
      947  VOLFB=(BUX-XFQ)/BUX
           KROW=IOLNWB(ITOB)
           KCOL=NWBQ
           CALL LOCATN(KROW,KCOL,LCTN)
           XTQ=XBUS(LCTN)
           IF(XTQ)950,948
      948  PRINT 1948
     1948  FORMAT(1H ,*WRONG...1948 IN RESULT*)
           STOP
      950  VOLTB=(BUX-XTQ)/BUX
           CMNPU=(VOLFB-VOLTB)/XOLBRN(IBR)/FACTOR(ICODMG,JCOVIF)
      960  IF(LINE-50)968,962,962
      962  LINE=0
           CALL OTL(JCOVIF)
           PRINT 1403
           PRINT 1400,IOBQ
```

POOR PRINT

```
      PRINT 1472
 968  LINE=LINE+2
      PRINT 1969,IFROMB,ITOB,CHNPU,VOLFB,VOLTB
1969  FORMAT(1H ,T25,*FROM BUS*,I4,* TO BUS*,I4,
     -*//*,T55,*FROM BUS*,T70,*TO BUS*/
     -1H ,T30,*=*,F15.5,*(P.U.)//*,T55,F7.3,*(P.U.)*,T70,F7.3,*(P.U.)*)
C
 970  CONTINUE
      GO TO 1100
 980  MN=MN+1
      INOYES=0
      IF(MN-MAXMON)983,984,1090
 984  KTOB=MOD(MONTOR(MN),1000)
      KFROMB=(MONTOR(MN)-KTOB)/1000
 983  IF(KTOB-KFROMB)981,1100
 981  IF(KTOB)985,982
 982  KROW=IOLNWB(KFROMB)
      KCOL=NWBQ
      CALL LOCATN(KROW,KCOL,LCTN)
      XFQ=XBUS(LCTN)
      IF(XFQ)1010,995
 995  PRINT 1995,KFROMB,KTOB
1995  FORMAT(1H ,T30,*INPUT ERROR...CHECK"REMOTE MONITORING"*
     -/1H ,T30,*FAULT BUS IS NOT CONNECTED TO THE NETWORK*
     -,*WHICH CONTAINS F.BUS*,I4,*AND/OR T.BUS*,I4,*.*)
      GO TO 980
 985  KROW=IOLNWB(KTOB)
      KCOL=NWBQ
      CALL LOCATN(KROW,KCOL,LCTN)
      XTQ=XBUS(LCTN)
      IF(XTQ)987,995
 987  IF(KFROMB)990,1030
 990  KROW=IOLNWB(KFROMB)
      KCOL=NWBQ
      CALL LOCATN(KROW,KCOL,LCTN)
      XFQ=XBUS(LCTN)
      IF(XFQ)1050,995
1010  IF(KFROMB-IOBQ)1011,980
1011  KFTB=KFROMB
      DO 1014 KF=1,IBRN
      INTERM=INCDEN(KF)/1000
      IFTB=MOD(INTERM,10000)
      ICODMG=INTERM/10000
      IF(IFTB-KFTB)1014,1016
1016  CHNPU=-XFQ/BUX/XOLBBN(KF)/FACTOR(ICODMG,JCOVIF)
      VOLFB=(BUX-XFQ)/BUX
      VOLTB=0
      INOYES=1
      IF(LINE-50)1020,1018,1018
1018  LINE=1-1
      CALL DTL(JCOVIF)
      PRINT 1403
      PRINT 1400,IOBQ
      PRINT 1472
1020  LINE=LINE+2
      PRINT 1969,KFROMB,KTOB,CHNPU,VOLFB,VOLTB
1014  CONTINUE
```

POOR PRINT

```
           GO TO 1066
   1030    IF(KTOB-1080)1031,980
   1031    KFTB=KTOB
           DO 1034 KT=1,IBRN
           INTERM=INCOEN(KT)/1000
           IFTB=MOD(INTERM,10000)
           ICODMG=INTERM/10000
           IF(IFTB-KFTB)1034,1036
   1036    CHNPU=XTQ/BUX/XOLBRN(KT)/FACTOR(ICODMG,JCOVIF)
           VOLFA=0
           VOLTA=(BUX-XTQ)/BUX
           INOYES=1
           IF(LINE-50)1039,1038,1038
   1038    LINE=0
           CALL DTL(JCOVIF)
           PRINT 1401
           PRINT 1400,1080
           PRINT 1472
   1039    LINE=LINE+2
           PRINT 1969,KFROMB,KTOB,CHNPU,VOLFB,VOLTB
   1034    CONTINUE
           GO TO 1066
   1050    IF(KTOB-1080)1051,980
   1051    IF(KFROMB-1080)1052,980
   1052    IF(KTOB-KFROMB)1054,1090
   1054    KFTB=KTOB*100+KFROMB
           KKFTB=KFROMB*100+KTOB
   1057    DO 1060 KFT=1,IBRN
           INTERM=INCOEN(KFT)/1000
           IFTB=MOD(INTERM,10000)
           ICODMG=INTERM/10000
           IF(IFTB-KFTB)1063,1062
   1063    IF(IFTB-KKFTB)1060,1062
   1062    VOLFA=(BUX-XFQ)/BUX
           VOLTA=(BUX-XTQ)/BUX
           CHNPU=(VOLFB-VOLTB)/XOLBRN(KFT)/FACTOR(ICODMG,JCOVIF)
           INOYES=1
   1080    IF(LINE-50)1085,1082,1082
   1082    LINE=0
           CALL DTL(JCOVIF)
           PRINT 1401
           PRINT 1400,1080
           PRINT 1472
   1085    LINE=LINE+2
           PRINT 1969,KFROMB,KTOB,CHNPU,VOLFB,VOLTB
   1060    CONTINUE
    1066   IF(INOYES)980,1065
   1065    PRINT 1061,KFROMB,KTOB
   1061    FORMAT(1H ,T31,*INPUT ERROR...NO BRANCH*/
          -* CONNECTS BUS*,I4,* AND BUS*,I4)
           GO TO 980
   1090    PRINT 11090
   11090   FORMAT(1H ,*WRONG  11090 IN RESULT*)
           STOP
   C
   C
   1100    IF(JCOVIF-2)500,700,600
```

POOR PRINT !

```
 500    IF(NOUR)502,550
 502    XOVR=BUX/BUR
        CALL LVMF(XOVR,ALVMF)
        DUTY=EOVXMP*ALVMF
        PRINT 1505,XOVR,ALVMF,DUTY
 1505   FORMAT(1H ,T20,*X/R=*,F10.4/1H ,T20,*M.F.=*,
       -F10.4,*(ANSI C 37.13-1973...9.1.4.3)*/1H ,T20,
       -*INT.DUTY=*,F15.5,*(SYM,KA)*)
        LINE=LINE+3
        GO TO 30
 550    DUTY=EOVXMP*1.15
        PRINT 1555,EOVXMP,DUTY
 1555   FORMAT(1H ,T20,*X/R=UNKNOWN*/
       -1H ,T20,*INT.DUTY=*,F15.5,*IF NO M.F. IS*,
       -*APPLIED*/1H ,T20,8X,*=*,F15.5,*IF M.F.=1.15 IS*,
       -*APPLIED AS PER ANSI C 37.13-1973...9.1.4.3*)
        LINE=LINE+3
        GO TO 30
 600    DUTY=EOVXMP*1.6
        PRINT 1600,DUTY
 1600   FORMAT(1H ,T20,*MOM.DUTY(FIRST CYCLE DUTY)=*,F15.5,*(ASYM,KA)*)
        LINE=LINE+1
        GO TO 30
 700    XOVR=BUX/BUR
        IF(LINE-45)701,702,702
 702    LINE=0
        CALL DTL(JCDVIF)
        PRINT 1403
        PRINT 1400,IOUQ
        PRINT 1472
 701    PRINT 1700,XOVR
 1700   FORMAT(1H ,T20,*X/R =*,F10.4)
 C      ***********        ***    ***
 C        SECTION FOR ANACD
        ALLCUR=0.
        RMTCUR=0.
        DO 799 NOBN=1,IBRN
        BRANX=XOLBRN(NOBN)
        BRANR=ROLBRN(NOBN)
        INTERM=INCDEN(NOBN)/1000
        ITOB=MOD(INTERM,100)
        INTERM=INTERM/100
        IFROMB=MOD(INTERM,100)
         ICODMG=INTERM/100
        IF(ICODMG-4)710,730
 710    IF(IFROMB)799,7155
 7155   IF(ICODMG-2)713,713,799
 713    NTOB=IOLNWB(ITOB)
        IF(NWOQ-NTOB)715,714
 714    GENRMT=0
        ALLCUR=ALLCUR+1./(BRANX*FACTOR(ICODMG,JCDVIF))
        GO TO 716
 715    KROW=NWOQ$KCOL=NTOB
        CALL LOCATN(KROW,KCOL,LCTN)
        XIJ=XBUS(LCTN)
        GENCUR=XIJ/(BRANX*FACTOR(ICODMG,JCDVIF)*BUX)
        ALLCUR=ALLCUR+GENCUR
```

```
          GNTCA=1./(BRANX*FACTOR(ICODMG,JCDVIF))
          GENRMT=GENCUR-GENCUR**2/GNTCA
   716    RMTCUR=RMTCUR+GENRMT
          GO TO 799
   730    IF(JFROMB)732,733
   732    PRINT 1732
   1732   FORMAT(1H ,*WRONG...732 IN RESULT*)
          STOP
   733    NTOB=IOLNWB(ITOB)
          KROW=NWBQ$KCOL=NTOB
          CALL LOCATN(KROW,KCOL,LCTN)
          XIJ=XBUS(LCTN)
          UTLCUR=XIJ/(BRANX*FACTOR(ICODMG,JCDVIF)*BUX)
          ALLCUR=ALLCUR+UTLCUR
          RMTCUR=RMTCUR+UTLCUR
   799    CONTINUE
          IF(ALLCUR)835,830
   830    IF(ALLCUR+RMTCUR)845,840
   840    RNACO=0.5
          GO TO 850
   845    PRINT 1845
   1845   FORMAT(1H WRONG...1845 IN RESULT.*)
          STOP
   835    RNACO=RMTCUR/ALLCUR
   850    PRINT 1800,RNACO
   1800   FORMAT(1H ,T20,*NACO RATIO=*,F15.5)
   C      END OF RNACO SECTION
          PRINT 1805
   1805   FORMAT(1H ,T20,*INT.DUTY*/1H ,T25,*C.B.INT.TIME/*,
         -*CONT.PRTNG TIME/  H.F.  / DUTY(SYM,KA)*)
          LINE=LINE+4
   808    K=1
          DENOM=10.D0**K
          TIM=DMOD(ENFO,DENOM)
          IF(TIM)812,30,812
   812    IF(TIM-9.)814,30,814
   814    CBITIM=TIM
   810    ENFO=(ENFO-TIM)/DENOM
          K=2
          DENOM=10.D0**K
   818    TIM=DMOD(ENFO,DENOM)
          IF(TIM-99.)816,806,816
   806    ENFO=(ENFO-TIM)/DENOM
          GO TO 808
   816    CPTIM=TIM/10.
          CALL HVMF(RNACO,XOVR,ITYPE,CBITIM,CPTIM,RHVMF)
          DUTY=EOVXMP*RHVMF
          IF(LINE-51)820,821,821
   821    LINE=0
          CALL DTL(JCDVIF)
          PRINT 1403
          PRINT 1400,IOBQ
          PRINT 1472
   820    LINE=LINE+1
          PRINT 1830,CBITIM,CPTIM,RHVMF,DUTY
   1830   FORMAT(1H ,T25,F5.1,T36,F5.1,T53,F5.2,T59,F15.5)
          GO TO 810
```

POOR PRINT

