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Appendix A

Theoretical Study of The Convergence of The Newton-Raphson Method

A.1. Introduction

The solution of the Load-Flow problem by NRLF, DLF, and FDLF is presented in Chapter 2. These methods are focusing on solution of linear (see Appendix C) and nonlinear equations. This appendix shall be focusing on the solution of nonlinear algebraic equations.

A.2. Iteration Formulas (14-16)

Let f(x) be a continuous real-valued function which as many derivatives as are required in what follow. Furthermore, it is assumed that in some neighborhood of the desired root c is a simple root. Let g(x) be an inverse of f(x). The Taylor-series expansion of g(y) about a point y_i is given by

$$x = g(y)$$

$$= \sum_{j=0}^{m+1} \frac{(y-y_i)^j g^{(j)}(y_i)}{j!} + \frac{(y-y_i)^{m+2} g^{(m+2)}(n)}{(m+2)!}$$

$$= x_i + \sum_{j=1}^{m+1} \frac{(y - y_i)^j g^{(j)}(y_i)}{j!} + \frac{(y - y_i)^{m+2} g^{(m+2)}(n)}{(m+2)!} \qquad (A.1)$$

$$g^{(j)}(y_i) = \left. \frac{d^j g(y)}{d y^j} \right|_{y = y_i}$$

where n is between y and y_i. Since $c = g(0)$, we have

$$c = x_i + \sum_{j=1}^{m+1} \frac{(-1)^j y_i^j}{j!} g^{(j)}(y_i) + \frac{(-1)^{m+2}}{(m+2)!} y_i^{m+2} g^{(m+2)}(n)$$

$$= x_i + \sum_{j=1}^{m+1} \frac{(-1)^j}{j!} f_i^j g_i^{(j)} + \frac{(-1)^{m+2}}{(m+2)!} f_i^{m+2} g^{(m+2)}(n) \qquad (A.2)$$

where it has been written

$$y_i = f(x_i) = f_i$$

and

$$g^{(j)}(y_i) = g_i^{(j)}$$

Equation (A.2) suggests consideration of the iterations formula

$$x_{i+1} = x_i + \sum_{j=1}^{m+1} \frac{(-1)^j}{j!} f_i^j g_i^{(j)} \qquad (A.3)$$

Subtracting eq. (A.3) from eq. (A.2) and gives,

$$e_i = c - x_i$$

then

$$e_{i+1} = \frac{(-1)^{m+2} \, f_i^{m+2} \, g^{(m+2)}(n)}{(m+2)!} \qquad (A.4)$$

Since, from the mean-value theorem,

$$f'(l_1) = \frac{f(x_i) - f(c)}{x_i - c}$$

then

$$f_i = f(x_i) = f(x_i) - f(c)$$

$$= (x_i - c) \, f'(l_1) \qquad (A.5)$$

with l_1 between x_i and c, then

$$e_{i+1} = \frac{1}{(m+2)!} \{ [f'(l_1)]^{m+2} \, g^{(m+2)}(n) \} \, e_i^{m+2} \qquad (A.6)$$

If the root is simple, the term in braces in eq. (A.6) is bounded in some neighborhood of c. Therefore, the order of eq. (A.3) is m+2, and if the initial approximation is sufficiently good, the iteration will converge.

The evalution of eq. (A.3) requires the evalution of $f(x_i)$ and its first m+1 derivatives. If O_j is the cost of evaluating $f^{(j)}(x_i)$ relative to the cost at evaluating f(x), and it is given to 1, the efficiency index of eq. (A.3) is given by

$$EI = (m+2)^{1/Z} \qquad (A.7)$$

where

$$Z = 1 + \sum_{j=1}^{m+1} O_j$$

One important and familiar special case of eq. (A.3) is that for m = 0, which is the Newton-Raphson iteration,

$$x_{i+1} = x_i - f'(x_i)^{-1} f(x_i) \qquad (A.8)$$

The error is given by eq. (A.6)

$$e_{i+1} = \frac{1}{2} [f'(l_1)]^2 g''(n) e_i^2 \qquad (A.9)$$

The value of eq. (A.3) will depend party and whether the $g_i^{(j)}$ can easily be calculated. Clearly

$$g_i^{(1)} = \frac{d\ g(y)}{d\ y} \quad y = y_i$$

$$= \frac{1}{f'_i}$$

For $j > 1$, it can be computed the $g_i^{(j)}$ in terms of derivatives of $f(x)$ at $x = x_i$ as follows. If the operator D is defined,

$$D = \frac{d}{dy}$$

$$D = \frac{1}{f'} \frac{d}{dx}$$

Hence

$$D^j g = D^{j-1} g'$$

$$= \left(\frac{1}{f'} \frac{d}{dx} \right)^{j-1} \frac{1}{f'}$$

Then

$$g'' = g^{(2)}$$

$$= \left(\frac{1}{f'} \frac{d}{dx} \right)^{2-1} \frac{1}{f'}$$

$$= - \frac{f''}{(f')^3} \qquad \text{(A.10)}$$

So that, eq. (A.9) becomes

$$e_{i+1} = - \frac{f''(1) \left[f'(1) \right]_1^2 e_i^2}{2 \left[f'(1) \right]^3} \qquad \text{(A.11)}$$

In fact it can shown that the terms in f'(x) can be canceled as if

$$l = l_1 = x_i$$

so that

$$e_{i+1} = -\frac{1}{2}\frac{f''(l)}{f'(x_i)}e_i^2 \qquad (A.12)$$

From eq. (A.7), the efficiency index of Newton-Raphson method is

$$EI = 2^{1/(1+O_1)}$$

where O_1 is the cost of evaluating f'(x).

It can be concluded from eq. (A.12) that if the first and second derivatives are nearly constant from iteration to iteration, the error in the iterate will decrease as the square of the error in the previous step. This type of convergence is called "quadratic convergence", and the Newton-Raphson algorithm exhibits quadratic convergence near the solution. If e is plotted versus i with e on a logarithmic scale, quadratic convergence implied a straight line characteristic. For this reason, an alternative form for quadratic convergence is logarithmic convergence.

A.3. Newton-Raphson Method in Vector Form (8)

In the vector case, the result is similar and obtained nothing but the vector equation

$$F(X) = 0$$

has solution X_s. The Newton-Raphson iteration formula

$$X^{(i+1)} = X^{(i)} - [J(X^{(i)})]^{-1} F(X^{(i)}) \qquad (A.13)$$

Applying the mean value theorem to each row of X there exist a Z such that $row_j(Z)$ is between $row_j(X_s)$ and $row_j(X^{(i)})$ for all i. Then $J(Z)$ is the Jacobian at Z_j, and

$$[X_s - X^{(i+1)}] = [X_s - X^{(i)}] - [J(X^{(i)})]^{-1} J(Z) [X_s - X^{(i)}] \qquad (A.14)$$

Let the Euclidean norm of $X_s - X^{(i)}$ denote the magnitude of the error at iteration i , $e^{(i)}$; then

$$[e^{(i+1)}]^t [e^{(i+1)}] = ([X_s - X^{(i)}]^t [Q]^t)([Q][X_s - X^{(i)}]) \qquad (A.15)$$

where

$$[Q] = [I] - [J^{(i)}]^{-1} [J(Z)] \qquad (A.16)$$

Equation (A.15) is not as readily interpreted as in the scalar case; however, the size of $e^{(i+1)}$ is readily shown to be related to

$$[X_s - X^{(i)}]^t [X_s - X^{(i)}]$$

through the eigenvalues of $[Q]^t [Q]$. When the eigenvalues of $[Q]^t [Q]$ are in the range -1 to 1, the error at the iteration i + 1 is a quadratic function of the term-by-term errors at iteration i. As in the scalar case, the term quadratic or logarithmic convergence apply.