```
      SUBROUTINE RESULT     73/172  OPT=1                    FTN 4.6+446       78/06/20. 13.58.27        PAGE     8

  400            END
```

POOR PRINT

APPENDIX C

SAMPLE RUNNINGS

POOR PRINT

1. SAMPLE 1

The first sample calculates solutions for the same sample system that Stagg(1) used, with some modifications and additions. A "change case" demonstration has been included.

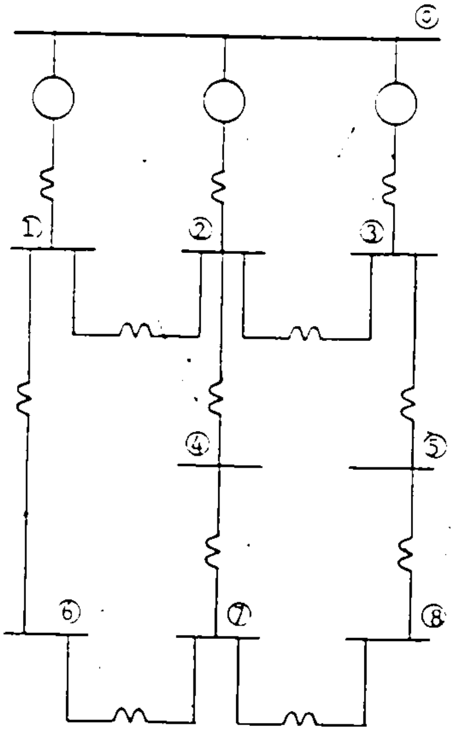
The validity of this program concerning the formation of R_{BUS} and X_{BUS} can be checked by comparing X_{BUS} for "L.V. int. duty calculation" of this sample running with the same given in(1).

Note that lines R and X are corrected by correction factors before they are used to form R_{BUS} and X_{BUS} in the cases of H.V. int. and mom. duty calculations. So X_{BUS} for H.V. duty calculations cannot be compared with that of (1).

In this sample, the base MVA is 100 MVA and type of fault is a 3 phase short circuit.

1.1 System Description

Fig. C1 shows the initial case which is identical to Stagg(1) in its topology. Bus voltages are assigned to system buses arbitrarily as shown in Fig. C1. Line information is tabulized in Table C1.



Bus Voltages

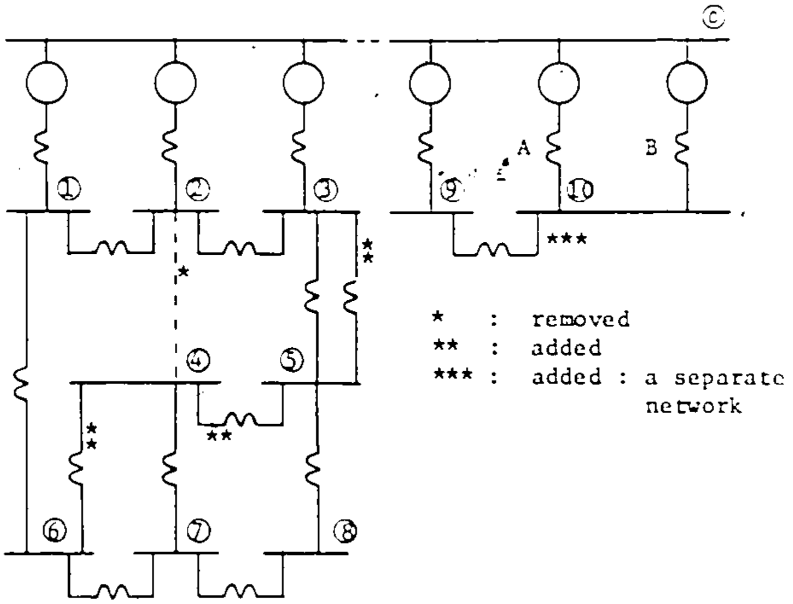
Bus	Voltage (kV)
1	4.16
2	4.16
3	0.48
4	4.16
5	0.48
6	0.48
7	0.48
8	0.48

Fig. C1 Sample running 1 - initial case

Table C1: Line Information - sample running 1

Line		R	X	Identification
0	1	0.001	0.01	Utility
0	2	0.0005	0.015	Turbogenerator
1	2	0.002	0.084	Cable
0	3	0.0002	0.005	Induction motor 500 hp 1800 rpm
2	3	0.008	0.122	Cable, Transformer, etc.
2	4	0.002	0.084	
3	5	0.001	0.037	
1	6	0.007	0.126	
6	7	0.01	0.168	
4	7	0.0015	0.084	
5	8	0.0008	0.037	
7	8	0.008	0.14	

Fig. C2 shows change case. In addition to several changes in the original system, a separate system is included together with new bus voltages as shown in the figure. Additional information to get Fig. C2 from Fig. C1 is tabulized in Tables C2 and C3.



Additional Bus Voltages

Bus	Voltage (kV)
9	13.8
10	4.16

Fig. C2
Sample running 1
- change case

Table C2: Added Information - sample running 1

Line		R	X	Identification
3	5	0.001	0.06	Transformer
4	5	0.002	0.04	Transformer
4	6	0.003	0.05	Transformer
0	9	0.0002	0.004	Turbogenerator
0	10(A)	0.001	0.5	Synch. motor
0	10(B)	0.002	0.7	700 hp 1800 rpm Ind. motor

Table C3: Removed Information - sample running 1

Line		R	X	Identification
2	4	0.002	0.084	Cable

POOR PRINT !

1.2 Input Data

CARD NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	E	X	A	M	P	L	E	.	.	.	G	.	W	.	S	T	A	G	G						
2	1	0	0	.	0						3	1													
3	0	0	1	0	0	3	0	0	8																
4	0																								
5	2	1	.	5																					
6	3	2	.	0																					
7	9																								
8	0	0	2	0	0	4	0	0	5																
9	0																								
10	5	3	.	0	4	.	0																		
11	3	4	.	0	5	.	0																		
12	9																								
13			6			7																			
14																									
15	9																								
16	0																								
17			1			2			3			3			5										
18			3			5			8			6			7										
19			8			4			7			1			2										
20			2						1						3										
21			4			1			2			2			3										
22			5			1			2			1			6										
23			6			1			2			2			3										
24			7			1			2			2			3										
25	0																								
26	4	.	1	6																					
27			1			2						4													
28	0																								
29	0	.	4	8																					
30			3			5			6			7			8										
31	0																								
32	0																								
33	0	7	0	8	0	.	0	0	8							0	.	1	4	0					
34	0	5	0	8	0	.	0	0	0	8						0	.	0	3	7					
35	0	4	0	7				0	.	0	0	1	5		0	.	0	8	4						
36	0	6	0	7	0	.	0	1							0	.	1	6	8						
37	0	1	0	6	0	.	0	0	7						0	.	1	2	6						
38	0	3	0	5	0	.	0	0	1						0	.	0	3	7						7
39	0	2	0	4	0	.	0	0	2						0	.	0	8	4						7
40	0	2	0	3	0	.	0	0	8						0	.	1	2	2						7
41	0	0	0	3	0	.	0	0	0	2					0	.	0	0	5						5
42	0	1	0	2	0	.	0	0	2						0	.	0	8	4						7
43	0	0	0	2	0	.	0	0	0	5					0	.	0	1	5						1
44	0	0	0	1	0	.	0	0	1						0	.	0	1							8
45	0																								
46	1																								

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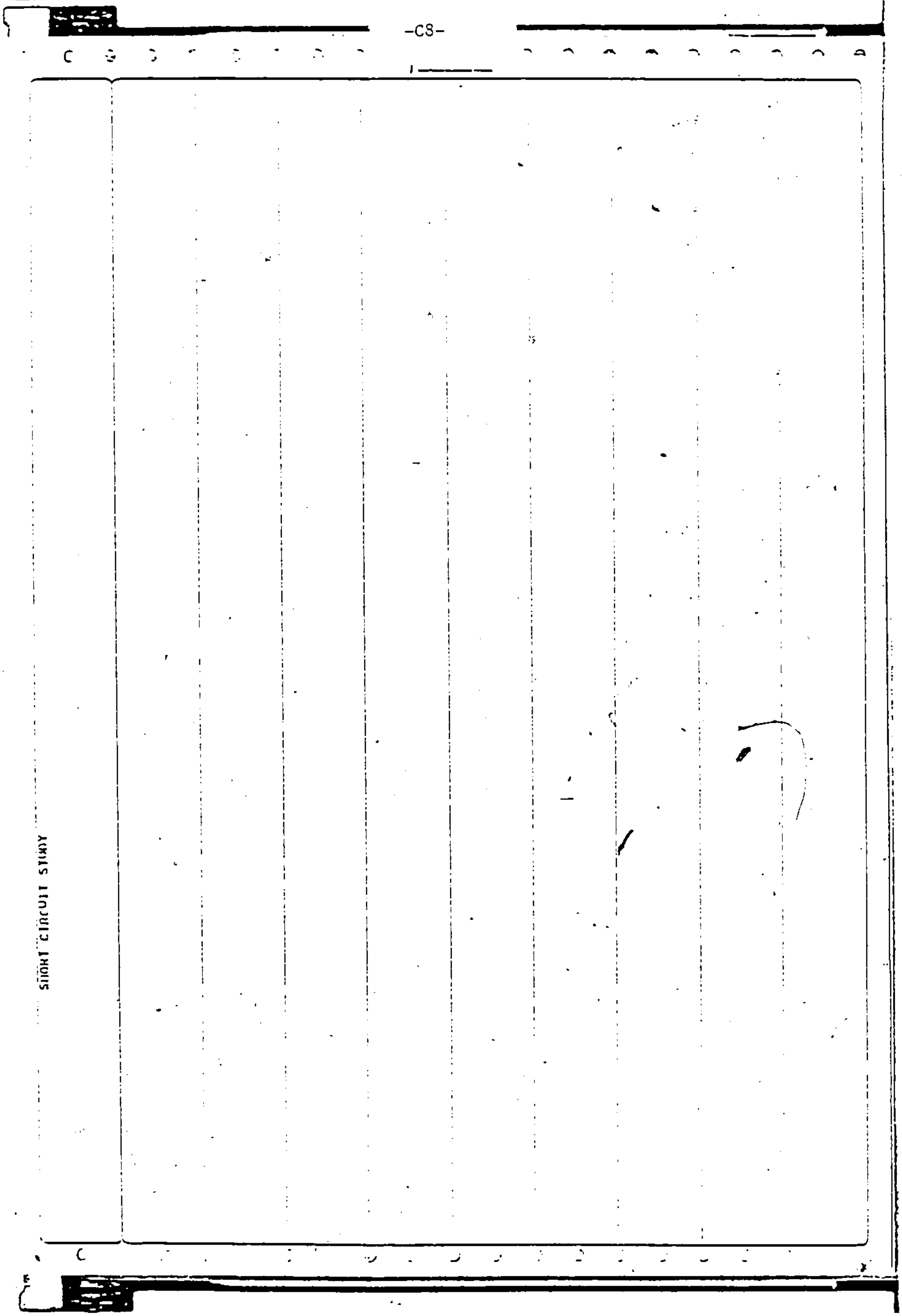
CARD NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
47	C	H	A	N	G	E		C	A	S	E		1	.	.	.									
48	1	0	0	.	0						3	1													
49	0	0	1	0	0	3	0	0	8			9													
50	0																								
51	2	1	.	5																					
52	3	2	.	0																					
53	9																								
54	0	0	2	0	0	4	0	0	5		1	0													
55	0																								
56	5	3	.	0	4	.	0																		
57	8	3	.	0	5	.	0																		
58	9																								
59			6			7																			
60	0																								
61	9																								
62	0																								
63			1			2			3			3			5										
64			3			5			8			6			7										
65			8			4			7			1			2										
66			2			1			3																
67			4			1			2			2			3										
68			5			1			2			1			6										
69			6			1			2			2			3										
70			7			1			2			2			3										
71	0																								
72	1	3	.	8																					
73	9																								
74	0																								
75	4	.	1	6																					
76			1			2						4		1	0										
77	0																								
78	0	.	4	8																					
79			3			5			6			7			8										
80	0																								
81																									
82		2		4	–	.	0	0	2						–	[illegible]	8	4							
83		4		6	.	0	0	3							.	0	5								
84		4		5	.	0	0	2							.	0	4								
85	0	3	0	5	.	0	0	1							.	0	6								
86		0		9	.	0	0	0	2						.	0	0	4							1
87		9	1	0	.	0	0	2							.	0	5								
88	1	0		0	.	0	0	1							.	5									5
89		0	1	0	.	0	0	2							.	7									3
90	0																								
91	0																								

POOR PRINT

1.3 Result of computer running

POOR PRINT



POOR PRINT

```
JOB NAME=EXAMPLE...G.W.STAGG

DESCRIPTION=DONE BY HWANG
BASE MVA=    100.00
TYPE OF FAULT=3PHASE SHORT CIRCUIT


DUTY CALCULATIONS TO BE DONE BY THIS STUDY ARE...
(IF H.V. INT.DUTY CAL. IS REQUIRED,
RATED INT.TIME AND CONT.PARTING TIME IN CYCLES
OF THE C.B. TO BE CHECKED ARE AS SHOWN.)

AT BUSES
   1,   3,   8,
          INT.TIME=  2,  PARTING TIME=1.5,
          INT.TIME=  3,  PARTING TIME=2.0,
          FIRST CYCLE DUTY WANTED

AT BUSES
   2,   4,   5,
          INT.TIME=  5,  PARTING TIME=3.0, 4.0,
          INT.TIME=  8,  PARTING TIME=4.0, 5.0,
          FIRST CYCLE DUTY WANTED

AT BUSES
   6,   7,
          FIRST CYCLE DUTY WANTED
```

POOR PRINT

```
REMOTE MONITORING
   FAULTED BUS///MONITORED BRANCH(FROM BUS/TO BUS)
      1
                 2/   3,   3/   5,
      3
                 5/   8,   6/   7,
      8
                 4/   7,   1/   2,
      2
                 0/   1,   0/   3,
      4
                 1/   2,   2/   3,
      5
                 1/   2,   1/   6,
      6
                 1/   2,   2/   3,
      7
                 1/   2,   2/   3,
```

POOR PRINT

```
BUS VOLTAGES
          BUSES AT        4.16KV
                        1, 2, 4,
                       AT LEAST   3BUSES AT THIS VOLTAGE.
          BUSES AT         .48KV
                        3, 5, 6, 7, 8,
                       AT LEAST   5BUSES AT THIS VOLTAGE.
IDENTIFICATION CODE FOR BRANCH IMPEDANCES

  ID CODE1=A T/G,M/G WITH AMOR.WINDING,OR CONDENSER.
  ID CODE2=AN M/G WITHOUT AMOR.WINDING.
  ID CODE3=A SYNCH.MOTOR.
  ID CODE4=AN IND.MTR.ABV 1000HP AT 1800RPM.OR
          ABV 250HP AT 3600RPM.
  ID CODE5=AN IND.MTR.50HP AND ABV...NOT BIGGER THAN
          1000HP AT 1800 RPM OR 250HP AT 3600RPM.
  ID CODE6=AN IND.MTR.SMALLER THAN 50HP.
  ID CODE7=A STATIC ELEMENT...CABLE,BUSDUCT,TRF,RXTR,ETC.
  ID CODE8=UTILITY SYSTEM,OFFSITE SOURCE,ETC.
```

POOR PRINT

```
IMPEDANCES
     FROM BUS      TO BUS          R          X      IDEN.CODE
         7            8          .0080      .1400       7
         5            8          .0008      .0370       7
         4            7          .0015      .0840       7
         6            7          .0100      .1680       7
         1            6          .0070      .1260       7
         3            5          .0010      .0370       7
         2            4          .0020      .0840       7
         2            3          .0080      .1220       7
         0            3          .0002      .0050       5
         1            2          .0020      .0840       7
         0            2          .0005      .0150       1
         0            1          .0010      .0100       8
```

POOR PRINT

```
RBUS AND XBUS MATRICES FOR
L.V. INT.DUTY STUDY


RBUS AND XBUS MATRICES ...(BUS,BUS)
          RBUS(  1,  1)=          .0006922259          XBUS(  1,  1)=          .0088910445
          RBUS(  2,  1)=          .0001369019          XBUS(  2,  1)=          .0013284169
          RBUS(  2,  2)=          .0003945925          XBUS(  2,  2)=          .0113462337
          RBUS(  3,  1)=          .0000067941          XBUS(  3,  1)=          .0001116721
          RBUS(  3,  2)=          .0000147826          XBUS(  3,  2)=          .0005537136
          RBUS(  3,  3)=          .0001927281          XBUS(  3,  3)=          .0047595927
          RBUS(  4,  1)=          .0001617125          XBUS(  4,  1)=          .0020426828
          RBUS(  4,  2)=          .0003256052          XBUS(  4,  2)=          .0083338747
          RBUS(  4,  3)=          .0000374154          XBUS(  4,  3)=          .0012007004
          RBUS(  4,  4)=          .0018639664          XBUS(  4,  4)=          .0662061306
          RBUS(  5,  1)=          .0000245008          XBUS(  5,  1)=          .0005690330
          RBUS(  5,  2)=          .0000412196          XBUS(  5,  2)=          .0013780532
          RBUS(  5,  3)=          .0001786120          XBUS(  5,  3)=          .0042561324
          RBUS(  5,  4)=          .0001884687          XBUS(  5,  4)=          .0079225433
          RBUS(  5,  5)=          .0010888460          XBUS(  5,  5)=          .0366243723
          RBUS(  6,  1)=          .0004814413          XBUS(  6,  1)=          .0062621463
          RBUS(  6,  2)=          .0041932984          XBUS(  6,  2)=          .0030397449
          RBUS(  6,  3)=          .0000263924          XBUS(  6,  3)=          .0008556785
          RBUS(  6,  4)=          .0007200757          XBUS(  6,  4)=          .0183436987
          RBUS(  6,  5)=          .0001374910          XBUS(  6,  5)=          .0065253189
          RBUS(  6,  6)=          .0048600308          XBUS(  6,  6)=          .0899987918
          RBUS(  7,  1)=          .0001803205          XBUS(  7,  1)=          .0027569487
          RBUS(  7,  2)=          .0002738648          XBUS(  7,  2)=          .0053215156
          RBUS(  7,  3)=          .0000543900          XBUS(  7,  3)=          .0018476871
          RBUS(  7,  4)=          .0015177373          XBUS(  7,  4)=          .0400783865
          RBUS(  7,  5)=          .0002989054          XBUS(  7,  5)=          .0144670334
          RBUS(  7,  6)=          .0011151586          XBUS(  7,  6)=          .0336476524
          RBUS(  7,  7)=          .0024506416          XBUS(  7,  7)=          .0748352574
          RBUS(  8,  1)=          .0000386663          XBUS(  8,  1)=          .0010263939
          RBUS(  8,  2)=          .0000623692          XBUS(  8,  2)=          .0022023928
          RBUS(  8,  3)=          .0001673191          XBUS(  8,  3)=          .0037526721
          RBUS(  8,  4)=          .0003093113          XBUS(  8,  4)=          .0148443862
          RBUS(  8,  5)=          .0010170332          XBUS(  8,  5)=          .0319926122
          RBUS(  8,  6)=          .0002263698          XBUS(  8,  6)=          .0121949592
          RBUS(  8,  7)=          .0004945178          XBUS(  8,  7)=          .0270063796
          RBUS(  8,  8)=          .0016968046          XBUS(  8,  8)=          .0602325523
```

POOR PRINT