A similar, but more conclusive result is found by considering the Newton-Raphson update formula,

$$[X^{(i+1)}] = [X^{(i)}] - [J]^{-1} F(X^{(i)})$$

written as

$$X_i = [P] F_i \qquad (A.17)$$

where X_i is the update on X at iteration i,

[P] is the inverse of the Jacobian matrix,

and F_i is a shorthand notation for $F(X^{(i)})$.

Let the eigenvalues of the Jacobian matrix inverse [P] be p_1, p_2, ..., p_N and let the corresponding eigenvectors be k_1, k_2, ..., k_N. Further, let the model matrix, [M], be defined as

$$[\,M\,] = (\,k_1\,,\,k_2\,,\,.....\,,\,k_N\,)$$

and let

$$E = \mathrm{diag}\,(\,p_j\,)\quad,\; j = 1,2,......,N$$

Consider only the case of linearly independent eigenvectors (if the eigenvalues of [P] is repeat, it is possible to rewrite the development below in terms of generalized eigenvectors and the result is similar but slighty more complicated). Since the R, span Euclidean N-space (R^N), both X_i and F_i may be expressed as linear combinations of the k_i,

$$X_i = \sum_{j=1}^{N} b_j\,k_j \qquad (A.18)$$

$$F_i = \sum_{j=1}^{N} c_j\,k_j \qquad (A.19)$$

Let B denote the N-vector of scalar elements b_j, and let C denote the N-vector of scalar elements c_j,

$$X_i = [\,M\,]\,B \qquad (A.20)$$

$$F_i = [\,M\,]\,C \qquad (A.21)$$

Then eq.(A.17) is rewritten using eq.(A.20) and eq.(A.21)

$$[M]B = [P][M]C$$

Hence

$$B = [M]^{-1}[P][M]C \quad (A.22)$$

Equation (A.22) is possible since the k_j are linearly independent and $[M]^{-1}$ exists. Since $[M]$ is the model matrix of $[P]$ in the term of $[M]^{-1}[P][M]$ is a similarity transformation on $[P]$ which diagonalizes $[P]$,

$$B = E\,C \quad (A.23)$$

Examine eq.(A.23) in some detail. The magnitude of vector B may be though of as the "length" of the correction term and the magnitude of vector C as the "length" of the residuals at iteration i. The term "length" used in this context is broad, but note that for the case of orthonormal M,

$$\|X_i\|^2 = (X_i)^t X_i$$

$$= B^t[M]^t[M]B$$

$$= \|B\|^2$$

Even if $[M]$ is not orthonormal, B is a measure of the norm of X_i. A similar argument applies to C.

Hence eq.(A.23) states that the correction applied at iteration i is related to the residual at iteration i by the eigenvalues of [P] (i.e., the eigenvalues of the inverse Jacobian). When these eigenvalues are smaller than 1,

$$\left| p_j \right| < 1 \quad , j = 1, 2, \ldots\ldots , N$$

the correction will be expected to be monotone decreasing in amplitude (if [J] is constant from step to step). One concludes that the largest eigenvalues of $[\ J\ ]^{-1}$ degrade and control the convergence at each iteration.

Appendix B

The Bus Admittance Matrix

B.1. Bus Admittance and Impedance Matrices (10)

Consider a network consisting of N+1 node, including the reference node as shown in Fig. B.1 where node O is chosen as the reference node.

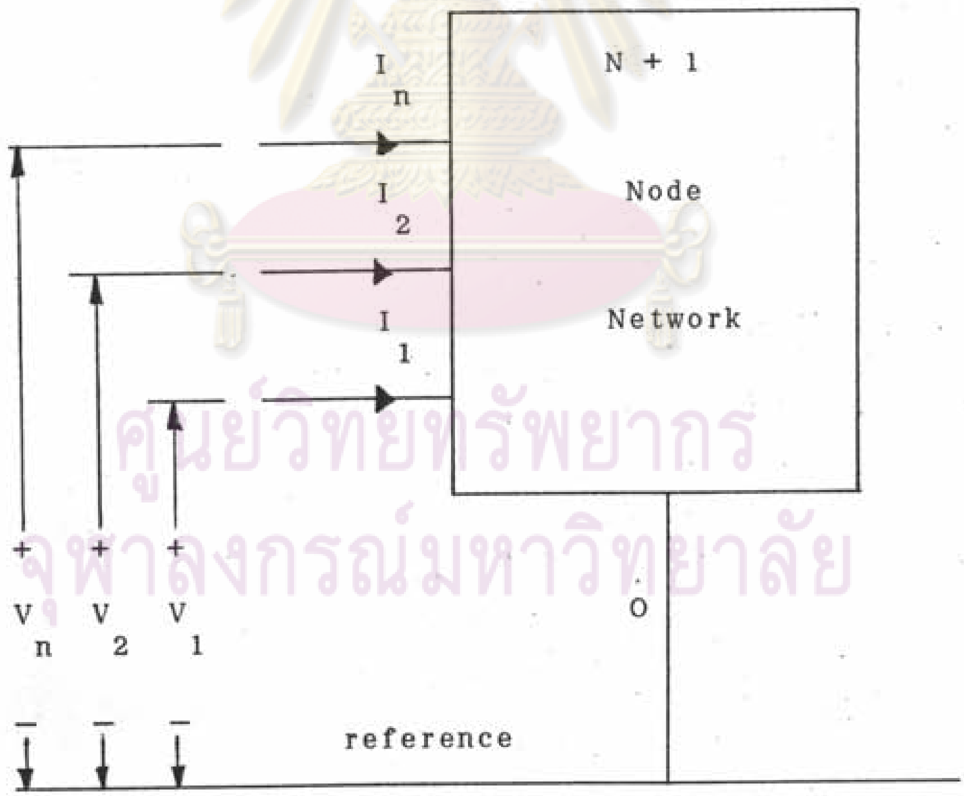

Fig. B.1 A N+1 Node Network With Node O As Reference.

It is possible to write:

$$[\,I\,] = [\,Y\,][\,V\,] \qquad (B.1),$$

where [Y] is the node admittance matrix.

[V] is column vector of node voltages.

[I] is column vector of node currents.

If the inverse of [Y] exists, or we may write:

$$[\,V\,] = [\,Z\,][\,I\,] \qquad (B.2),$$

where,

$$[\,Z\,] = [\,Y\,]^{-1} .$$

[Z] is called "open circuit driving point and transfer impedance matrix", and [Y] is called "short circuit driving point and transfer admittance matrix". They are also called, as Power System models, [Z-Bus] and [Y-Bus].

From eq. (B.1) and Fig. B.1 , we can write:

$$\begin{bmatrix} I_0 \\ I_1 \\ --- \\ I_n \end{bmatrix} = \begin{bmatrix} Y_{00} & Y_{01} & \cdots & Y_{0n} \\ Y_{10} & Y_{11} & \cdots & Y_{1n} \\ - & - & - & - \\ Y_{n0} & Y_{n1} & \cdots & Y_{nn} \end{bmatrix} \begin{bmatrix} V_0 \\ V_1 \\ --- \\ V_n \end{bmatrix}$$

(B.3).

This equation shows clearly the way to calculate [Y-Bus]. Each element is a "short circuit admittance." For example, the k th column is defined by:

$$\begin{bmatrix} I_0 \\ I_1 \\ --- \\ I_n \end{bmatrix} = \begin{bmatrix} Y_{0k} \\ Y_{1k} \\ --- \\ Y_{nk} \end{bmatrix} V_k \qquad (B.4),$$

with all terminals except k shorted.