```
LOW VOLTAGE INT.DUTY(=FIRST CYCLE DUTY)

      AT BUS    3
                BUS      VOLTAGE=          .4800(KV)
                CALCULATED E/X=  25271.3442(SYM.KA)=  210.1020(P.U.)
                    -CONTRIBUTIONS FROM ADJACENT BUSES-
                    FROM BUS    5=       343.86808(SYM.KA)=   2.85887(P.U.)
                    FROM BUS    2=       871.21490(SYM.KA)=   7.24314(P.U.)
                    FROM BUS    0=     24056.26122(SYM.KA)= 200.00000(P.U.)
                    -REMOTE MONITORING-
                    /CURRENT/                         /BUS VOLT/
                    FROM BUS    5 TO BUS    8//       FROM BUS          TO BUS
                         =         -2.85887(P.U.)//      .106(P.U.)        .212(P.U.)
                    FROM BUS    6 TO BUS    7//       FROM BUS          TO BUS
                         =          1.24061(P.U.)//      .820(P.U.)        .612(P.U.)
                X/R=    24.6959
                M.F.=     1.1500(ANSI C 37.13-1973...9.1.4.3)
                INT.DUTY=     29062.04583(SYM.KA)


      AT BUS    5
                BUS      VOLTAGE=          .4800(KV)
                CALCULATED E/X=   3284.1875(SYM.KA)=   27.3042(P.U.)
                    -CONTRIBUTIONS FROM ADJACENT BUSES-
                    FROM BUS    8=       411.12348(SYM.KA)=   3.41802(P.U.)
                    FROM BUS    3=      2873.06403(SYM.KA)=  23.88621(P.U.)
                    -REMOTE MONITORING-
                    /CURRENT/                         /BUS VOLT/
                    FROM BUS    1 TO BUS    2//       FROM BUS          TO BUS
                         =           .26297(P.U.)//      .984(P.U.)        .962(P.U.)
                    FROM BUS    1 TO BUS    6//       FROM BUS          TO BUS
                         =          1.29073(P.U.)//      .984(P.U.)        .822(P.U.)
                X/R=    33.6360
                M.F.=     1.1500(ANSI C 37.13-1973...9.1.4.3)
                INT.DUTY=      3776.81564(SYM.KA)


      AT BUS    6
                BUS      VOLTAGE=          .4800(KV)
                CALCULATED E/X=   1336.4769(SYM.KA)=   11.1113(P.U.)
                    -CONTRIBUTIONS FROM ADJACENT BUSES-
                    FROM BUS    7=       448.20569(SYM.KA)=   3.72[illegible](P.U.)
                    FROM BUS    1=       888.19121(SYM.KA)=   7.38428(P.U.)
                    -REMOTE MONITORING-
                    /CURRENT/                         /BUS VOLT/
                    FROM BUS    1 TO BUS    2//       FROM BUS          TO BUS
                         =          -.42625(P.U.)//      .930(P.U.)        .966(P.U.)
                    FROM BUS    2 TO BUS    3//       FROM BUS          TO BUS
                         =          -.19892(P.U.)//      .966(P.U.)        .990(P.U.)
                X/R=    18.5182
                M.F.=     1.1397(ANSI C 37.13-1973...9.1.4.3)
                INT.DUTY=      1523.17136(SYM.KA)
```

POOR PRINT

```
LOW VOLTAGE INT.DUTY(=FIRST CYCLE DUTY)     CONT"D

    AT BUS    7
              BUS     VOLTAGE=         .4800(KV)
              CALCULATED E/X=   1607*2813(SYM.KA)=    13.3627(P.U.)
                    -CONTRIBUTIONS FROM ADJACENT BUSES-
                    FROM BUS    8=       548.18483(SYM.KA)=   4.55752(P.U.)
                    FROM BUS    4=       665.04842(SYM.KA)=   5.52911(P.U.)
                    FROM BUS    6=       394.04801(SYM.KA)=   3.27605(P.U.)
                    -REMOTE MONITORING-
                    /CURRENT/                           /BUS VOLT/
                    FROM BUS    1 TO BUS    2//       FROM BUS         TO BUS
                        =            .49797(P.U.)//     .963(P.U.)       .929(P.U.)
                    FROM BUS    2 TO BUS    3//       FROM BUS         TO BUS
                        =           -.38049(P.U.)//     .929(P.U.)       .975(P.U.)
              X/R=   30.5370
              M.F.=    1.1500(ANSI C 37.13-1973...9.1.4.3)
              INT.DUTY=      1848.37344(SYM.KA)


    AT BUS    8
              BUS     VOLTAGE=         .4800(KV)
              CALCULATED E/X=   1996*9485(SYM.KA)=    16.6023(P.U.)
                    -CONTRIBUTIONS FROM ADJACENT BUSES-
                    FROM BUS    7=       472.79429(SYM.KA)=   3.93074(P.U.)
                    FROM BUS    5=      1524.15423(SYM.KA)=  12.67158(P.U.)
                    -REMOTE MONITORING-
                    /CURRENT/                           /BUS VOLT/
                    FROM BUS    4 TO BUS    7//       FROM BUS         TO BUS
                        =           2.45912(P.U.)//     .757(P.U.)       .550(P.U.)
                    FROM BUS    1 TO BUS    2//       FROM BUS         TO BUS
                        =            .22243(P.U.)//     .983(P.U.)       .963(P.U.)
              X/R=   35.4976
              M.F.=    1.1500(ANSI C 37.13-1973...9.1.4.3)
              INT.DUTY=      2296.49080(SYM.KA)
```

POOR PRINT

```
RBUS AND XBUS MATRICES FOR
H.V.INT.DUTY STUDY


RBUS AND XBUS MATRICES ...(BUS,BUS)
            RBUS(  1,  1)=          .0006926562          XBUS(  1,  1)=          .0088955951
            RBUS(  2,  1)=          .0001378382          XBUS(  2,  1)=          .0013509809
            RBUS(  2,  2)=          .0003966296          XBUS(  2,  2)=          .0114581144
            RBUS(  3,  1)=          .0000190005          XBUS(  3,  1)=          .0003056264
            RBUS(  3,  2)=          .0000413416          XBUS(  3,  2)=          .0015154143
            RBUS(  3,  3)=          .0005389898          XBUS(  3,  3)=          .0130261461
            RBUS(  4,  1)=          .0001640822          XBUS(  4,  1)=          .0020916116
            RBUS(  4,  2)=          .0003307613          XBUS(  4,  2)=          .0085764825
            RBUS(  4,  3)=          .0001046371          XBUS(  4,  3)=          .0032861001
            RBUS(  4,  4)=          .0018770165          XBUS(  4,  4)=          .0667322135
            RBUS(  5,  1)=          .0000358132          XBUS(  5,  1)=          .0007424712
            RBUS(  5,  2)=          .0000658333          XBUS(  5,  2)=          .0022380271
            RBUS(  5,  3)=          .0004995121          XBUS(  5,  3)=          .0116482661
            RBUS(  5,  4)=          .0002507668          XBUS(  5,  4)=          .0097873536
            RBUS(  5,  5)=          .0013862422          XBUS(  5,  5)=          .0432345806
            RBUS(  6,  1)=          .0004831129          XBUS(  6,  1)=          .0062970154
            RBUS(  6,  2)=          .0001969354          XBUS(  6,  2)=          .0032126393
            RBUS(  6,  3)=          .0000738098          XBUS(  6,  3)=          .0023418377
            RBUS(  6,  4)=          .0007292811          XBUS(  6,  4)=          .0187186114
            RBUS(  6,  5)=          .0001814353          XBUS(  6,  5)=          .0078542750
            RBUS(  6,  6)=          .0048665242          XBUS(  6,  6)=          .0902659732
            RBUS(  7,  1)=          .0001837653          XBUS(  7,  1)=          .0028322423
            RBUS(  7,  2)=          .0002813601          XBUS(  7,  2)=          .0056948505
            RBUS(  7,  3)=          .0001521088          XBUS(  7,  3)=          .0050567860
            RBUS(  7,  4)=          .0015367080          XBUS(  7,  4)=          .0408879445
            RBUS(  7,  5)=          .0003894669          XBUS(  7,  5)=          .0173366801
            RBUS(  7,  6)=          .0011285403          XBUS(  7,  6)=          .0342245835
            RBUS(  7,  7)=          .0024782189          XBUS(  7,  7)=          .0760010385
            RBUS(  8,  1)=          .0000492634          XBUS(  8,  1)=          .0011793160
            RBUS(  8,  2)=          .0000854266          XBUS(  8,  2)=          .0029606399
            RBUS(  8,  3)=          .0004679300          XBUS(  8,  3)=          .0102703861
            RBUS(  8,  4)=          .0003676705          XBUS(  8,  4)=          .0162886071
            RBUS(  8,  5)=          .0012956263          XBUS(  8,  5)=          .0378208952
            RBUS(  8,  6)=          .0002675358          XBUS(  8,  6)=          .0133667124
            RBUS(  8,  7)=          .0005793535          XBUS(  8,  7)=          .0296165742
            RBUS(  8,  8)=          .0019577833          XBUS(  8,  8)=          .0653714044
```

POOR PRINT

```
HIGH VOLTAGE INT.DUTY
     .
       AT BUS    1
                  BUS     VOLTAGE=      4.1600(KV)
                  CALCULATED E/X=   1560.1668(SYM.KA)=  112.4152(P.U.)
                       -CONTRIBUTIONS FROM ADJACENT BUSES-
                       FROM BUS     6=        32.17633(SYM.KA)=   2.31841(P.U.)
                       FROM BUS     2=       140.12925(SYM.KA)=  10.09678(P.U.)
                       FROM BUS     0=      1387.86122(SYM.KA)= 100.00000(P.U.)
                       -REMOTE MONITORING-
                       /CURRENT/                        /BUS VOLT/
                       FROM BUS    2 TO BUS    3//      FROM BUS        TO BUS
                            =          -.96323(P.U.)//     .848(P.U.)      .966(P.U.)
                       FROM BUS    3 TO BUS    5//      FROM BUS        TO BUS
                            =          1.32724(P.U.)//     .966(P.U.)      .917(P.U.)
                  X/R =    12.8427
                  NACD RATIO=          .98604
                  INT.DUTY
                       C.B.INT.TIME/CONT.PRTNG TIME/  M.F.   / DUTY(SYM.KA)
                         2.0         1.5              1.00      1560.16680
                         3.0         2.0              1.00      1560.16680


       AT BUS    2
                  BUS     VOLTAGE=      4.1600(KV)
                  CALCULATED E/X=   1211.2475(SYM.KA)=   87.2744(P.U.)
                       -CONTRIBUTIONS FROM ADJACENT BUSES-
                       FROM BUS     4=        41.55202(SYM.KA)=   2.99396(P.U.)
                       FROM BUS     3=        98.71369(SYM.KA)=   7.11265(P.U.)
                       FROM BUS     1=       145.74095(SYM.KA)=  10.50112(P.U.)
                       FROM BUS     0=       925.24082(SYM.KA)=  66.66667(P.U.)
                       -REMOTE MONITORING-
                       /CURRENT/                        /BUS VOLT/
                       FROM BUS    0 TO BUS    1//      FROM BUS        TO BUS
                            =         11.79060(P.U.)//   0.000(P.U.)      .882(P.U.)
                       FROM BUS    0 TO BUS    3//      FROM BUS        TO BUS
                            =          8.81712(P.U.)//   0.000(P.U.)      .068(P.U.)
                  X/R =    28.8887
                  NACD RATIO=          .15028
                  INT.DUTY
                       C.B.INT.TIME/CONT.PRTNG TIME/  M.F.   / DUTY(SYM.KA)
                         5.0         3.0              1.04      1256.71321
                         5.0         4.0              1.03      1242.04344
                         8.0         4.0              1.05      1266.09055
                         8.0         5.0              1.02      1233.22151
```

POOR PRINT

```
HIGH VOLTAGE INT.DUTY                              CONT'D

       AT BUS    4
                  BUS     VOLTAGE=       4.1600(KV)
                  CALCULATED E/X=     207.9747(SYM.KA)=    14.9853(P.U.)
                      -CONTRIBUTIONS FROM ADJACENT BUSES-
                      FROM BUS    7=        63.98755(SYM.KA)=   4.61051(P.U.)
                      FROM BUS    2=       143.98715(SYM.KA)=  10.37475(P.U.)
                      -REMOTE MONITORING-
                      /CURRENT/                       /BUS VOLT/
                      FROM BUS   1 TO BUS   2//       FROM BUS        TO BUS
                          =          1.15688(P.U.)//     .969(P.U.)      .871(P.U.)
                      FROM BUS   2 TO BUS   3//       FROM BUS        TO BUS
                          =         -.64982(P.U.)//      .871(P.U.)      .951(P.U.)
                  X/R =   35.5523
                  NACD RATIO=          .99590
                  INT.DUTY
                      C.B.INT.TIME/CONT.PRTNG TIME/  M.F.   / DUTY(SYM.KA)
                         5.0         3.0               1.17       242.66436
                         5.0         4.0               1.11       230.80928
                         8.0         4.0               1.21       250.98104
                         8.0         5.0               1.15       239.85735
```

POOR PRINT

```
RBUS AND XBUS MATRICES FOR
H.V.HOM.(FIRST CYCLE) DUTY STUDY


RBUS AND XBUS MATRICES ...(BUS,BUS)
            RBUS(  1,  1)=      0.0000000000          XBUS(  1,  1)=      .0088915386
            RBUS(  2,  1)=      0.0000000000          XBUS(  2,  1)=      .0013308667
            RBUS(  2,  2)=      0.0000000000          XBUS(  2,  2)=      .0113583808
            RBUS(  3,  1)=      0.0000000000          XBUS(  3,  1)=      .0001327302
            RBUS(  3,  2)=      0.0000000000          XBUS(  3,  2)=      .0006581276
            RBUS(  3,  3)=      0.0000000000          XBUS(  3,  3)=      .0056571108
            RBUS(  4,  1)=      0.0000000000          XBUS(  4,  1)=      .0020479951
            RBUS(  4,  2)=      0.0000000000          XBUS(  4,  2)=      .0083602151
            RBUS(  4,  3)=      0.0000000000          XBUS(  4,  3)=      .0014271169
            RBUS(  4,  4)=      0.0000000000          XBUS(  4,  4)=      .0662632486
            RBUS(  5,  1)=      0.0000000000          XBUS(  5,  1)=      .0005878636
            RBUS(  5,  2)=      0.0000000000          XBUS(  5,  2)=      .0014714225
            RBUS(  5,  3)=      0.0000000000          XBUS(  5,  3)=      .0050587128
            RBUS(  5,  4)=      0.0000000000          XBUS(  5,  4)=      .0081250099
            RBUS(  5,  5)=      0.0000000000          XBUS(  5,  5)=      .0373420573
            RBUS(  6,  1)=      0.0000000000          XBUS(  6,  1)=      .0062659321
            RBUS(  6,  2)=      0.0000000000          XBUS(  6,  2)=      .0030585165
            RBUS(  6,  3)=      0.0000000000          XBUS(  6,  3)=      .0010170341
            RBUS(  6,  4)=      0.0000000000          XBUS(  6,  4)=      .0183844038
            RBUS(  6,  5)=      0.0000000000          XBUS(  6,  5)=      .0666696066
            RBUS(  6,  6)=      0.0000000000          XBUS(  6,  6)=      .0900278003
            RBUS(  7,  1)=      0.0000000000          XBUS(  7,  1)=      .0027651235
            RBUS(  7,  2)=      0.0000000000          XBUS(  7,  2)=      .0053620494
            RBUS(  7,  3)=      0.0000000000          XBUS(  7,  3)=      .0021961061
            RBUS(  7,  4)=      0.0000000000          XBUS(  7,  4)=      .0401662820
            RBUS(  7,  5)=      0.0000000000          XBUS(  7,  5)=      .0147785973
            RBUS(  7,  6)=      0.0000000000          XBUS(  7,  6)=      .0337102911
            RBUS(  7,  7)=      0.0000000000          XBUS(  7,  7)=      .0749705146
            RBUS(  8,  1)=      0.0000000000          XBUS(  8,  1)=      .0010429970
            RBUS(  8,  2)=      0.0000000000          XBUS(  8,  2)=      .0022847174
            RBUS(  8,  3)=      0.0000000000          XBUS(  8,  3)=      .0044603148
            RBUS(  8,  4)=      0.0000000000          XBUS(  8,  4)=      .0148229029
            RBUS(  8,  5)=      0.0000000000          XBUS(  8,  6)=      .0326254019
            RBUS(  8,  6)=      0.0000000000          XBUS(  8,  6)=      .0123221791
            RBUS(  8,  7)=      0.0000000000          XBUS(  8,  7)=      .0273610885
            RBUS(  8,  8)=      0.0000000000          XBUS(  8,  8)=      .0607904889
```

POOR PRINT

```
HIGH VOLTAGE MOM.DUTY(=FIRST CYCLE DUTY)


      AT BUS    1
                 BUS     VOLTAGE=        4.1600(KV)
                 CALCULATED E/X=    1560.8786(SYM.KA)=  112.4665(P.U.)
                      -CONTRIBUTIONS FROM ADJACENT BUSES-
                      FROM BUS    6=        32.52582(SYM.KA)=   2.34359(P.U.)
                      FROM BUS    2=       140.49156(SYM.KA)=  10.12288(P.U.)
                      FROM BUS    0=      1387.86122(SYM.KA)= 100.00000(P.U.)
                      -REMOTE MONITORING-
                      /CURRENT/                       /BUS VOLT/
                      FROM BUS   2 TO BUS   3//       FROM BUS        TO BUS
                            =         -1.10451(P.U.)//     .850(P.U.)      .985(P.U.)
                      FROM BUS   3 TO BUS   5//       FROM BUS        TO BUS
                            =          1.38344(P.U.)//     .985(P.U.)      .934(P.U.)
                 MOM.DUTY(FIRST CYCLE DUTY)=     2497.40576(ASYM.KA)


      AT BUS    2
                 BUS     VOLTAGE=        4.1600(KV)
                 CALCULATED E/X=    1221.8830(SYM.KA)=   88.0407(P.U.)
                      -CONTRIBUTIONS FROM ADJACENT BUSES-
                      FROM BUS    4=        43.61200(SYM.KA)=   3.14239(P.U.)
                      FROM BUS    3=       107.16768(SYM.KA)=   7.72179(P.U.)
                      FROM BUS    1=       145.86249(SYM.KA)=  10.50988(P.U.)
                      FROM BUS    0=       925.24082(SYM.KA)=  66.66667(P.U.)
                      -REMOTE MONITORING-
                      /CURRENT/                       /BUS VOLT/
                      FROM BUS   0 TO BUS   1//       FROM BUS        TO BUS
                            =         11.71705(P.U.)//   0.000(P.U.)      .883(P.U.)
                      FROM BUS   0 TO BUS   3//       FROM BUS        TO BUS
                            =          9.62700(P.U.)//   0.000(P.U.)      .942(P.U.)
                 MOM.DUTY(FIRST CYCLE DUTY)=     1955.01277(ASYM.KA)


      AT BUS    4
                 BUS     VOLTAGE=        4.1600(KV)
                 CALCULATED E/X=     209.4466(SYM.KA)=   15.0913(P.U.)
                      -CONTRIBUTIONS FROM ADJACENT BUSES-
                      FROM BUS    7=        65.07049(SYM.KA)=   4.68854(P.U.)
                      FROM BUS    2=       144.37611(SYM.KA)=  10.40278(P.U.)
                      -REMOTE MONITORING-
                      /CURRENT/                       /BUS VOLT/
                      FROM BUS   1 TO BUS   2//       FROM BUS        TO BUS
                            =          1.13404(P.U.)//     .969(P.U.)      .874(P.U.)
                      FROM BUS   2 TO BUS   3//       FROM BUS        TO BUS
                            =          -.85762(P.U.)//     .874(P.U.)      .978(P.U.)
                 MOM.DUTY(FIRST CYCLE DUTY)=      335.11456(ASYM.KA)
```

POOR PRINT

```
JOB NAME=CHANGE CASF 1...

DESCRIPTION=        ........
BASE MVA=     100.00
TYPE OF FAULT=3PHASE SHORT CIRCUIT


DUTY CALCULATIONS TO BE DONE BY THIS STUDY ARE...
(IF H/V. INT.DUTY CAL. IS REQUIRED.
RATED INT.TIME AND CONT.PARTING TIME IN CYCLES
OF THF C.B. TO BE CHECKED ARE AS SHOWN.)

AT BUSES
    1.    3,    8.    9.
             INT.TIME=  2,  PARTING TIME=1.5,
             INT.TIME=  3,  PARTING TIME=2.0,
             FIRST CYCLE DUTY WANTED

AT BUSES
    2.    4.    5.  10.
             INT.TIME=  5.  PARTING TIME=3.0, 4.0,
             INT.TIME=  8.  PARTING TIME=4.0, 5.0,
             FIRST CYCLE DUTY WANTED

AT BUSES
    6.    7.
             FIRST CYCLE DUTY WANTED
```

POOR PRINT

```
REMOTE MONITORING
   FAULTED BUS///MONITORED BRANCH(FROM BUS/TO BUS)
      1
              2/   3,   3/   5,
      3
              5/   8,   6/   7,
      8
              4/   7,   1/   2,
      2
              0/   1,   0/   3,
      4
              1/   2,   2/   3,
      5
              1/   2,   1/   6,
      6
              1/   2,   2/   3,
      7
              1/   2,   2/   3,
```

POOR PRINT

```
BUS VOLTAGES
          BUSES AT      13.80KV
                          9
                         AT LEAST   1BUSES AT THIS VOLTAGE.
          BUSES AT       4.16KV
                          1, 2, 4,10,
                         AT LEAST   4BUSES AT THIS VOLTAGE.
          BUSES AT        .48KV
                          3, 5, 6, 7, 8,
                         AT LEAST   5BUSES AT THIS VOLTAGE.
IDENTIFICATION CODE FOR BRANCH IMPEDANCES


  ID CODE1=A T/G.H/G WITH AMOR.WINDING,OR CONDENSER,
  ID CODE2=AN H/G WITHOUT AMOR,WINDING.
  ID CODE3=A SYNCH.MOTOR.
  ID CODE4=AN IND.MTR.ABV 1000HP AT 1800RPM,OR
          ABV 250HP AT 3600RPM,
  ID CODE5=AN IND.MTR.50HP AND ABV...NOT BIGGER THAN
          1000HP AT 1800 RPM OR 250HP AT 3600RPM.
  ID CODE6=AN IND.MTR.SMALLER THAN 50HP.
  ID CODE7=A STATIC ELEMENT...CABLE,BUSDUCT,TRF,RXTR,ETC.
  ID CODE8=UTILITY SYSTEM,OFFSITE SOURCE,ETC,
```

POOR PRINT

```
IMPEDANCES
   FROM BUS     TO BUS      R        X      IDEN.CODE
       2           4      -.0020   -.0840     7
       4           6       .0030    .0500     7
       4           5       .0020    .0400     7
       3           5       .0010    .0600     7
       0           9       .0002    .0040     1
       9          10       .0020    .0500     7
      10           0       .0010    .5000     5
       0          10       .0020    .7000     3
```

POOR PRINT

SHORT CIRCUIT DUTIES

POOR PRINT

```
RBUS AND XBUS MATRICES FOR
L.V. INT.DUTY STUDY


RBUS AND XBUS MATRICES ...(BUS,BUS)
          RBUS(  1,  1)=       .0006712311          XBUS(  1,  1)=       .0087212532
          RBUS(  2,  1)=       .0001285364          XBUS(  2,  1)=       .0012186004
          RBUS(  2,  2)=       .0004060018          XBUS(  2,  2)=       .0117373398
          RBUS(  3,  1)=       .0000143392          XBUS(  3,  1)=       .0002331733
          RBUS(  3,  2)=       .0000118920          XBUS(  3,  2)=       .0004782532
          RBUS(  3,  3)=       .0001922753          XBUS(  3,  3)=       .0047239956
          RBUS(  4,  1)=       .0001360463          XBUS(  4,  1)=       .0023584552
          RBUS(  4,  2)=       .0000335035          XBUS(  4,  2)=       .0006636245
          RBUS(  4,  3)=       .0001593893          XBUS(  4,  3)=       .0035995642
          RBUS(  4,  4)=       .0019330049          XBUS(  4,  4)=       .0466112849
          RBUS(  5,  1)=       .0000430500          XBUS(  5,  1)=       .0011156205
          RBUS(  5,  2)=       .0000169902          XBUS(  5,  2)=       .0005552220
          RBUS(  5,  3)=       .0001845939          XBUS(  5,  3)=       .0042571157
          RBUS(  5,  4)=       .0005657305          XBUS(  5,  4)=       .0206266880
          RBUS(  5,  5)=       .0006565539          XBUS(  5,  5)=       .0244377520
          RBUS(  6,  1)=       .0002692800          XBUS(  6,  1)=       .0038630235
          RBUS(  6,  2)=       .0000571619          XBUS(  6,  2)=       .0007948559
          RBUS(  6,  3)=       .0001232793          XBUS(  6,  3)=       .0028035363
          RBUS(  6,  4)=       .0014472696          XBUS(  6,  4)=       .0346172361
          RBUS(  6,  5)=       .0004356097          XBUS(  6,  5)=       .0160130364
          RBUS(  6,  6)=       .0028966533          XBUS(  6,  6)=       .0571393703
          RBUS(  7,  1)=       .0001391766          XBUS(  7,  1)=       .0024407332
          RBUS(  7,  2)=       .0000340594          XBUS(  7,  2)=       .0006700010
          RBUS(  7,  3)=       .0001585409          XBUS(  7,  3)=       .0035560331
          RBUS(  7,  4)=       .0017013283          XBUS(  7,  4)=       .0373289402
          RBUS(  7,  5)=       .0005626734          XBUS(  7,  5)=       .0203743882
          RBUS(  7,  6)=       .0014813227          XBUS(  7,  6)=       .0358488701
          RBUS(  7,  7)=       .0026653223          XBUS(  7,  7)=       .0754200173
          RBUS(  8,  1)=       .0000517888          XBUS(  8,  1)=       .0013926215
          RBUS(  8,  2)=       .0000185419          XBUS(  8,  2)=       .0005793826
          RBUS(  8,  3)=       .0001822255          XBUS(  8,  3)=       .0041105617
          RBUS(  8,  4)=       .0006689667          XBUS(  8,  4)=       .0241181192
          RBUS(  8,  5)=       .0006480193          XBUS(  8,  5)=       .0235883483
          RBUS(  8,  6)=       .0005306745          XBUS(  8,  6)=       .0201595101
          RBUS(  8,  7)=       .0007538233          XBUS(  8,  7)=       .0318811016
          RBUS(  8,  8)=       .0013849106          XBUS(  8,  8)=       .0545873984
          RBUS(  9,  1)=      0.0000000000          XBUS(  9,  1)=      0.0000000000
          RBUS(  9,  2)=      0.0000000000          XBUS(  9,  2)=      0.0000000000
          RBUS(  9,  3)=      0.0000000000          XBUS(  9,  3)=      0.0000000000
          RBUS(  9,  4)=      0.0000000000          XBUS(  9,  4)=      0.0000000000
          RBUS(  9,  5)=      0.0000000000          XBUS(  9,  5)=      0.0000000000
          RBUS(  9,  6)=      0.0000000000          XBUS(  9,  6)=      0.0000000000
          RBUS(  9,  7)=      0.0000000000          XBUS(  9,  7)=      0.0000000000
          RBUS(  9,  8)=      0.0000000000          XBUS(  9,  8)=      0.0000000000
          RBUS(  9,  9)=       .0001860465          XBUS(  9,  9)=       .0039537126
          RBUS( 10,  1)=      0.0000000000          XBUS( 10,  1)=      0.0000000000
          RBUS( 10,  2)=      0.0000000000          XBUS( 10,  2)=      0.0000000000
          RBUS( 10,  3)=      0.0000000000          XBUS( 10,  3)=      0.0000000000
          RBUS( 10,  4)=      0.0000000000          XBUS( 10,  4)=      0.0000000000
          RBUS( 10,  5)=      0.0000000000          XBUS( 10,  5)=      0.0000000000
          RBUS( 10,  6)=      0.0000000000          XBUS( 10,  6)=      0.0000000000
          RBUS( 10,  7)=      0.0000000000          XBUS( 10,  7)=      0.0000000000
          RBUS( 10,  8)=      0.0000000000          XBUS( 10,  8)=      0.0000000000
          RBUS( 10,  9)=       .0000465116          XBUS( 10,  9)=       .0033751205
          RBUS( 10, 10)=       .0005116279          XBUS( 10, 10)=       .0455641273
```

POOR PRINT

```
(LOW VOLTAGE INT.DUTY(=FIRST CYCLE DUTY)