For a given network we can let $V_k = 1.0$, for example, and short all other terminals. Then the k th column of admittance is equal to the currents entering the N+1 nodes as specified by eq. (B.4). This relatively simple task for most networks and can often be done by inspection.

In general we may state the rules for finding the elements of [Y-Bus] as follows:

$$Y_{ik} = \frac{I_i}{V_k}, \quad V_e = 0, \ e \neq k \qquad (B.5).$$

This technique is more direct than the augmented node incidence.

B.2. Element Stamps (2,3)

For an equivalent ¶ -circuit of a transmission line, which is connected at buses m and n, let:

Y_s is longitudinal admittance of the line.
Y_c is charging admittance at buses m and n.

From KCL, we can write;

$$\begin{bmatrix} I_m \\ I_n \end{bmatrix} = \begin{bmatrix} Y_s + Y_c & -Y_s \\ -Y_s & Y_s + Y_c \end{bmatrix} \begin{bmatrix} V_m \\ V_n \end{bmatrix} \quad (B.6)$$

The y-matrix in eq. (B.6) is called stamp for a transmission line.

A transformer is connected at bus i and j and turn ratio is 1:a , i is reference. Let

Y_t is transformer admittance.

From KCL , we can write;

$$\begin{bmatrix} I_i \\ I_j \end{bmatrix} = \begin{bmatrix} Y_t & \dfrac{-Y_t}{a} \\ \dfrac{-Y_t}{a^{*}} & \dfrac{Y_t}{|a|^2} \end{bmatrix} \begin{bmatrix} V_i \\ V_j \end{bmatrix} \qquad (B.7),$$

where * is conjugate of complex number.

The y-matrix in eq. (B.7) is called stamp for a transformer.

A shunt element to ground is connected at bus f.

Case 1: an admittance to ground, Y_e.

From KCL, we can write;

$$I_f = Y_e V_f \qquad (B.8).$$

Y_e is called stamp of a shunt element.

Case 2: a received power element at bus f, P + j Q is a complex power of the element: example of this kind of elements are shunt reactor and capactor, which their rating are said to MVAr. By definition, we can write;

$$P + j\,Q = S_f = V_f I_f^{*} ,$$

then

$$\dot{I}_f = \frac{S_f}{V_f}$$

such that,

$$Y_f = I_f = \frac{\dot{S}_f}{V_f} \qquad (B.9).$$

If V_f is in per unit then Y_f is equal to $\dot{S}_f$.

Occasionally transmission lines are mutually coupled, especially in the zero-sequence network. Consider the two mutually coupled transmission lines shown in Fig. B.2.

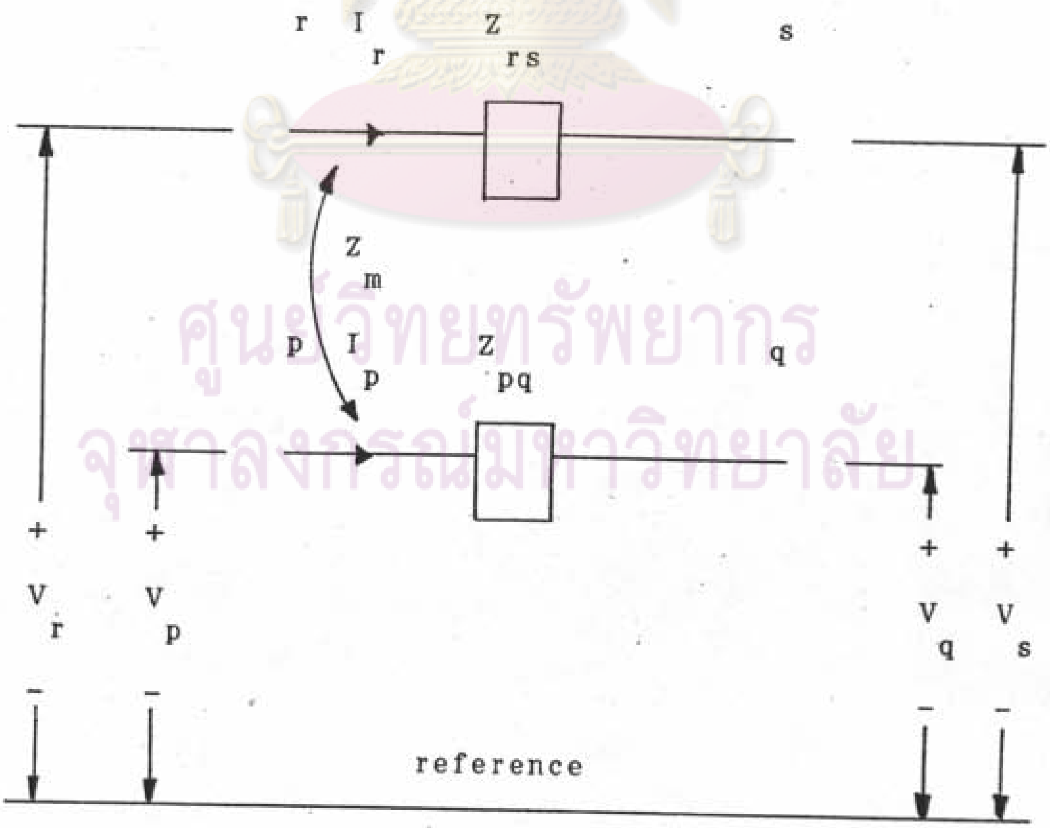

Fig. B.2 Two Mutually Coupled Lines.

The voltage drop equation is:

$$\begin{bmatrix} V_r - V_s \\ V_p - V_q \end{bmatrix} = \begin{bmatrix} Z_{rs} & Z_m \\ Z_m & Z_{pq} \end{bmatrix} \begin{bmatrix} I_r \\ I_p \end{bmatrix} \quad (B.10).$$

Inverting and solving for the currents, we have

$$\begin{bmatrix} I_r \\ I_p \end{bmatrix} = \begin{bmatrix} Y'_{rs} & Y_m \\ Y_m & Y'_{pq} \end{bmatrix} \begin{bmatrix} V_r - V_s \\ V_p - V_q \end{bmatrix} \quad (B.11),$$

where the admittance are uniquely defined by the matrix inversion. Expanding we have:

$$\begin{aligned} I_r &= (Y'_{rs} V_r - Y'_{rs} V_s) + (Y_m V_p - Y_m V_q) \\ I_p &= (Y'_{pq} V_p - Y'_{pq} V_q) + (Y_m V_r - Y_m V_s) \end{aligned} \quad (B.12),$$

or in general for a coupled line, I_{rs} = (self admittance term) + (mutual admittance term), we have the self admittance term is exactly the same as eq. (B.6) for the uncoupled line. The mutual term specifies that Y_m be added in the r th row to the column having the same polarity as r, namely p, and subtracted from the column having opposite polarity, namely q.

Eq. (B.12) may be expanded to the full admittance form by adding two more equations which are negative of eq. (B.12). The result in matrix is:

$$\begin{bmatrix} I_r \\ I_s \\ I_p \\ I_q \end{bmatrix} = \begin{bmatrix} Y'_{rs} & -Y'_{rs} & Y_m & -Y_m \\ -Y'_{rs} & Y'_{rs} & -Y_m & Y_m \\ Y_m & -Y_m & Y'_{pq} & -Y'_{pq} \\ -Y_m & Y_m & -Y'_{pq} & Y'_{pq} \end{bmatrix} \begin{bmatrix} V_r \\ V_s \\ V_p \\ V_q \end{bmatrix} \quad (B.13).$$

The admittance matrix in eq. (B.13) is called stamp for a coupled line.