    AT BUS    3
               BUS      VOLTAGE=         .4800(KV)
               CALCULATED E/X=  25461.7734(SYM.KA)=  211.6852(P.U.)
                    -CONTRIBUTIONS FROM ADJACENT BUSES-
                    FROM BUS     5=       321.28621(SYM.KA)=    2.67112(P.U.)
                    FROM BUS     2=       886.09943(SYM.KA)=    7.36689(P.U.)
                    FROM BUS     0=     24056.26122(SYM.KA)= 200.00000(P.U.)
                    FROM BUS     5=       198.12650(SYM.KA)=    1.64719(P.U.)
                    -REMOTE MONITORING-
                    /CURRENT/                        /BUS VOLT/
                    FROM BUS    5 TO BUS    8//      FROM BUS        TO BUS
                         =        -.83847(P.U.)//      .099(P.U.)       .130(P.U.)
                    FROM BUS    6 TO BUS    7//      FROM BUS        TO BUS
                         =         .94817(P.U.)//      .407(P.U.)       .247(P.U.)
               X/R=    24.5561
               M.F.=     1.1500(ANSI C 37.13-1973...9.1.4.3)
               INT.DUTY=     29281.03936(SYM.KA)

    AT BUS    5
               BUS      VOLTAGE=         .4800(KV)
               CALCULATED E/X=   4921.9464(SYM.KA)=   40.9203(P.U.)
                    -CONTRIBUTIONS FROM ADJACENT BUSES-
                    FROM BUS     8=       112.99243(SYM.KA)=     .93940(P.U.)
                    FROM BUS     3=      2684.54082(SYM.KA)=   22.31885(P.U.)
                    FROM BUS     4=       468.94633(SYM.KA)=    3.89875(P.U.)
                    FROM BUS     3=      1655.46684(SYM.KA)=   13.76329(P.U.)
                    -REMOTE MONITORING-
                    /CURRENT/                        /BUS VOLT/
                    FROM BUS    1 TO BUS    2//      FROM BUS        TO BUS
                         =        -.27300(P.U.)//      .954(P.U.)       .977(P.U.)
                    FROM BUS    1 TO BUS    6//      FROM BUS        TO BUS
                         =        4.83815(P.U.)//      .954(P.U.)       .345(P.U.)
               X/R=    37.2212
               M.F.=     1.1500(ANSI C 37.13-1973...9.1.4.3)
               INT.DUTY=      5660.23838(SYM.KA)

    AT BUS    6
               BUS      VOLTAGE=         .4800(KV)
               CALCULATED E/X=   2105.0513(SYM.KA)=   17.5011(P.U.)
                    -CONTRIBUTIONS FROM ADJACENT BUSES-
                    FROM BUS     7=       266.77140(SYM.KA)=    2.21790(P.U.)
                    FROM BUS     1=       890.07495(SYM.KA)=    7.39994(P.U.)
                    FROM BUS     4=       948.20496(SYM.KA)=    7.88323(P.U.)
                    -REMOTE MONITORING-
                    /CURRENT/                        /BUS VOLT/
                    FROM BUS    1 TO BUS    2//      FROM BUS        TO BUS
                         =        -.63924(P.U.)//      .932(P.U.)       .986(P.U.)
                    FROM BUS    2 TO BUS    3//      FROM BUS        TO BUS
                         =         .28815(P.U.)//      .986(P.U.)       .951(P.U.)
               X/R=    19.7260
               M.F.=     1.1481(ANSI C 37.13-1973...9.1.4.3)
               INT.DUTY=      2416.79653(SYM.KA)
```

POOR PRINT

```
LOW VOLTAGE INT.DUTY(=FIRST CYCLE DUTY)     CONT"D

    AT BUS    7
               BUS     VOLTAGE=         .4800(KV)
               CALCULATED E/X=   1594.8194(SYM.KA)=    13.2591(P.U.)
                   -CONTRIBUTIONS FROM ADJACENT BUSES-
                   FROM BUS     8=       495.97648(SYM.KA)=   4.12347(P.U.)
                   FROM BUS     4=       723.19510(SYM.KA)=   6.01253(P.U.)
                   FROM BUS     6=       375.64781(SYM.KA)=   3.12308(P.U.)
                   -REMOTE MONITORING-
                   /CURRENT/                        /BUS VOLT/
                   FROM BUS   1 TO BUS    2//       FROM BUS         TO BUS
                         =          -.27938(P.U.)//     .968(P.U.)       .991(P.U.)
                   FROM BUS   2 TO BUS    3//       FROM BUS         TO BUS
                         =           .31357(P.U.)//     .991(P.U.)       .953(P.U.)
               X/R=   28.2968
               M.F.=     1.1500(ANSI C 37.13-1973...9.1.4.3)
               INT.DUTY=      1834.04230(SYM.KA)

    AT BUS    8
               BUS     VOLTAGE=         .4800(KV)
               CALCULATED E/X=   2203.4629(SYM.KA)=    18.3192(P.U.)
                   -CONTRIBUTIONS FROM ADJACENT BUSES-
                   FROM BUS     7=       357.37487(SYM.KA)=   2.97116(P.U.)
                   FROM BUS     5=      1846.08801(SYM.KA)=  15.34809(P.U.)
                   -REMOTE MONITORING-
                   /CURRENT/                        /BUS VOLT/
                   FROM BUS   4 TO BUS    7//       FROM BUS         TO BUS
                         =          1.49300(P.U.)//     .558(P.U.)       .416(P.U.)
                   FROM BUS   1 TO BUS    2//       FROM BUS         TO BUS
                         =          -.17736(P.U.)//     .974(P.U.)       .989(P.U.)
               X/R=   39.4158
               M.F.=     1.1500(ANSI C 37.13-1973...9.1.4.3)
               INT.DUTY=      2533.98231(SYM.KA)
```

POOR PRINT

```
RBUS AND XBUS MATRICES FOR
H.V.INT.DUTY STUDY


RBUS AND XBUS MATRICES ...(BUS,BUS)
            RBUS(  1,  1)=        .0006731415         XBUS(  1,  1)=        .0087408389
            RBUS(  2,  1)=        .0001301208         XBUS(  2,  1)=        .0012587717
            RBUS(  2,  2)=        .0004073158         XBUS(  2,  2)=        .0118197338
            RBUS(  3,  1)=        .0000399701         XBUS(  3,  1)=        .0006299700
            RBUS(  3,  2)=        .0000331486         XBUS(  3,  2)=        .0012921086
            RBUS(  3,  3)=        .0005362396         XBUS(  3,  3)=        .0127629364
            RBUS(  4,  1)=        .0001572823         XBUS(  4,  1)=        .0026608041
            RBUS(  4,  2)=        .0000511153         XBUS(  4,  2)=        .0012837616
            RBUS(  4,  3)=        .0004442922         XBUS(  4,  3)=        .0097250322
            RBUS(  4,  4)=        .0021690564         XBUS(  4,  4)=        .0512787353
            RBUS(  5,  1)=        .0000676442         XBUS(  5,  1)=        .0014732012
            RBUS(  5,  2)=        .0000373869         XBUS(  5,  2)=        .0012886428
            RBUS(  5,  3)=        .0005145491         XBUS(  5,  3)=        .0115015554
            RBUS(  5,  4)=        .0008391093         XBUS(  5,  4)=        .0261467663
            RBUS(  5,  5)=        .0009731627         XBUS(  5,  5)=        .0309662124
            RBUS(  6,  1)=        .0002857050         XBUS(  6,  1)=        .0040985093
            RBUS(  6,  2)=        .0000707836         XBUS(  6,  2)=        .0012778524
            RBUS(  6,  3)=        .0003436367         XBUS(  6,  3)=        .0075743837
            RBUS(  6,  4)=        .0016298430         XBUS(  6,  4)=        .0382525002
            RBUS(  6,  5)=        .0006470539         XBUS(  6,  5)=        .0203123734
            RBUS(  6,  6)=        .0030378642         XBUS(  6,  6)=        .0599707115
            RBUS(  7,  1)=        .0001602996         XBUS(  7,  1)=        .0027394258
            RBUS(  7,  2)=        .0000515774         XBUS(  7,  2)=        .0012834384
            RBUS(  7,  3)=        .0004419274         XBUS(  7,  3)=        .0096074229
            RBUS(  7,  4)=        .0019361233         XBUS(  7,  4)=        .0419399450
            RBUS(  7,  5)=        .0008345970         XBUS(  7,  5)=        .0258277097
            RBUS(  7,  6)=        .0016629243         XBUS(  7,  6)=        .0394401713
            RBUS(  7,  7)=        .0028988675         XBUS(  7,  7)=        .0799752591
            RBUS(  8,  1)=        .0000760674         XBUS(  8,  1)=        .0017378922
            RBUS(  8,  2)=        .0000386770         XBUS(  8,  2)=        .0012875549
            RBUS(  8,  3)=        .0005079472         XBUS(  8,  3)=        .0111056068
            RBUS(  8,  4)=        .0009368379         XBUS(  8,  4)=        .0294481653
            RBUS(  8,  5)=        .0009602659         XBUS(  8,  5)=        .0298920621
            RBUS(  8,  6)=        .0007394057         XBUS(  8,  6)=        .0243108397
            RBUS(  8,  7)=        .0010222580         XBUS(  8,  7)=        .0371466889
            RBUS(  8,  8)=        .0016934470         XBUS(  8,  8)=        .0606741027
            RBUS(  9,  1)=       0.0000000000         XBUS(  9,  1)=       0.0000000000
            RBUS(  9,  2)=       0.0000000000         XBUS(  9,  2)=       0.0000000000
            RBUS(  9,  3)=       0.0000000000         XBUS(  9,  3)=       0.0000000000
            RBUS(  9,  4)=       0.0000000000         XBUS(  9,  4)=       0.0000000000
            RBUS(  9,  5)=       0.0000000000         XBUS(  9,  5)=       0.0000000000
            RBUS(  9,  6)=       0.0000000000         XBUS(  9,  6)=       0.0000000000
            RBUS(  9,  7)=       0.0000000000         XBUS(  9,  7)=       0.0000000000
            RBUS(  9,  8)=       0.0000000000         XBUS(  9,  8)=       0.0000000000
            RBUS(  9,  9)=        .0001891892         XBUS(  9,  9)=        .0039761780
            RBUS( 10,  1)=       0.0000000000         XBUS( 10,  1)=       0.0000000000
            RBUS( 10,  2)=       0.0000000000         XBUS( 10,  2)=       0.0000000000
            RBUS( 10,  3)=       0.0000000000         XBUS( 10,  3)=       0.0000000000
            RBUS( 10,  4)=       0.0000000000         XBUS( 10,  4)=       0.0000000000
            RBUS( 10,  5)=       0.0000000000         XBUS( 10,  5)=       0.0000000000
            RBUS( 10,  6)=       0.0000000000         XBUS( 10,  6)=       0.0000000000
            RBUS( 10,  7)=       0.0000000000         XBUS( 10,  7)=       0.0000000000
            RBUS( 10,  8)=       0.0000000000         XBUS( 10,  8)=       0.0000000000
            RBUS( 10,  9)=        .0000819811         XBUS( 10,  9)=        .0036784025
            RBUS( 10, 10)=        .0008918919         XBUS( 10, 10)=        .0496584341
```

POOR PRINT

```
HIGH VOLTAGE INT.DUTY

     AT BUS    1
                BUS      VOLTAGE=        4.1600(KV)
                CALCULATED E/X=    1587.7895(SYM.KA)=   114.4055(P.U.)
                     -CONTRIBUTIONS FROM ADJACENT BUSES-
                     FROM BUS     6=          58.50033(SYM.KA)=    4.21514(P.U.)
                     FROM BUS     2=         141.42795(SYM.KA)=   10.19035(P.U.)
                     FROM BUS     0=        1387.86122(SYM.KA)=  100.00000(P.U.)
                     -REMOTE MONITORING-
                     /CURRENT/                              /BUS VOLT/
                     FROM BUS    2 TO BUS    3//          FROM BUS          TO BUS
                          =        -.58966(P.U.)//           .856(P.U.)          .928(P.U.)
                     FROM BUS    3 TO BUS    5//          FROM BUS          TO BUS
                          =        2.60730(P.U.)//           .928(P.U.)          .831(P.U.)
                     FROM BUS    3 TO BUS    5//          FROM BUS          TO BUS
                          =        1.60784(P.U.)//           .928(P.U.)          .831(P.U.)
                X/R =    12.9851
                NACD RATIO=          .98739
                INT.DUTY
                     C.B.INT.TIME/CONT.PRTNG TIME/  M.F.   / DUTY(SYM.KA)
                       2.0           1.5                1.00       1587.78951
                       3.0           2.0                1.00       1587.78951

   . AT BUS    2
                BUS      VOLTAGE=        4.1600(KV)
                CALCULATED E/X=    1174.1899(SYM.KA)=    84.6043(P.U.)
                     -CONTRIBUTIONS FROM ADJACENT BUSES-
                     FROM BUS     3=         101.32321(SYM.KA)=    7.30067(P.U.)
                     FROM BUS     1=         147.62589(SYM.KA)=   10.63693(P.U.)
                     FROM BUS     0=         925.24082(SYM.KA)=   66.66667(P.U.)
                     -REMOTE MONITORING-
                     /CURRENT/                              /BUS VOLT/
                     FROM BUS    0 TO BUS    1//          FROM BUS          TO BUS
                          =       10.64975(P.U.)//          0.000(P.U.)          .894(P.U.)
                     FROM BUS    0 TO BUS    3//          FROM BUS          TO BUS
                          =        7.28786(P.U.)//          0.000(P.U.)          .891(P.U.)
                X/R =    29.0186
                NACD RATIO=          .13774
                INT.DUTY
                     C.B.INT.TIME/CONT.PRTNG TIME/  M.F.   / DUTY(SYM.KA)
                       5.0           3.0                1.04       1217.88610
                       5.0           4.0                1.02       1202.56388
                       8.0           4.0                1.04       1226.15749
                       8.0           5.0                1.02       1193.86849
```

POOR PRINT

```
HIGH VOLTAGE INT.DUTY                              CONT'D

       AT BUS    4
                 BUS      VOLTAGE=        4.1600(KV)
                 CALCULATED E/X=     270.6504(SYM.KA)=    19.5013(P.U.)
                      -CONTRIBUTIONS FROM ADJACENT BUSES-
                      FROM BUS     7=        30.08985(SYM.KA)=   2.16807(P.U.)
                      FROM BUS     6=        70.51113(SYM.KA)=   5.08056(P.U.)
                      FROM BUS     5=       170.04946(SYM.KA)=  12.25263(P.U.)
                      -REMOTE MONITORING-
                      /CURRENT/                          (   /BUS VOLT/
                      FROM BUS    1 TO BUS    2//         FROM BUS          TO BUS
                            =          -.31969(P.U.)//      .948(P.U.)        .975(P.U.)
                      FROM BUS    2 TO BUS    3//         FROM BUS          TO BUS
                            =          1.37931(P.U.)//      .975(P.U.)        .810(P.U.)
                 X/R =    23.6410
                 NACD RATIO=           .99391
                 INT.DUTY
                      C.B.INT.TIME/CONT.PRTNG TIME/   M.F.   / DUTY(SYM.KA)
                          5.0         3.0              1.08        291.47533
                          5.0         4.0              1.02        276.17808
                          8.0         4.0              1.12        303.01578
                          8.0         5.0              1.08        292.88587


       AT BUS    9
                 BUS      VOLTAGE=       13.8000(KV)
                 CALCULATED E/X=    1052.1907(SYM.KA)=   251.4978(P.U.)
                      -CONTRIBUTIONS FROM ADJACENT BUSES-
                      FROM BUS     0=      1045.92440(SYM.KA)= 250.00000(P.U.)
                      FROM BUS    10=         6.26633(SYM.KA)=   1.49780(P.U.)
                 X/R =    21.0169
                 NACD RATIO=          0.00000
                 INT.DUTY
                      C.B.INT.TIME/CONT.PRTNG TIME/   M.F.   / DUTY(SYM.KA)
                          2.0         1.5              1.00       1052.19073
                          3.0         2.0              1.00       1052.19073


       AT BUS   10
                 BUS      VOLTAGE=        4.1600(KV)
                 CALCULATED E/X=     279.4815(SYM.KA)=    20.1376(P.U.)
                      -CONTRIBUTIONS FROM ADJACENT BUSES-
                      FROM BUS     9=       257.01134(SYM.KA)=  18.51852(P.U.)
                      FROM BUS     0=        27.75722(SYM.KA)=   2.00000(P.U.)
                      FROM BUS     0=        19.82659(SYM.KA)=   1.42857(P.U.)
                 X/R =    55.6776
                 NACD RATIO=           .92593
                 INT.DUTY
                      C.B.INT.TIME/CONT.PRTNG TIME/   M.F.   / DUTY(SYM.KA)
                          5.0         3.0              1.29        360.53229
                          5.0         4.0              1.22        340.80452
                          8.0         4.0              1.34        374.20533
```

POOR PRINT

```
HIGH VOLTAGE INT.DUTY                    CONT'D

      AT BUS  10    CONT'D
                       8.0        5.0             1.28      357.16692
```

POOR PRINT

```
RBUS AND XBUS MATRICES FOR
H.V.MOM.(FIRST CYCLE) DUTY STUDY

RBUS AND XBUS MATRICES ...(BUS,BUS)
         RBUS(  1,  1)=       0.0000000000         XBUS(  1,  1)=       .0087234043
         RBUS(  2,  1)=       0.0000000000         XBUS(  2,  1)=       .0012230123
         RBUS(  2,  2)=       0.0000000000         XBUS(  2,  2)=       .0117463889
         RBUS(  3,  1)=       0.0000000000         XBUS(  3,  1)=       .0002767525
         RBUS(  3,  2)=       0.0000000000         XBUS(  3,  2)=       .0005676371
         RBUS(  3,  3)=       0.0000000000         XBUS(  3,  3)=       .0056068937
         RBUS(  4,  1)=       0.0000000000         XBUS(  4,  1)=       .0023916614
         RBUS(  4,  2)=       0.0000000000         XBUS(  4,  2)=       .0007317327
         RBUS(  4,  3)=       0.0000000000         XBUS(  4,  3)=       .0042723100
         RBUS(  4,  4)=       0.0000000000         XBUS(  4,  4)=       .0471239000
         RBUS(  5,  1)=       0.0000000000         XBUS(  5,  1)=       .0011548927
         RBUS(  5,  2)=       0.0000000000         XBUS(  5,  2)=       .0006357719
         RBUS(  5,  3)=       0.0000000000         XBUS(  5,  3)=       .0050527556
         RBUS(  5,  4)=       0.0000000000         XBUS(  5,  4)=       .0212329453
         RBUS(  5,  5)=       0.0000000000         XBUS(  5,  5)=       .0251547575
         RBUS(  6,  1)=       0.0000000000         XBUS(  6,  1)=       .0038888063
         RBUS(  6,  2)=       0.0000000000         XBUS(  6,  2)=       .0008479023
         RBUS(  6,  3)=       0.0000000000         XBUS(  6,  3)=       .0073275073
         RBUS(  6,  4)=       0.0000000000         XBUS(  6,  4)=       .0350164886
         RBUS(  6,  5)=       0.0000000000         XBUS(  6,  5)=       .0164852225
         RBUS(  6,  6)=       0.0000000000         XBUS(  6,  6)=       .0574503299
         RBUS(  7,  1)=       0.0000000000         XBUS(  7,  1)=       .0024735379
         RBUS(  7,  2)=       0.0000000000         XBUS(  7,  2)=       .0007380855
         RBUS(  7,  3)=       0.0000000000         XBUS(  7,  3)=       .0042206430
         RBUS(  7,  4)=       0.0000000000         XBUS(  7,  4)=       .0378353561
         RBUS(  7,  5)=       0.0000000000         XBUS(  7,  5)=       .0209733137
         RBUS(  7,  6)=       0.0000000000         XBUS(  7,  6)=       .0362432943
         RBUS(  7,  7)=       0.0000000000         XBUS(  7,  7)=       .0759203088
         RBUS(  8,  1)=       0.0000000000         XBUS(  8,  1)=       .0014305417
         RBUS(  8,  2)=       0.0000000000         XBUS(  8,  2)=       .0006571595
         RBUS(  8,  3)=       0.0000000000         XBUS(  8,  3)=       .0048788112
         RBUS(  8,  4)=       0.0000000000         XBUS(  8,  4)=       .0247035057
         RBUS(  8,  5)=       0.0000000000         XBUS(  8,  5)=       .0242806704
         RBUS(  8,  6)=       0.0000000000         XBUS(  8,  6)=       .0206154409
         RBUS(  8,  7)=       0.0000000000         XBUS(  8,  7)=       .0324594087
         RBUS(  8,  8)=       0.0000000000         XBUS(  8,  8)=       .0552558869
         RBUS(  9,  1)=       0.0000000000         XBUS(  9,  1)=      0.0000000000
         RBUS(  9,  2)=       0.0000000000         XBUS(  9,  2)=      0.0000000000
         RBUS(  9,  3)=       0.0000000000         XBUS(  9,  3)=      0.0000000000
         RBUS(  9,  4)=       0.0000000000         XBUS(  9,  4)=      0.0000000000
         RBUS(  9,  5)=       0.0000000000         XBUS(  9,  5)=      0.0000000000
         RBUS(  9,  6)=       0.0000000000         XBUS(  9,  6)=      0.0000000000
         RBUS(  9,  7)=       0.0000000000         XBUS(  9,  7)=      0.0000000000
         RBUS(  9,  8)=       0.0000000000         XBUS(  9,  8)=      0.0000000000
         RBUS(  9,  9)=       0.0000000000         XBUS(  9,  9)=       .0039575683
         RBUS( 10,  1)=       0.0000000000         XBUS( 10,  1)=      0.0000000000
         RBUS( 10,  2)=       0.0000000000         XBUS( 10,  2)=      0.0000000000
         RBUS( 10,  3)=       0.0000000000         XBUS( 10,  3)=      0.0000000000
         RBUS( 10,  4)=       0.0000000000         XBUS( 10,  4)=      0.0000000000
         RBUS( 10,  5)=       0.0000000000         XBUS( 10,  5)=      0.0000000000
         RBUS( 10,  6)=       0.0000000000         XBUS( 10,  6)=      0.0000000000
         RBUS( 10,  7)=       0.0000000000         XBUS( 10,  7)=      0.0000000000
         RBUS( 10,  8)=       0.0000000000         XBUS( 10,  8)=      0.0000000000
         RBUS( 10,  9)=       0.0000000000         XBUS( 10,  9)=       .0034271726
         RBUS( 10, 10)=       0.0000000000         XBUS( 10, 10)=       .0462668299
```

POOR PRINT

```
HIGH VOLTAGE MOM.DUTY(=FIRST CYCLE DUTY)


    AT BUS    1
                BUS      VOLTAGE=        4.1600(KV)
                CALCULATED E/X=    1590.9629(SYM.KA)=  114.6341(P.U.)
                      -CONTRIBUTIONS FROM ADJACENT BUSES-
                      FROM BUS     6=          61.04396(SYM.KA)=   4.39842(P.U.)
                      FROM BUS     2=         142.05768(SYM.KA)=  10.23573(P.U.)
                      FROM BUS     0=        1387.86122(SYM.KA)= 100.00000(P.U.)
                      -REMOTE MONITORING-
                      /CURRENT/                          /BUS VOLT/
                      FROM BUS    2 TO BUS    3//        FROM BUS        TO BUS
                            =          -.88913(P.U.)//     .860(P.U.)       .968(P.U.)
                      FROM BUS    3 TO BUS    5//        FROM BUS        TO BUS
                            =          2.72067(P.U.)//     .968(P.U.)       .868(P.U.)
                      FROM BUS    3 TO BUS    5//        FROM BUS        TO BUS
                            =          1.67775(P.U.)//     .968(P.U.)       .868(P.U.)
                MOM.DUTY(FIRST CYCLE DUTY)=        2545.54058(ASYM.KA)


    AT BUS    2
                BUS      VOLTAGE=        4.1600(KV)
                CALCULATED E/X=    1181.5216(SYM.KA)=   85.1325(P.U.)
                      -CONTRIBUTIONS FROM ADJACENT BUSES-
                      FROM BUS     3=         108.26178(SYM.KA)=   7.80062(P.U.)
                      FROM BUS     1=         148.01901(SYM.KA)=  10.66526(P.U.)
                      FROM BUS     0=         925.24082(SYM.KA)=  66.66667(P.U.)
                      -REMOTE MONITORING-
                      /CURRENT/                          /BUS VOLT/
                      FROM BUS    0 TO BUS    1//        FROM BUS        TO BUS
                            =         10.41182(P.U.)//   0.000(P.U.)       .896(P.U.)
                      FROM BUS    0 TO BUS    3//        FROM BUS        TO BUS
                            =          8.05406(P.U.)//   0.000(P.U.)       .952(P.U.)
                MOM.DUTY(FIRST CYCLE DUTY)=        1890.43456(ASYM.KA)


    AT BUS    4
                BUS      VOLTAGE=        4.1600(KV)
                CALCULATED E/X=     294.5132(SYM.KA)=   21.2207(P.U.)
                      -CONTRIBUTIONS FROM ADJACENT BUSES-
                      FROM BUS     7=          32.56666(SYM.KA)=   2.34654(P.U.)
                      FROM BUS     6=          71.31586(SYM.KA)=   5.13854(P.U.)
                      FROM BUS     5=         190.63072(SYM.KA)=  13.73558(P.U.)
                      -REMOTE MONITORING-
                      /CURRENT/                          /BUS VOLT/
                      FROM BUS    1 TO BUS    2//        FROM BUS        TO BUS
                            =          -.41934(P.U.)//     .949(P.U.)       .984(P.U.)
                      FROM BUS    2 TO BUS    3//        FROM BUS        TO BUS
                            =           .61585(P.U.)//     .984(P.U.)       .909(P.U.)
                MOM.DUTY(FIRST CYCLE DUTY)=         471.22118(ASYM.KA)
```

POOR PRINT

```
HIGH VOLTAGE MOM.DUTY(=FIRST CYCLE DUTY)   CONT'D


   AT BUS    9
            BUS     VOLTAGE=       13.8000(KV)
            CALCULATED E/X=    1057.1384(SYM.KA)=  252.6804(P.U.)
                 -CONTRIBUTIONS FROM ADJACENT BUSES-
                 FROM BUS     0=      1045.92440(SYM.KA)= 250.00000(P.U.)
                 FROM BUS    10=        11.21403(SYM.KA)=   2.68041(P.U.)
            MOM.DUTY(FIRST CYCLE DUTY)=      1691.42150(ASYM.KA)


   AT BUS   10
            BUS     VOLTAGE=        4.1600(KV)
            CALCULATED E/X=    299.9689(SYM.KA)=   21.6138(P.U.)
                 -CONTRIBUTIONS FROM ADJACENT BUSES-
                 FROM BUS     9=       257.01134(SYM.KA)=  18.51852(P.U.)
                 FROM BUS     0=        27.75722(SYM.KA)=   2.00000(P.U.)
                 FROM BUS     0=        19.82659(SYM.KA)=   1.42857(P.U.)
            MOM.DUTY(FIRST CYCLE DUTY)=       479.95032(ASYM.KA)
```

POOR PRINT

THANK YOU.BYE-BYE.

```
        HWANALV.    78/06/18. CONCORDIA UNIVERSITY  -  CYBER 172/2.