To calculate [Y-Bus], the element stamp method is useful, if an element is added then we add its stamp to [Y-Bus]. Since the latest element was added, the [Y-Bus] is completed. In contingency study, we add an element but negative stamp to [Y-Bus]. The calculation of maximum non-zero elements in [Y-Bus] is:

$$NZ = B + 2 (L + T) \quad (B.14),$$

where B is total bus in system.

L is total transmission line in system.

T is total transformer in system.

Appendix C

Solution of Linear Equation by The Martix Factorization Method

In linear equation, we can write in matrix form as below:

$$[A][X] = [B] \quad (C.1),$$

where [A] is matrix dimension of n x n.

[X] is column unknown vector.

[B] is column known vector.

If [A] is not a singular matrix, then [A] is transformed to the product of two matrices [L] and [U]:

$$[A] = [L][U],$$

where [L] is a lower triangular matrix and,

[U] is an upper triangular matrix with 1.0 on its diagonal.

The elements of [L] and [U] can be calculated by Crout's factorization;

$$L_{ij} = A_{ij} - \sum_{k=1}^{j-1} L_{ik} U_{kj} \quad , j < i \quad , i = 1, 2, \ldots, n; \quad (C.2).$$

$$U_{ij} = \frac{A_{ij} - \sum_{k=1}^{i-1} L_{ik} U_{kj}}{L_{ii}} \quad , j > i$$

$$, j = 2, 3, .., n;$$

The general solution for reduction of B is;

$$B'_{i} = \frac{B_{i} - \sum_{k=1}^{i-1} L_{ik} B'_{k}}{L_{ii}} \qquad (C.3).$$

$$, i = 2, 3, .., n ,$$

$$B'_{1} = \frac{B_{1}}{L_{11}}$$

The equation for back substitution are:

$$X_{n} = B'_{n}$$

$$X_{i} = B'_{j} - \sum_{k=j+1}^{n} U_{ik} X_{k}$$

$$, j = n-1, n-2, .., 1.$$

If [A] is symmetric, positive definite, it has a unique triangular factorization:

$$[A] = [L] [L]^{t},$$

where [L] is a lower triangular matrix with positive diagonal entires.

The elements of the r th row of [L] can be completed directly form:

$$\sum_{j=1}^{i-1} L_{rj} L_{ij} + L_{ri} L_{ii} = A_{rj} \quad , \ i = 1, 2, \ldots, r-1$$

$$\sum_{j=1}^{r-1} L_{rj}^2 + L_{ri}^2 = A_{rr} \tag{C.4}$$

So that, this decomposition, called Cholesky's factorization of [A], requires N square roots and about N / 6 multiplications. From eq. (C.4), we can see that;

$$\sum_{j=1}^{r} L_{rj}^2 = A_{rr} \ .$$

which implies that all elements of [L] are bounded by max(A_{ii}).

Appendix D

Sparse Matrix and Optimal Ordering

A matrix having only a small percentage of non-zero elements is said to be sparse (59). The [Y-Bus] is a sparse matrix, then we keep only non-zero elements of [Y-Bus]. The two vectors, [YD] and [YOFF], are needed; [YD] is kept the diagonal elements of [Y-Bus], and [YOFF] is kept the off-diagonal elements of [Y-Bus]. Then we are needed two more vectors; [IROW] and [ICOL]. The vector [IROW] indentifies where each row starts in the vector [YOFF]. The vector [ICOL] identifies the column position of each element in [YOFF].

A near optimum reordering of the matrix would result before factorization matrix. The reorder process is easily implemented and involves searching each row for the row with the least number of terms shall be eliminated first. Since we completely searched at every row, then we have to do the process again but in columnwise. However normally, for a symmetric matrix, as [B'] and [B"] matrices, the row process is enough, and its result is used automatically for column.

Example Reordering a matrix

$$
\begin{bmatrix}
3 & -1 & 0 & 0 & -2 \\
-1 & 13 & -5 & -4 & -3 \\
0 & -5 & 5 & 0 & 0 \\
0 & -4 & 0 & 10 & -6 \\
-2 & -3 & 0 & -6 & 13
\end{bmatrix}
$$

Step 1 row operation

$$
\begin{bmatrix}
0 & -5 & 5 & 0 & 0 \\
3 & -1 & 0 & 0 & -2 \\
0 & -4 & 0 & 10 & -6 \\
-2 & -3 & 0 & -6 & 13 \\
-1 & 13 & -5 & -4 & -3
\end{bmatrix}
$$

Step 2 column operation

$$
\begin{bmatrix}
5 & 0 & 0 & 0 & -5 \\
0 & 3 & 0 & -2 & -1 \\
0 & 0 & 10 & -6 & -4 \\
0 & -2 & -6 & 13 & -3 \\
-5 & -1 & -4 & -3 & 13
\end{bmatrix}
$$

Appendix E

Non-Unique Load-Flow Solution

Multiple Load-Flow solutions are possible for realistic systems with resonable intial conditions (16). To prove in mathematical term, consider Fig. E.1:

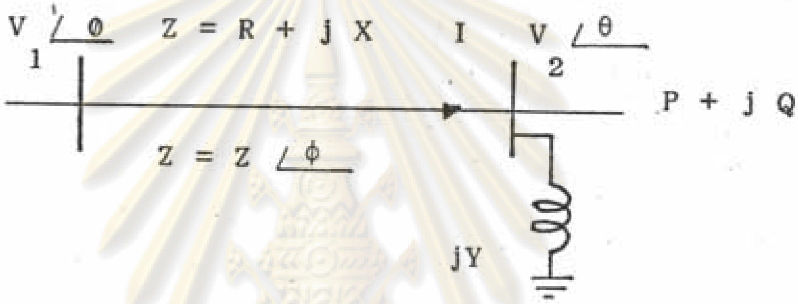

Fig. E.1 A Simple Power System.

$$I = \frac{V_1 - V_2 \angle \theta}{Z}$$

$$P + jQ = V_2 \overset{*}{I} + jYV_2^2$$

$$= \frac{V_1 V_2 \angle \theta + \phi - V_2^2 \angle \phi}{Z} + jYV_2^2$$

Let; $\frac{V_1}{Z} = C_1$; $\frac{\cos\phi}{Z} = C_2$; $\frac{\sin\phi}{Z} = C_3$;

$\gamma = \theta + \phi$; $C_4 = Y - C_3$; then

$$P = C_1 V_2 \cos\gamma - C_2 V_2^2 \quad (E.1),$$

$$Q = C_1 V_2 \, SIN\gamma + C_4 V_2^2 \quad (E.2).$$

From eq. (E.1),

$$COS\ \gamma = \frac{P}{C_1 V_2} + \frac{C_2 V_2}{C_1}$$

$$= \sqrt{1 - SIN^2\gamma}$$

$$SIN\gamma = \sqrt{1 - \left(\frac{P}{C_1 V_2} + \frac{C_2 V_2}{C_1}\right)^2} \quad (E.3).$$

From eq. (E.2), we find,

$$\left(\frac{Q}{C_1 V_2} - \frac{C_4 V_2}{C_1}\right)^2 = 1 - \left(\frac{P}{C_1 V_2} + \frac{C_2 V_2}{C_1}\right)^2.$$

Multiplier both sides by V_2^2 and square both sides, we get:

$$\frac{Q^2}{C_1^2} - \frac{2 Q C_4 V_2^2}{C_1 C_2} + \frac{C_4^2 V_2^4}{C_1^2} =$$

$$V_2^2 - \frac{P^2}{C_1^2} - \frac{2 P C_2}{C_1^2} - \frac{C_2^2 V_2^4}{C_1^2}$$

Then,

$$\frac{\left[C_4^2 + C_2^2 \right]}{C_1^2} V_2^4 + \left[\frac{2QC_4}{C_1 C_2} + \frac{2PC_2}{C_1^2} - 1 \right] V_2^2 + \frac{\left[P^2 + Q^2 \right]}{C_1^2} = 0 .$$

V_2^2 is in a standard form, then

$$V_2^2 = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A} \qquad (E.4).$$

So, V_2 is not unique.