12.23.11.HWANG1.T100.
12.23.11.ACCOUNT.K755161..
12.23.12.FTN.
12.23.38.      17.087 CP SECONDS COMPILATION TIME
12.23.38.LGO.
12.23.42.     STOP
12.23.42.      2.576 CP SECONDS EXECUTION TIME
12.23.42.UEAD,        0.001KUNS.
12.23.42.UEMS,        2.016KUNS.
12.23.42.UECP,       20.975SECS.
12.23.42.AESR,       24.980UNTS.
```

2. SAMPLE 2

This sample demonstrates the option feature - 3 phase and 1L-G fault calculations -- with one running.

Note that, in the result for 1L-G fault, no "CONTRIBUTION FROM ADJACENT BUSES" is printed.

2.1 System Description

The system to be studied is shown in Fig. C3, which is a part of a real system for a nuclear power plant.

Fig. C4 and Fig. C5 show positive and negative sequence networks of the system, respectively.

In this sample running, the base MVA is 10000 MVA.

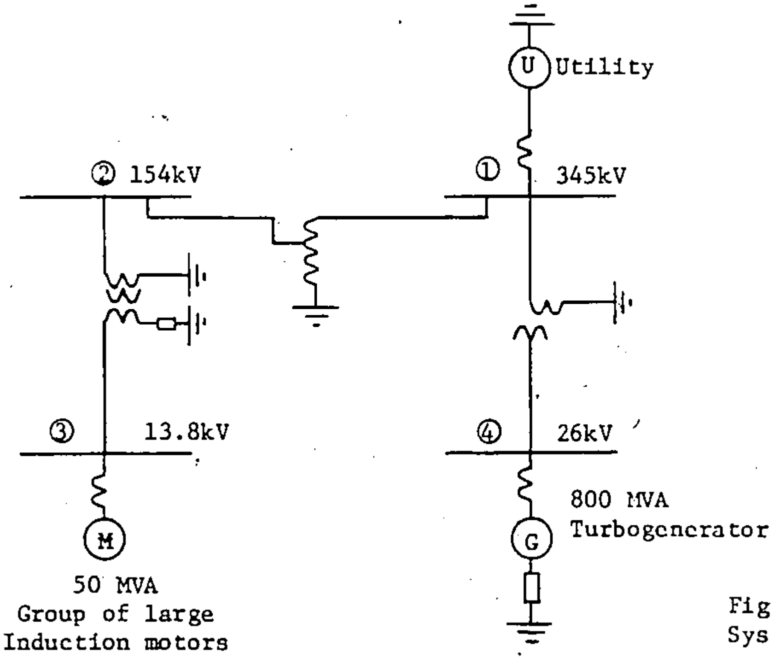


Fig. C3 Sample running 2
System Single line diagram

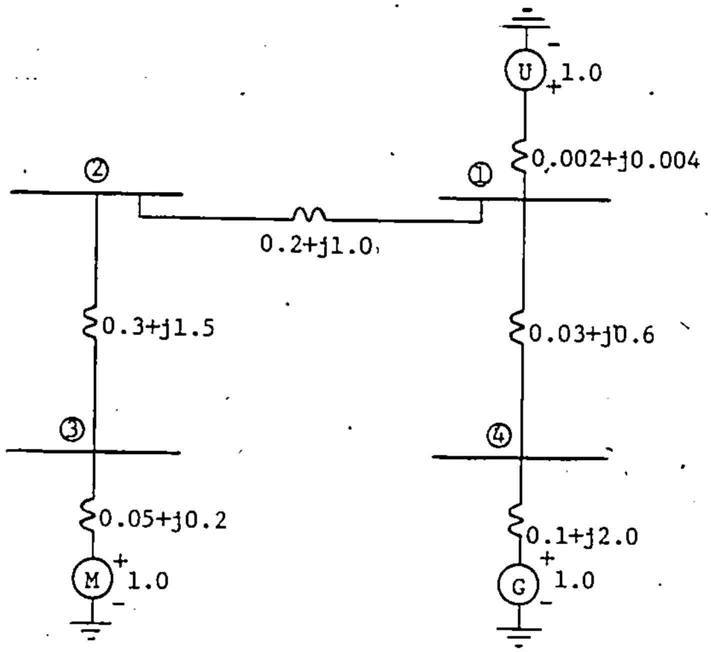


Fig. C4 Sample running 2
- Positive sequence

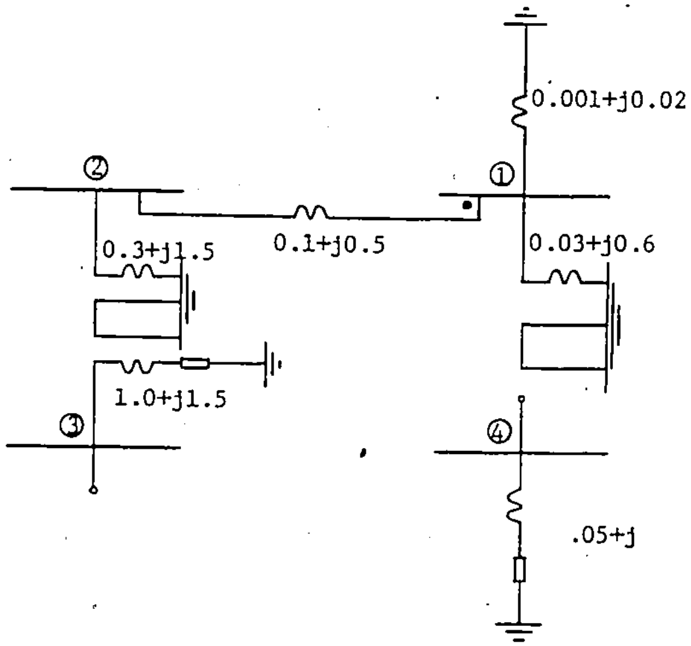


Fig. C5 Sample running 2
- Zero sequence

POOR PRINT !

2.2 Input Data

CARD NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	S	A	M	P	L	E	2	.	.	.	3	P	H	A	S	E		F	A	U	L	T			
2	1	0	0	0	0	.					3	1													
3	1	1	1																						
4			1																						
5			2																						
6			3																						
7			4																						
8	0																								
9	3	4	5	.																					
10			1																						
11	0																								
12	1	5	4	.																					
13			2																						
14	0																								
15	2	6	.																						
16			4																						
17	0																								
18	1	3	.	8																					
19			3																						
20	0																								
21	0																								
22		0		1			0	.	0	0	2							0	.	0	4				8
23		0		4			0	.	1										2	.	0				1
24		0		3			0	.	0	5								0	.	2					4
25		1		2			0	.	2										1	.	0				
26		2		3			0	.	3										1.	5					
27		1		4			0	.	0	3								0	.	6					
28	0																								
29	2																								

Cont'd

POOR PRINT

CARD NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
30	S	A	M	P	L	E	2	.	.	..	1	L	G		F	A	U	L	T						
31	1	0	0	0	0	.					1	1													
32	1	1	1																						
33	0																								
34	3	4	5	.																					
35			1																						
36	0																								
37	1	5	4	.																					
38		.	2																						
39	0																								
40	2	6	.																						
41			4																						
42	0																								
43	1	3	.	8																					
44			3																						
45	0																								
46	0																								
47		0		1			0	.	0	0	1						0	.	0	2					8
48		0		4			0	..	0	5								1	.	0					1
49		0		3				1	.	0								1.	5						
50		0		1			0	.	0	3							0	.	6						
51		0		2			0	.	3									1.	5						
52		1		2			0	.	1								0	.	5						
53	0																								
54	0																								

POOR PRINT

2.3 Result of computer running

POOR PRINT

SHORT CIRCUIT STUDY

POOR PRINT

```
JOB NAME=SAMPLE2...3PHASE FAULT

DESCRIPTION=
BASE MVA=  10000.00
TYPE OF FAULT=3PHASE SHORT CIRCUIT
FOR ALL BUSES OF HIGH VOLTAGE,CHECKS FOR
2-1.5,3-2.0,5-3.0,8-9.0 BREAKER"S INT,DUTY AND CHECKS FOR
FIRST CYCLE DUTYWILL BE DONE.
FOR ALL BUSES OF LOWVOLTAGE, CHECKS FOR FIRST CYCLE DUTY WILL BE DONE,
```

POOR PRINT

```
REMOTE MONITORING
   FAULTED BUS///MONITORED BRANCH(FROM BUS/TO BUS)
      1            ALL BRANCHES
      2            ALL BRANCHES
      3            ALL BRANCHES
      4            ALL BRANCHES
```

POOR PRINT

```
BUS VOLTAGES
          BUSES AT     345.00KV
                          1
                         AT LEAST   1BUSES AT THIS VOLTAGE.
          BUSES AT     154.00KV
                          2
                         AT LEAST   1BUSES AT THIS VOLTAGE.
          BUSES AT      26.00KV
                          4
                         AT LEAST   1BUSES AT THIS VOLTAGE.
          BUSES AT      13.80KV
                          3
                         AT LEAST   1BUSES AT THIS VOLTAGE.
IDENTIFICATION CODE FOR BRANCH IMPEDANCES

  ID CODE1=A T/G.H/G WITH AMOR.WINDING.OR CONDENSER.
  ID CODE2=AN H/G WITHOUT AMOR.WINDING.
  ID CODE3=A SYNCH.MOTOR.
  ID CODE4=AN IND.MTR.ABV 1000HP AT 1800RPM.OR
          ABV 250HP AT 3600RPM.
  ID CODE5=AN IND.MTR.50HP AND ABV...NOT BIGGER THAN
          1000HP AT 1800 RPM OR 250HP AT 3600RPM.
  ID CODE6=AN IND.MTR.SMALLER THAN 50HP.
  ID CODE7=A STATIC ELEMENT...CABLE.BUSDUCT.TRF.RXTR.ETC.
  ID CODE8=UTILITY SYSTEM.OFFSITE SOURCE.ETC.
```

POOR PRINT

```
IMPEDANCES
     FROM BUS        TO BUS          R          X      IDEN.CODE
          0             1          .0020      .0400      8
          0             4          .1000     2.0000      1
          0             3          .0500      .2000      4
          1             2          .2000     1.0000      7
          2             3          .3000     1.5000      7
          1             4          .0300      .6000      7
```

POOR PRINT

SHORT CIRCUIT DUTIES

POOR PRINT

```
RBUS AND XBUS MATRICES FOR
H.V.INT.DUTY STUDY

RBUS AND XBUS MATRICES ...(BUS,BUS)
          RBUS(  1,  1)=          .0019629727          XBUS(  1,  1)=          .0388473853
          RBUS(  2,  1)=          .0012801996          XBUS(  2,  1)=          .0249733191
          RBUS(  2,  2)=          .1312696954          XBUS(  2,  2)=          .6509114196
          RBUS(  3,  1)=          .0002560399          XBUS(  3,  1)=          .0041622199
          RBUS(  3,  2)=          .0262539391          XBUS(  3,  2)=          .1098165694
          RBUS(  3,  3)=          .0652507878          XBUS(  3,  3)=          .2683030950
          RBUS(  4,  1)=          .0015099790          XBUS(  4,  1)=          .0298826041
          RBUS(  4,  2)=          .0009847689          XBUS(  4,  2)=          .0192102455
          RBUS(  4,  3)=          .0001969538          XBUS(  4,  3)=          .0032017076
          RBUS(  4,  4)=          .0242384454          XBUS(  4,  4)=          .4846250800
```

POOR PRINT

```
HIGH VOLTAGE INT.DUTY

   AT BUS    1
             BUS    VOLTAGE=     345.0000(KV)
             CALCULATED E/X=     430.7829(SYM.KA)=    25.7418(P.U.)
                  -CONTRIBUTIONS FROM ADJACENT BUSES-
                  FROM BUS     0=        418.36976(SYM.KA)=  25.00000(P.U.)
                  FROM BUS     2=          5.97671(SYM.KA)=    .35714(P.U.)
                  FROM BUS     4=          6.43646(SYM.KA)=    .38462(P.U.)
                  -REMOTE MONITORING-
                  /CURRENT/                          /BUS VOLT/
                  FROM BUS    0 TO BUS    4//        FROM BUS          TO BUS
                       =           .38462(P.U.)//     0.000(P.U.)         .231(P.U.)
                  FROM BUS    0 TO BUS    3//        FROM BUS          TO BUS
                       =           .35714(P.U.)//     0.000(P.U.)         .893(P.U.)
                  FROM BUS    2 TO BUS    3//        FROM BUS          TO BUS
                       =          -.35714(P.U.)//      .357(P.U.)         .893(P.U.)
             X/R =    19.7901
             NACD RATIO=          .98834
             INT.DUTY
                  C.B.INT.TIME/CONT.PRTNG TIME/  M.F.   / DUTY(SYM.KA)
                    2.0        1.5               1.00       430.78293
                    3.0        2.0               1.05       452.55427
                    5.0        3.0               1.04       448.92841
                    8.0        4.0               1.09       467.61496

   AT BUS    2
             BUS    VOLTAGE=     154.0000(KV)
             CALCULATED E/X=      56.8973(SYM.KA)=     1.5177(P.U.)
                  -CONTRIBUTIONS FROM ADJACENT BUSES-
                  FROM BUS     1=         36.06936(SYM.KA)=    .96210(P.U.)
                  FROM BUS     3=         20.82793(SYM.KA)=    .55556(P.U.)
                  -REMOTE MONITORING-
                  /CURRENT/                          /BUS VOLT/
                  FROM BUS    0 TO BUS    1//        FROM BUS          TO BUS
                       =           .94752(P.U.)//     0.000(P.U.)         .962(P.U.)
                  FROM BUS    0 TO BUS    4//        FROM BUS          TO BUS
                       =           .01458(P.U.)//     0.000(P.U.)         .971(P.U.)
                  FROM BUS    0 TO BUS    3//        FROM BUS          TO BUS
                       =           .55556(P.U.)//     0.000(P.U.)         .833(P.U.)
                  FROM BUS    1 TO BUS    4//        FROM BUS          TO BUS
                       =          -.01458(P.U.)//      .962(P.U.)         .971(P.U.)
             X/R =     5.0195
             NACD RATIO=          .99956
             INT.DUTY
                  C.B.INT.TIME/CONT.PRTNG TIME/  M.F.   / DUTY(SYM.KA)
                    2.0        1.5               1.00        56.89729
                    3.0        2.0               1.00        56.89729
                    5.0        3.0               1.00        56.89729
                    8.0        4.0               1.00        56.89729
```

```
HIGH VOLTAGE INT.DUTY                        CONT"D


        AT BUS    3
                BUS     VOLTAGE=       13.8000(KV)
                CALCULATED E/X=   1559.3177(SYM.KA)=     3.7271(P.U.)
                    -CONTRIBUTIONS FROM ADJACENT BUSES-
                    FROM BUS     0=      2091.84880(SYM.KA)=   5.00000(P.U.)
                    FROM BUS     2=       164.75181(SYM.KA)=    .39379(P.U.)
                    -REMOTE MONITORING-
                    /CURRENT/                        /BUS VOLT/
                    FROM BUS    0 TO BUS    1//      FROM BUS          TO BUS
                          =        .38783(P.U.)//     0.000(P.U.)        .984(P.U.)
                    FROM BUS    0 TO BUS    4//      FROM BUS          TO BUS
                          =        .00597(P.U.)//     0.000(P.U.)        .988(P.U.)
                    FROM BUS    1 TO BUS    2//      FROM BUS          TO BUS
                          =        .39379(P.U.)//      .984(P.U.)        .591(P.U.)
                    FROM BUS    1 TO BUS    4//      FROM BUS          TO BUS
                          =       -.00597(P.U.)//      .984(P.U.)        .988(P.U.)
                X/R =     4.1119
                MACO RATIO=           .99982
                INT.DUTY
                    C.B.INT.TIME/CONT.PRTNG TIME/   M.F.  / DUTY(SYM.KA)
                      2.0          1.5              1.00       1559.31768
                      3.0          2.0              1.00       1559.31768
                      5.0          3.0              1.00       1559.31768
                      8.0          4.0              1.00       1659.31768


        AT BUS    4
                BUS     VOLTAGE=       26.0000(KV)
                CALCULATED E/X=    458.2999(SYM.KA)=     2.0639(P.U.)
                    -CONTRIBUTIONS FROM ADJACENT BUSES-
                    FROM BUS     0=       111.02890(SYM.KA)=    .50000(P.U.)
                    FROM BUS     1=       347.27100(SYM.KA)=   1.56388(P.U.)
                    -REMOTE MONITORING-
                    /CURRENT/                        /BUS VOLT/
                    FROM BUS    0 TO BUS    1//      FROM BUS          TO BUS
                          =       1.54185(P.U.)//     0.000(P.U.)        .938(P.U.)
                    FROM BUS    0 TO BUS    3//      FROM BUS          TO BUS
                          =        .02203(P.U.)//     0.000(P.U.)        .993(P.U.)
                    FROM BUS    1 TO BUS    2//      FROM BUS          TO BUS
                          =       -.02203(P.U.)//      .938(P.U.)        .960(P.U.)
                    FROM BUS    2 TO BUS    3//      FROM BUS          TO BUS
                          =       -.02203(P.U.)//      .960(P.U.)        .993(P.U.)
                X/R =    19.9899
                MACO RATIO=           .75512
                INT.DUTY
                    C.B.INT.TIME/CONT.PRTNG TIME/   M.F.  / DUTY(SYM.KA)
                      2.0          1.5              1.00        458.29990
                      3.0          2.0              1.04        476.82969
                      5.0          3.0              1.03        473.67811
                      8.0          4.0              1.07        488.84028
```

POOR PRINT