If R is not included in the system then we find:

$$P = \frac{V_1 V_2 \sin\theta}{X} \qquad (E.5),$$

and

$$Q = \frac{V_1 V_2 \cos\theta}{X} - V_2^2 \left(\frac{1}{X} + Y \right) \qquad (E.6).$$

From eq. (E.5),

$$\sin\theta = \frac{PX}{V_1 V_2}$$

then, we find

$$\cos\theta = \sqrt{1 - \frac{(PX)^2}{(V_1 V_2)^2}}$$

Subsititute COS θ in eq. (E.6) and let,

$$D = \frac{1}{X} + Y$$

We find,

$$Q + V_2^2 D = \frac{(V_1 V_2)}{X} \sqrt{1 - \frac{(P X)^2}{(V_1 V_2)^2}} \quad (E.7).$$

Square eq. (E.7):

$$D^2 V_2^4 + \left[2 D Q - \frac{V_1^2}{X^2} \right] V_2^2 + (P^2 + Q^2) = 0$$

Then V_2 can be calculated and give two values.

If, from eq. (E.5):

$$V_2 = \frac{P X}{V_1 \, SIN \, \theta},$$

subsitiute V_2 in eq. (E.6) and let

$$E = \frac{(P X)^2}{V_1^2} \left(\frac{1}{X} + Y \right),$$

we find;

$$Q + \frac{E}{SIN^2 \theta} = \frac{P \sqrt{1 - SIN^2 \theta}}{SIN \, \theta} \quad (E.8).$$

Square eq. (E.8), and we can find;

$$(P^2 + Q^2) SIN^4 \theta + (2 Q E - P^2) SIN^2 \theta + E = 0 \quad (E.9).$$

Example A Power System has $V_1 = 1.0$, $X = 0.1$, $R = 0.0$

Case 1 $P = 9.0$, $Q = 0.1$, $Y = -5.0$, then

$V_2 = 1.6747 \angle -32.52$ or $1.07489 \angle -56.86$

Case 2 $P = 6.0$, $Q = 0.0$, $Y = -9.0$, then

$V_2 = 9.98193 \angle -3.45$ or $0.60109 \angle -86.55$

Case 3 $P = 5.0$, $Q = 0.0$, $Y = 0.0$, then

$V_2 = 0.70711 \angle -45.0$ and has only one solution.

The two conditions of false Load-Flow are:

1. A transmission line carries high load approaching its steady-state stability limit.

2. A generator feeds or receives reactive power approaching its limits, and NRLF checks the limit every iteration, and the expected at the first 2-3 iterations.

Appendix F

Program Application Guide

F.1. Input of The Program

While running the program, the name of input data file is requested to be entered as below:

INPUT FROM

Then, the user types a name of input-file. The program will ask the name of output-file; to be printed,

OUTPUT TO

The user types a name of output-file. The program will read the data and do the processes of FDLF.

F.2. Input-File

The first line of input-file is:

NB , NL , NC , NT , NA , LNIT , IN

NB is total number of buses in system.

NL is total number of lines in system.

NC is total number of shunt impedances in system.

NT is total number of transformers in system.

NA is total number of areas in system.

LNIT is maximum iteration; if LNIT is less than 1, it will be set to 10.

IN is a control data, its value is 0 for automatic tearing.

The second line of input-file is:

ERROR , PBASE , REF

ERROR is tolerant of program; if it is equal or less than 0.0 , it will be set to 0.0001.

PBASE is base power; if it equal 0.0, it will be setto 1.0.

REF is reference angle.

The first set of data is transmission line data. The program will work in a reading loop of NL loops.

NSB , NEB , Z1 , Z2 , YSH

NSB is sending end bus.

NEB is receiving end bus.

Z1 is resistance of line.

Z2 is reactance of line.

YSH is line charging.

The second set of data is bus data. The program will read the value of:

NTB , VSPEC , PD , QD , PG , QG , VBASE , QCX

NTB is type of bus;

1 means load bus,

2 means PV-bus,

3 means swing bus.

VSPEC is setting of voltage in per unit; if its value is 0.0, it will be set to 1.0.

PD is MW loading.

QD is MVAr loading.

PG is MW generating.

QG is MVAr generating.

VBASE is base voltage; if its value is 0.0 , it will be set to 1.0.

QCX is shunt MVAr, positive for capacitor.

The third set of data is transformer data. The program will work in a reading loop of NT loops.

N1A , NTA , ZT , Z1 , Z2

N1A is bus at turn ratio is 1.0.

NTA is bus at turn ratio is a.

ZT is transformer impedance.

Z1 is real part of turn ratio.

Z2 is imaginary part of turn ratio.

The forth set of data is shunt impedance data. The program will work in a reading loop of NC loops.

NCB , ZC

NCB is bus with shunt element.

ZC is impedance of the shunt element; positive for reactor.

If IN is not equal 0 , the user must set area of buses at the latest line of input-file.

<u>Example 1</u> A well-known 6-node network, Ward and Hale (66), is shown in Fig. F.1. It is used to test in many programs, the data as below:

```
6 5 3 2 2 10 0
0.001 50.0 0.0
1 6 0.123 0.518 0.0
1 4 0.080 0.370 0.0
4 6 0.097 0.407 0.0
2 5 0.282 0.640 0.0
2 3 0.723 1.050 0.0
3 1.05  0.0  0.0  0.0  0.0 100.0 0.0
2 1.10  0.0  0.0 25.0  0.0 100.0 0.0
1 1.00 27.5  6.5  0.0  0.0 100.0 0.0
1 1.00  0.0  0.0  0.0  0.0 100.0 0.0
1 1.00 15.0  9.0  0.0  0.0 100.0 0.0
1 1.00 25.0  2.5  0.0  0.0 100.0 0.0
5 6 0.300 0.976 0.0
3 4 0.133 0.909 0.0
4 -34.1
1 -29.5
6 -28.5
```


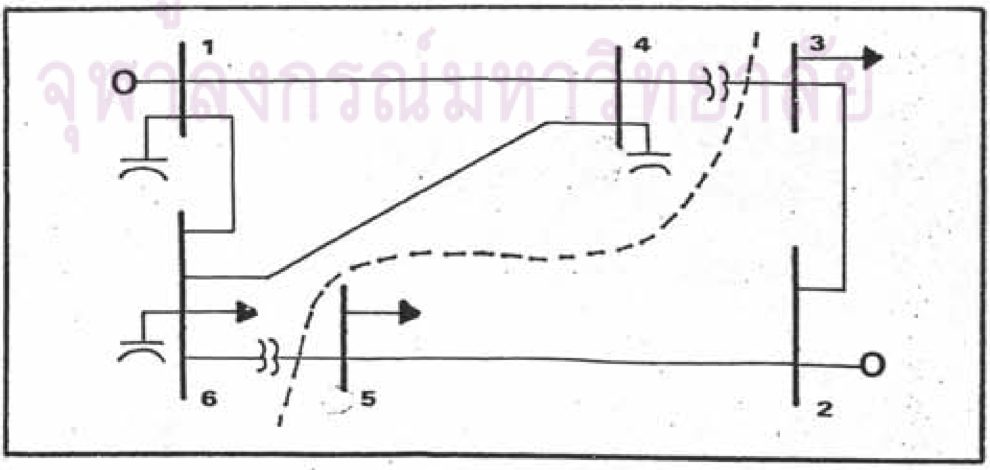

Fig. F.1 A 6-Node Network Shows An Optimum Tearing.

Y1 BLOCK FOR AREA 1

0.445 J	0.107	0.000 J	0.000	-0.445 J	0.646
0.000 J	0.000	0.577 J	-1.226	-0.577 J	1.308
-0.445 J	0.646	-0.577 J	1.308	1.021 J	-1.955

Y1 BLOCK FOR AREA 2

1.112 J	-5.706	-0.554 J	2.325	-0.558 J	2.582
-0.554 J	2.325	0.988 J	-4.201	-0.434 J	1.827
-0.558 J	2.582	-0.434 J	1.827	0.992 J	-4.376

**** P-D PROBLEM ****

MODIFIED JACOBIAN MATRICES

AREA 1

-0.1066	0.0000	-0.6461
0.0000	1.2265	-1.3085
-0.6461	-1.3085	1.9545

AREA 2

5.7057	-2.3249
-2.3249	4.2013

ZBUS AREA 1

-1.1712	-1.4450	-1.3545
-1.4450	1.0698	0.2385
-1.3545	0.2385	0.2236

ZBUS AREA 2

0.2263	0.1252
0.1252	0.3073

```
TIE LINE IN P-PROBLEM      1    IS LINE      6
TIE LINE IN P-PROBLEM      2    IS LINE      7

Z2 FOR AREA         1

 -1.4450   -1.1712
  1.0698   -1.4450
  0.2385   -1.3545

Z2 FOR AREA         2

 -0.1252   -0.2263
 -0.3073   -0.1252

          Z4 MATRIX

  1.6699   -1.3198
 -1.3198   -0.8240

 .... Q-V .... PROBLEM

MODIFY JACOBIAN MATRICES

AREA         1

 -0.1066    0.0000
  0.0000    1.2265

AREA         2

  5.7057   -2.3249
 -2.3249    4.2013

Z1 FOR AREA         1
```

-9.3770	0.0000
0.0000	0.8153

Z1 FOR AREA 2

0.2263	0.1252
0.1252	0.3073

TIE LINE IN Q-PROBLEM 1 IS LINE 6
TIE LINE IN Q-PROBLEM 2 IS LINE 7

Z2 FOR AREA 1

0.0000	-9.3770
0.8153	0.0000

Z2 FOR AREA 2

-0.1252	-0.2263
-0.3073	-0.1252

Z4 MATRIX

1.4155	0.1252
0.1252	-9.0298

P-D ITERATIVE

BUS	1	VOLT	1.05000	ANGLE	0.00000
BUS	2	VOLT	1.10000	ANGLE	0.00000
BUS	3	VOLT	1.00000	ANGLE	0.00000
BUS	4	VOLT	1.00000	ANGLE	0.00000
BUS	5	VOLT	1.00000	ANGLE	0.00000
BUS	6	VOLT	1.00000	ANGLE	0.00000

CURRENT IN TIE LINE NO.	1	5- 6	0.000000	J	0.000000
CURRENT IN TIE LINE NO.	2	3- 4	0.000000	J	0.000000

```
BUS       2     P WITHOUT TIE CURRENT  0.112354     PCAL       0.112354
BUS       3     P WITHOUT TIE CURRENT -0.044486     PCAL      -0.044486
BUS       5     P WITHOUT TIE CURRENT -0.057654     PCAL      -0.057654
BUS       4     P WITHOUT TIE CURRENT -0.027913     PCAL      -0.027913
BUS       6     P WITHOUT TIE CURRENT -0.021697     PCAL      -0.021697

      **** ERROR MAXIMUM ****        0.505514

      STEP 1  ET0

      AREA        1

      BUS         1       ET0      -0.464908
      BUS         2       ET0      -0.555283
      BUS         3       ET0      -0.705712

      AREA        2

      BUS         1       ET0       0.053580
      BUS         2       ET0       0.143497

                        STEP2 EC1

      TIE LINE NO       1       EC1        0.698779
      TIE LINE NO       2       EC1        0.518488

                        STEP 3  IC

      TIE LINE NO.      1      CURRENT         -0.034805
      TIE LINE NO.      2      CURRENT         -0.573492

                        STEP4 ET1

      AREA        1       IT1       -0.573492
      AREA        1       IT1       -0.034805
      AREA        1       IT1        0.000000

      AREA        1       ET1        0.721956
      AREA        1       ET1        0.791483
      AREA        1       ET1        0.768501
```

AREA	2	IT1	0.573492
AREA	2	IT1	0.034805

AREA	2	ET1	0.134135
AREA	2	ET1	0.082513

Q-V ITERATIVE

BUS	1	VOLT	1.050000	ANGLE	0.000000
BUS	2	VOLT	1.100000	ANGLE	-0.062789
BUS.	3	VOLT	1.000000	ANGLE	-0.257048
BUS	4	VOLT	1.000000	ANGLE	-0.187715
BUS	5	VOLT	1.000000	ANGLE	-0.236200
BUS	6	VOLT	1.000000	ANGLE	-0.226009

CURRENT IN TIE LINE NO.	1	5- 6	-0.033879	J	0.007972
CURRENT IN TIE LINE NO.	2	3- 4	-0.559255	J	0.126460

BUS	3	Q WITHOUT TIE CURRENT	-0.709483	QCAL	-0.689611
BUS	5	Q WITHOUT TIE CURRENT	-0.081800	QCAL	-0.081623
BUS	4	Q WITHOUT TIE CURRENT	0.807141	QCAL	0.827014
BUS	6	Q WITHOUT TIE CURRENT	0.131342	QCAL	0.131520

**** ERROR MAXIMUM **** 0.827014

STEP 1 ET0

AREA 1

BUS	1	ET0	5.247455
BUS	2	ET0	0.080210

AREA 2

BUS	1	ET0	0.209877
BUS	2	ET0	0.159349

STEP2 EC1

TIE LINE NO	1	EC1	0.079139
TIE LINE NO	2	EC1	-5.037578

STEP 3 IC

TIE LINE NO.	1	CURRENT	0.006546
TIE LINE NO.	2	CURRENT	0.557975

STEP4 ET1

AREA	1	IT1	0.557975
AREA	1	IT1	0.006546
AREA	1	ET1	-5.232121
AREA	1	ET1	0.005337
AREA	2	IT1	-0.557975
AREA	2	IT1	-0.006546
AREA	2	ET1	-0.127085
AREA	2	ET1	-0.071885

P-D ITERATIVE

BUS	1	VOLT	1.05000	ANGLE	0.00000
BUS	2	VOLT	1.10000	ANGLE	-0.06279
BUS	3	VOLT	0.98467	ANGLE	-0.25705
BUS	4	VOLT	0.91721	ANGLE	-0.18771
BUS	5	VOLT	0.91445	ANGLE	-0.23620
BUS	6	VOLT	0.91254	ANGLE	-0.22601

CURRENT IN TIE LINE NO.	1	5- 6	-0.032448 J	0.000911
CURRENT IN TIE LINE NO.	2	3- 4	-0.654807 J	-0.423659

BUS	2	P WITHOUT TIE CURRENT	0.554054	PCAL	0.554054
BUS	3	P WITHOUT TIE CURRENT	-0.176541	PCAL	-0.694070
BUS	5	P WITHOUT TIE CURRENT	-0.316224	PCAL	-0.345267
BUS	4	P WITHOUT TIE CURRENT	-0.445377	PCAL	0.072151
BUS	6	P WITHOUT TIE CURRENT	-0.512766	PCAL	-0.483723