```
RBUS AND XBUS MATRICES FOR
H.V.MOM.(FIRST CYCLE) DUTY STUDY


RBUS AND XBUS MATRICES ...(BUS,BUS)
           RBUS(  1,   1)=        0.0000000000          XBUS(  1,   1)=        .0388274336
           RBUS(  2,   1)=        0.0000000000          XBUS(  2,   1)=        .0244469027
           RBUS(  2,   2)=        0.0000000000          XBUS(  2,   2)=        .6450221239
           RBUS(  3,   1)=        0.0000000000          XBUS(  3,   1)=        .0028761062
           RBUS(  3,   2)=        0.0000000000          XBUS(  3,   2)=        .0758849558
           RBUS(  3,   3)=        0.0000000000          XBUS(  3,   3)=        .1653982301
           RBUS(  4,   1)=        0.0000000000          XBUS(  4,   1)=        .0298672566
           RBUS(  4,   2)=        0.0000000000          XBUS(  4,   2)=        .0188053097
           RBUS(  4,   3)=        0.0000000000          XBUS(  4,   3)=        .0022123894
           RBUS(  4,   4)=        0.0000000000          XBUS(  4,   4)=        .4845132743
```

POOR PRINT

```
HIGH VOLTAGE MOM.DUTY(=FIRST CYCLE DUTY)

     AT BUS    1
                  BUS     VOLTAGE=      345.0000(KV)
                  CALCULATED E/X=      431.0043(SYM.KA)=    25.7550(P.U.)
                      -CONTRIBUTIONS FROM ADJACENT BUSES-
                      FROM BUS     0=       418.36976(SYM.KA)=  25.00000(P.U.)
                      FROM BUS     2=         6.19807(SYM.KA)=    .37037(P.U.)
                      FROM BUS     4=         6.43646(SYM.KA)=    .38462(P.U.)
                      -REMOTE MONITORING-
                      /CURRENT/                        /BUS VOLT/
                      FROM BUS    0 TO BUS    4//      FROM BUS          TO BUS
                           =          .38462(P.U.)//    0.000(P.U.)         .231(P.U.)
                      FROM BUS    0 TO BUS    3//      FROM BUS          TO BUS
                           =          .37037(P.U.)//    0.000(P.U.)         .926(P.U.)
                      FROM BUS    2 TO BUS    3//      FROM BUS          TO BUS
                           =         -.37037(P.U.)//     .370(P.U.)         .926(P.U.)
                  MOM.DUTY(FIRST CYCLE DUTY)=       689.60686(ASYM.KA)

     AT BUS    2
                  BUS     VOLTAGE=      154.0000(KV)
                  CALCULATED E/X=       58.1225(SYM.KA)=     1.5503(P.U.)
                      -CONTRIBUTIONS FROM ADJACENT BUSES-
                      FROM BUS     1=        36.06936(SYM.KA)=     .96210(P.U.)
                      FROM BUS     3=        22.05310(SYM.KA)=     .58824(P.U.)
                      -REMOTE MONITORING-
                      /CURRENT/                        /BUS VOLT/
                      FROM BUS    0 TO BUS    1//      FROM BUS          TO BUS
                           =          .94752(P.U.)//    0.000(P.U.)         .962(P.U.)
                      FROM BUS    0 TO BUS    4//      FROM BUS          TO BUS
                           =          .01458(P.U.)//    0.000(P.U.)         .971(P.U.)
                      FROM BUS    0 TO BUS    3//      FROM BUS          TO BUS
                           =          .58824(P.U.)//    0.000(P.U.)         .882(P.U.)
                      FROM BUS    1 TO BUS    4//      FROM BUS          TO BUS
                           =         -.01458(P.U.)//     .962(P.U.)         .971(P.U.)
                  MOM.DUTY(FIRST CYCLE DUTY)=        92.99595(ASYM.KA)

     AT BUS    3
                  BUS     VOLTAGE=       13.8000(KV)
                  CALCULATED E/X=     2256.6006(SYM.KA)=     5.3938(P.U.)
                      -CONTRIBUTIONS FROM ADJACENT BUSES-
                      FROM BUS     0=      2091.84880(SYM.KA)=   5.00000(P.U.)
                      FROM BUS     2=       164.75181(SYM.KA)=    .39379(P.U.)
                      -REMOTE MONITORING-
                      /CURRENT/                        /BUS VOLT/
                      FROM BUS    0 TO BUS    1//      FROM BUS          TO BUS
                           =          .38783(P.U.)//    0.000(P.U.)         .984(P.U.)
                      FROM BUS    0 TO BUS    4//      FROM BUS          TO BUS
                           =          .00597(P.U.)//    0.000(P.U.)         .988(P.U.)
                      FROM BUS    1 TO BUS    2//      FROM BUS          TO BUS
                           =          .39379(P.U.)//     .984(P.U.)         .591(P.U.)
                      FROM BUS    1 TO BUS    4//      FROM BUS          TO BUS
                           =         -.00597(P.U.)//     .984(P.U.)         .988(P.U.)
                  MOM.DUTY(FIRST CYCLE DUTY)=      3610.56099(ASYM.KA)
```

```
HIGH VOLTAGE MOM.DUTY(=FIRST CYCLE DUTY)   CONT"D

        AT BUS    4
                 BUS     VOLTAGE=      26.0000(KV)
                 CALCULATED E/X=    458.3111(SYM.KA)=     2.0639(P.U.)
                      -CONTRIBUTIONS FROM ADJACENT BUSES-
                      FROM BUS     0=       111.02890(SYM.KA)=     .50000(P.U.)
                      FROM BUS     1=       347.28217(SYM.KA)=    1.56393(P.U.)
                      -REMOTE MONITORING-
                      /CURRENT/                     /BUS VOLT/
                      FROM BUS    0 TO BUS    1//      FROM BUS         TO BUS
                           =         1.54110(P.U.)//    0.000(P.U.)       .938(P.U.)
                      FROM BUS    0 TO BUS    3//      FROM BUS         TO BUS
                           =          .02283(P.U.)//    0.000(P.U.)       .995(P.U.)
                      FROM BUS    1 TO BUS    2//      FROM BUS         TO BUS
                           =        -.02283(P.U.)//     .938(P.U.)       .961(P.U.)
                      FROM BUS    2 TO BUS    3//      FROM BUS         TO BUS
                           =        -.02283(P.U.)//     .961(P.U.)       .995(P.U.)
                 MOM.DUTY(FIRST CYCLE DUTY)=       733.29771(ASYM.KA)
```

POOR PRINT

```
JOB NAME=SAMPLE2...1L-G FAULT

DESCRIPTION=
BASE MVA=  10000.00
TYPE OF FAULT=1LINE TO GROUND SHORT CIRCUIT.
FOR ALL BUSES OF HIGH VOLTAGE,CHECKS FOR
2-1.6,3-2.0,5-3.0,8-4.0 BREAKER"S INT.DUTY AND CHECKS FOR
FIRST CYCLE DUTYWILL BE DONE.
FOR ALL BUSES OF LOWVOLTAGE, CHECKS FOR FIRST CYCLE DUTY WILL BE DONE.
```

```
REMOTE MONITORING
    FAULTED BUS///MONITORED BRANCH(FROM BUS/TO BUS)
    NO REMOTE MONITORING
```

POOR PRINT

```
BUS VOLTAGES
          BUSES AT     345.00KV
                          1
                       AT LEAST   1BUSES AT THIS VOLTAGE.
          BUSES AT     154,00KV
                          2
                       AT LEAST   1BUSES AT THIS VOLTAGE.
          BUSES AT      26.00KV
                          4
                       AT LEAST   1BUSES AT THIS VOLTAGE.
          BUSES AT      13,80KV
                          3
                       AT LEAST   1BUSES AT THIS VOLTAGE.
IDENTIFICATION CODE FOR BRANCH IMPEDANCES


  ID CODE1=A T/G,H/G WITH AMOR,WINDING,OR CONDENSER,
  ID CODE2=AN H/G WITHOUT AMOR,WINDING,
  ID CODE3=A SYNCH.MOTOR,
  ID CODE4=AN IND.MTR.ABV 1000HP AT 1800RPM,OR
         ABV 250HP AT 3600RPM,
  ID CODE5=AN IND.MTR,50HP AND ABV...NOT BIGGER THAN
         1000HP AT 1800 RPM OR 250HP AT 3600RPM,
  ID CODE6=AN IND.MTR,SMALLER THAN 50HP.
  ID CODE7=A STATIC ELEMENT,,CABLE,BUSDUCT,TRF,RXTR,ETC,
  ID CODE8=UTILITY SYSTEM,OFFSITE SOURCE,ETC.
```

POOR PRINT

```
IMPEDANCES
    FROM BUS      TO BUS        R          X      IDEN.CODE
        0            1        .0010      .0200       8
        0            4        .0500     1.0000       1
        0            3       1.0000     1.5000       7
        0            1        .0300      .6000       7
        0            2        .3000     1.5000       7
        1            2        .1000      .5000       7
```

POOR PRINT

-C60-

SHORT CIRCUIT DUTIES

POOR PRINT

```
RBUS AND XBUS MATRICES FOR
H.V.INT.DUTY STUDY

RBUS AND XBUS MATRICES ...(BUS,BUS)
          RBUS(  1,  1)=        .0009654063         XBUS(  1,  1)=        .0191693291
          RBUS(  2,  1)=        .0007240547         XBUS(  2,  1)=        .0143769968
          RBUS(  2,  2)=        .0755430410         XBUS(  2,  2)=        .3857827476
          RBUS(  3,  1)=       0.0000000000         XBUS(  3,  1)=       0.0000000000
          RBUS(  3,  2)=       0.0000000000         XBUS(  3,  2)=       0.0000000000
          RBUS(  3,  3)=       1.0000000000         XBUS(  3,  3)=       1.5000000000
          RBUS(  4,  1)=       0.0000000000         XBUS(  4,  1)=       0.0000000000
          RBUS(  4,  2)=       0.0000000000         XBUS(  4,  2)=       0.0000000000
          RBUS(  4,  3)=       0.0000000000         XBUS(  4,  3)=       0.0000000000
          RBUS(  4,  4)=        .0500000000         XBUS(  4,  4)=       1.0000000000
```

POOR PRINT

```
HIGH VOLTAGE INT.DUTY

     AT BUS    1
               BUS    VOLTAGE=     345.0000(KV)
               CALCULATED E/X=     518.5106(SYM.KA)=    30.9840(P.U.)
               X/R =  180.2937
               MACO RATIO=         1.00000
               INT.DUTY
                    C.B.INT.TIME/CONT.PRTNG TIME/  M.F.  / DUTY(SYM.KA)
                         2.0          1.5            1.26      652.81491
                         3.0          2.0            1.34      693.41660
                         5.0          3.0            1.41      729.68220
                         8.0          4.0            1.48      767.38056

     AT BUS    2
               BUS    VOLTAGE=     154.0000(KV)
               CALCULATED E/X=      67.1136(SYM.KA)=     1.7902(P.U.)
               X/R =   24.1837
               MACO RATIO=         1.00000
               INT.DUTY
                    C.B.INT.TIME/CONT.PRTNG TIME/  M.F.  / DUTY(SYM.KA)
                         2.0          1.5            1.02       68.70666
                         3.0          2.0            1.08       72.38637
                         5.0          3.0            1.06       71.43018
                         8.0          4.0            1.11       74.32684

     AT BUS    3
               BUS    VOLTAGE=      13.8000(KV)
               CALCULATED E/X=     670.8957(SYM.KA)=     1.6036(P.U.)
               X/R =    1.8708
               MACO RATIO=          .50000
               INT.DUTY
                    C.B.INT.TIME/CONT.PRTNG TIME/  M.F.  / DUTY(SYM.KA)
                         2.0          1.5            1.00      670.89569
                         3.0          2.0            1.00      670.89569
                         5.0          3.0            1.00      670.89569
                         8.0          4.0            1.00      670.89569

     AT BUS    4
               BUS    VOLTAGE=      26.0000(KV)
               CALCULATED E/X=     338.3263(SYM.KA)=     1.5236(P.U.)
               X/R =   39.3805
               MACO RATIO=         0.00000
               INT.DUTY
                    C.B.INT.TIME/CONT.PRTNG TIME/  M.F.  / DUTY(SYM.KA)
                         2.0          1.5            1.12      378.80941
                         3.0          2.0            1.15      387.73162
                         5.0          3.0            1.16      393.79956
                         8.0          4.0            1.18      400.87471
```

POOR PRINT

```
RBUS AND XBUS MATRICES FOR
H.V.MON.(FIRST CYCLE) DUTY STUDY


RBUS AND XBUS MATRICES ...(BUS,BUS)
           RBUS(  1,  1)=       0.0000000000            XBUS(  1,  1)=         .0191693291
           RBUS(  2,  1)=       0.0000000000            XBUS(  2,  1)=         .0143769968
           RBUS(  2,  2)=       0.0000000000            XBUS(  2,  2)=         .3857827476
           RBUS(  3,  1)=       0.0000000000            XBUS(  3,  1)=        0.0000000000
           RBUS(  3,  2)=       0.0000000000            XBUS(  3,  2)=        0.0000000000
           RBUS(  3,  3)=       0.0000000000            XBUS(  3,  3)=        1.5000000000
           RBUS(  4,  1)=       0.0000000000            XBUS(  4,  1)=        0.0000000000
           RBUS(  4,  2)=       0.0000000000            XBUS(  4,  2)=        0.0000000000
           RBUS(  4,  3)=       0.0000000000            XBUS(  4,  3)=        0.0000000000
           RBUS(  4,  4)=       0.0000000000            XBUS(  4,  4)=        1.0000000000
```

POOR PRINT

```
HIGH VOLTAGE MOM.DUTY(=FIRST CYCLE DUTY)

      AT BUS    1
                  BUS     VOLTAGE=      345.0000(KV)
                  CALCULATED E/X=      518.5106(SYM,KA)=     30.9040(P.U.)
                  MOM.DUTY(FIRST CYCLE DUTY)=        829.61695(ASYM.KA)

      AT BUS    2
                  BUS     VOLTAGE=      154.0000(KV)
                  CALCULATED E/X=       67.1136(SYM,KA)=      1.7902(P.U.)
                  MOM,DUTY(FIRST CYCLE DUTY)=        107.38101(ASYM,KA)

      AT BUS    3
                  BUS     VOLTAGE=       13.8000(KV)
                  CALCULATED E/X=      670.0957(SYM,KA)=      1.6036(P.U.)
                  MOM.DUTY(FIRST CYCLE DUTY)=       1073.43310(ASYM,KA)

      AT BUS    4
                  BUS     VOLTAGE=       26.0000(KV)
                  CALCULATED E/X=      338.3263(SYM,KA)=      1.5236(P.U.)
                  MOM.DUTY(FIRST CYCLE DUTY)=        541.32202(ASYM.KA)
```

POOR PRINT

THANK YOU,BYE-BYE.

```
        HWANBQH.    78/06/20. CONCORDIA UNIVERSITY  -  CYBER 172/2.

21.58.27.HWANG1.T100.
21.58.27.ACCOUNT.BAKSK29,.
21.58.27.FTN.
21.58.58.      17.228 CP SECONDS COMPILATION TIME
21.58.58.LGO.
21.59.01.     STOP
21.59.01.       .954 CP SECONDS EXECUTION TIME
21.59.01.UEAD.       0.001KUNS.
21.59.01.UEMS.       1.958KUNS.
21.59.01.UECP.      19.494SECS.
21.59.01.AESR.      23.345UNTS.
```