**** ERROR MAXIMUM **** 0.144070

STEP 1 ET0

AREA 1

BUS	1	ET0	0.176330
BUS	2	ET0	0.170192
BUS	3	ET0	0.197362

AREA 2

BUS	1	ET0	0.020035
BUS	2	ET0	0.015332

STEP2 EC1

TIE LINE NO	1	EC1	-0.154859
TIE LINE NO	2	EC1	-0.156296

STEP 3 IC

TIE LINE NO.	1	CURRENT	0.025234
TIE LINE NO.	2	CURRENT	0.149263

STEP4 ET1

AREA	1	IT1	0.149263
AREA	1	IT1	0.025234
AREA	1	IT1	0.000000

AREA	1	ET1	-0.211278
AREA	1	ET1	-0.188695
AREA	1	ET1	-0.196160

AREA	2	IT1	-0.149263
AREA	2	IT1	-0.025234

AREA	2	ET1	-0.036937
AREA	2	ET1	-0.026447

Q-V ITERATIVE

BUS	1	VOLT	1.050000	ANGLE	0.000000
BUS	2	VOLT	1.100000	ANGLE	-0.063992
BUS	3	VOLT	0.984666	ANGLE	-0.222100
BUS	4	VOLT	0.917208	ANGLE	-0.170812
BUS	5	VOLT	0.914453	ANGLE	-0.217697
BUS	6	VOLT	0.912536	ANGLE	-0.214895

CURRENT IN TIE LINE NO. 1 5- 6 -0.009944 J -0.004517
CURRENT IN TIE LINE NO. 2 3- 4 -0.504488 J -0.468333

BUS	3	Q WITHOUT TIE CURRENT	-0.718576	QCAL	-0.159328
BUS	5	Q WITHOUT TIE CURRENT	-0.186248	QCAL	-0.180251
BUS	4	Q WITHOUT TIE CURRENT	0.476463	QCAL	-0.025499
BUS	6	Q WITHOUT TIE CURRENT	-0.047166	QCAL	-0.053128

**** ERROR MAXIMUM **** 0.029328

STEP 1 ET0

AREA 1

BUS 1 ET0 0.279289
BUS 2 ET0 -0.000224

AREA 2

BUS 1 ET0 -0.006720
BUS 2 ET0 -0.004535

STEP2 EC1

TIE LINE NO 1 EC1 -0.004311
TIE LINE NO 2 EC1 -0.286010

STEP 3 IC

TIE LINE NO.	1	CURRENT	-0.005841
TIE LINE NO.	2	CURRENT	0.031593

STEP4 ET1

AREA	1	IT1	0.031593
AREA	1	IT1	-0.005841
AREA	1	ET1	-0.296247
AREA	1	ET1	-0.004762
AREA	2	IT1	-0.031593
AREA	2	IT1	0.005841
AREA	2	ET1	-0.006418
AREA	2	ET1	-0.002161

P-D ITERATIVE

BUS	1	VOLT	1.05000	ANGLE	0.00000
BUS	2	VOLT	1.10000	ANGLE	-0.06399
BUS	3	VOLT	1.00162	ANGLE	-0.22210
BUS	4	VOLT	0.93035	ANGLE	-0.17081
BUS	5	VOLT	0.91944	ANGLE	-0.21770
BUS	6	VOLT	0.91923	ANGLE	-0.21490

CURRENT IN TIE LINE NO.	1	5-	6	-0.008745	J	0.001199
CURRENT IN TIE LINE NO.	2	3-	4	-0.516913	J	-0.498062

BUS	2	P WITHOUT TIE CURRENT	0.490323	PCAL	0.490323
BUS	3	P WITHOUT TIE CURRENT	-0.149798	PCAL	-0.544942
BUS	5	P WITHOUT TIE CURRENT	-0.291447	PCAL	-0.299536
BUS	4	P WITHOUT TIE CURRENT	-0.389139	PCAL	0.006005
BUS	6	P WITHOUT TIE CURRENT	-0.511483	PCAL	-0.503395

**** ERROR MAXIMUM ****   0.009677

STEP 1 ET0

AREA 1

BUS	1	ET0	0.005272
BUS	2	ET0	-0.008856
BUS	3	ET0	-0.008687

AREA 2

BUS	1	ET0	0.000998
BUS	2	ET0	-0.000327

STEP2 EC1

TIE LINE NO	1	EC1	0.008529
TIE LINE NO	2	EC1	-0.004274

STEP 3 IC

TIE LINE NO.	1	CURRENT	0.004063
TIE LINE NO.	2	CURRENT	-0.001321

STEP4 ET1

AREA	1	IT1	-0.001321
AREA	1	IT1	0.004063
AREA	1	IT1	0.000000

AREA	1	ET1	-0.004324
AREA	1	ET1	0.006256
AREA	1	ET1	0.002759

AREA	2	IT1	0.001321
AREA	2	IT1	-0.004063

AREA	2	ET1	-0.000210
AREA	2	ET1	-0.001083

Q-V ITERATIVE

BUS	1	VOLT	1.050000	ANGLE	0.000000
BUS	2	VOLT	1.100000	ANGLE	-0.058064
BUS	3	VOLT	1.001624	ANGLE	-0.223048
BUS	4	VOLT	0.930346	ANGLE	-0.171601

BUS	5	VOLT	0.919439	ANGLE	-0.215098
BUS	6	VOLT	0.919232	ANGLE	-0.213485

CURRENT IN TIE LINE NO.	1	5- 6	-0.005097 J	0.000388
CURRENT IN TIE LINE NO.	2	3- 4	-0.518596 J	-0.497362

BUS	3	Q WITHOUT TIE CURRENT	-0.728649	QCAL	-0.127919
BUS	5	Q WITHOUT TIE CURRENT	-0.179042	QCAL	-0.178390
BUS	4	Q WITHOUT TIE CURRENT	0.540021	QCAL	0.001712
BUS	6	Q WITHOUT TIE CURRENT	-0.051742	QCAL	-0.052386

**** ERROR MAXIMUM **** 0.002386

STEP 1 ET0

AREA 1

BUS	1	ET0	-0.019484
BUS	2	ET0	0.001428

AREA 2

BUS	1	ET0	0.000091
BUS	2	ET0	-0.000567

STEP2 EC1

TIE LINE NO	1	EC1	-0.001995
TIE LINE NO	2	EC1	0.019576

STEP 3 IC

TIE LINE NO.	1	CURRENT	-0.001216
TIE LINE NO.	2	CURRENT	-0.002185

STEP4 ET1

AREA 1 IT1 -0.002185

AREA	1	IT1	-0.001216

AREA	1	ET1	0.020487
AREA	1	ET1	-0.000992

AREA	2	IT1	0.002185
AREA	2	IT1	0.001216

AREA	2	ET1	0.000647
AREA	2	ET1	0.000647

P-D ITERATIVE

BUS	1	VOLT	1.05000	ANGLE	0.00000
BUS	2	VOLT	1.10000	ANGLE	-0.05806
BUS	3	VOLT	1.00062	ANGLE	-0.22305
BUS	4	VOLT	0.92961	ANGLE	-0.17160
BUS	5	VOLT	0.91900	ANGLE	-0.21510
BUS	6	VOLT	0.91915	ANGLE	-0.21349

CURRENT IN TIE LINE NO.	1	5-	6	-0.004837 J	0.001576
CURRENT IN TIE LINE NO.	2	3-	4	-0.517805 J	-0.495294

BUS	2	P WITHOUT TIE CURRENT	0.500889	PCAL	0.500889
BUS	3	P WITHOUT TIE CURRENT	-0.154379	PCAL	-0.550041
BUS	5	P WITHOUT TIE CURRENT	-0.295589	PCAL	-0.300241
BUS	4	P WITHOUT TIE CURRENT	-0.395852	PCAL	-0.000189
BUS	6	P WITHOUT TIE CURRENT	-0.504444	PCAL	-0.499792

**** ERROR MAXIMUM **** 0.000889

STEP 1 ET0

AREA 1

BUS	1	ET0	-0.000667
BUS	2	ET0	-0.000028
BUS	3	ET0	0.000174

AREA 2

BUS	1	ET0	-0.000018
BUS	2	ET0	0.000044

STEP2 EC1

TIE LINE NO	1	EC1	0.000072
TIE LINE NO	2	EC1	0.000650

STEP 3 IC

TIE LINE NO.	1	CURRENT	-0.000256
TIE LINE NO.	2	CURRENT	-0.000379

STEP4 ET1

AREA	1	IT1	-0.000379
AREA	1	IT1	-0.000256
AREA	1	IT1	0.000000

AREA	1	ET1	0.000813
AREA	1	ET1	0.000273
AREA	1	ET1	0.000452

AREA	2	IT1	0.000379
AREA	2	IT1	0.000256

AREA	2	ET1	0.000118
AREA	2	ET1	0.000126

Q-V ITERATIVE

BUS	1	VOLT	1.050000	ANGLE	0.000000
BUS	2	VOLT	1.100000	ANGLE	-0.058690
BUS	3	VOLT	1.000621	ANGLE	-0.223194
BUS	4	VOLT	0.929608	ANGLE	-0.171701
BUS	5	VOLT	0.919003	ANGLE	-0.215343
BUS	6	VOLT	0.919152	ANGLE	-0.213655

CURRENT IN TIE LINE NO.	1	5- 6	-0.005067 J 0.001627
CURRENT IN TIE LINE NO.	2	3- 4	-0.518224 J -0.495157

```
BUS     3     Q WITHOUT TIE CURRENT      -0.728101     QCAL -0.130148
BUS     5     Q WITHOUT TIE CURRENT      -0.179747     QCAL -0.180212
BUS     4     Q WITHOUT TIE CURRENT       0.535923     QCAL  0.000079
BUS     6     Q WITHOUT TIE CURRENT      -0.050314     QCAL -0.049840

                   **** ERROR MAXIMUM ****          0.000212

              STEP 1  ET0

              AREA          1

              BUS          1       ET0       0.001386
              BUS          2       ET0      -0.000188

              AREA          2

              BUS          1       ET0       0.000041
              BUS          2       ET0       0.000064

                                   STEP2 EC1

              TIE LINE NO         1       EC1        0.000252
              TIE LINE NO         2       EC1       -0.001345

                                   STEP 3  IC

              TIE LINE NO.         1     CURRENT          0.000165
              TIE LINE NO.         2     CURRENT          0.000151

                                   STEP4 ET1

              AREA         1       IT1        0.000151
              AREA         1       IT1        0.000165

              AREA         1       ET1       -0.001418
              AREA         1       ET1        0.000134
```

AREA	2	IT1	-0.000151
AREA	2	IT1	-0.000165

AREA	2	ET1	-0.000055
AREA	2	ET1	-0.000070

CURRENT IN TIE LINE NO.	1	5- 6	-0.005102 J 0.001465
CURRENT IN TIE LINE NO.	2	3- 4	-0.518263 J -0.495304

BUS	1	Q WITHOUT TIE CURRENT	0.435306	QCAL	0.435306
BUS	2	Q WITHOUT TIE CURRENT	0.185711	QCAL	0.185711
BUS	1	P WITHOUT TIE CURRENT	0.952294	PCAL	0.952294

**** OUT PUT ****

BUS NO.	VOLT PU.	VOLT KV	ANGLE (DEGREE)	GENERATION MW	GENERATION MVAR	DEMAND MW	DEMAND MVAR	SHUNT MVAR
1	1.0500	105.00	0.0000	47.61	21.77	0.00	0.00	1.87
2	1.1000	110.00	-3.3627	25.00	9.29	0.00	0.00	0.00
3	1.0007	100.07	-12.7881	0.00	0.00	27.50	6.50	0.00
4	0.9296	92.96	-9.8377	0.00	0.00	0.00	0.00	1.27
5	0.9191	91.91	-12.3382	0.00	0.00	15.00	9.00	0.00
6	0.9192	91.92	-12.2415	0.00	0.00	25.00	2.50	1.48

**** LINE FLOW ****

LINE NO.	FROM BUS P	TO BUS Q	FLOW FROM P		FLOW TO Q		LOSS	
			MW	MVAR	MW	MVAR	MW	MVAR
1	1	6	22.155	10.118	-20.832	-4.544	1.324	5.575
2	1	4	25.459	13.516	-24.254	-7.939	1.206	5.577
3	4	6	4.456	0.225	-4.412	-0.038	0.045	0.188
4	2	5	16.413	9.285	-14.756	-5.523	1.658	3.762
5	2	3	8.584	0.001	-7.704	1.278	0.881	1.279

**** SYSTEM TOTAL ****

	MW	MVAR
GENERATION	72.61	31.05
LOAD	67.50	18.00
LINE CHARGING	0.00	0.00
STATIC CAPACITOR	0.00	4.62
LOSS	5.11	17.67
MISMATCH	0.00	0.00

Example 2 The 14-node network optimal tearing as shown in Fig. 6.2. The data as below:

```
14 14 0 4 3 20 0
0.001 100.0 0.0
1  7  0.067 0.20 0.042
1  9  0.067 0.20 0.042
2  11 0.350 0.42 0.007
3  5  0.067 0.20 0.042
3  10 0.067 0.20 0.042
3  10 0.067 0.20 0.042
4  12 0.350 0.42 0.007
5  14 0.067 0.20 0.042
5  14 0.067 0.20 0.042
6  12 0.350 0.42 0.007
7  13 0.067 0.20 0.042
8  11 0.350 0.42 0.007
9  10 0.034 0.10 0.021
13 14 0.034 0.10 0.021
2 1.02 100.0 50.0 200.0  0.0 100.0  0.0
1 1.00   0.0  0.0   0.0  0.0 100.0  0.0
1 1.00 100.0 50.0 200.0 56.2 100.0  0.0
2 1.00   0.0  0.0   0.0  0.0 100.0  0.0
2 1.02 100.0 50.0 200.0  0.0 100.0  0.0
1 1.00   0.0  0.0   0.0  0.0 100.0  0.0
3 1.04 100.0 50.0   0.0  0.0 100.0  0.0
1 1.00   0.0  0.0   0.0  0.0 100.0  0.0
1 1.00  50.0 25.0   0.0  0.0 100.0 20.0
1 1.00  50.0 25.0   0.0  0.0 100.0  0.0
1 1.00  25.0 20.0   0.0  0.0 100.0 10.0
1 1.00  25.0 20.0   0.0  0.0 100.0 10.0
1 1.00  50.0 25.0   0.0  0.0 100.0 20.0
1 1.00  50.0 25.0   0.0  0.0 100.0  0.0
1 2 0.12 0.990 0.0
3 4 0.12 0.990 0.0
5 6 0.12 0.988 0.0
7 8 0.12 0.973 0.0
```

**** P-D PROBLEM ****

MODIFIED JACOBIAN MATRICES

AREA 1

17.2613	0.0000	-8.9910	0.0000	-8.4175
0.0000	8.7323	-8.9638	0.0000	0.0000
-8.9910	-8.9638	17.9023	0.0000	0.0000
0.0000	0.0000	0.0000	1.2982	-1.4052
-8.4175	0.0000	0.0000	-1.4052	9.9042

AREA 2

9.9042	0.0000	-1.4052	-8.4175
0.0000	10.2039	-1.4052	0.0000
-1.4052	-1.4052	2.7033	0.0000
-8.4175	0.0000	0.0000	12.7868

AREA 3

8.5335	0.0000	0.0000	-8.4345
0.0000	13.2278	-8.9638	0.0000
0.0000	-8.9638	17.9023	-8.9910
-8.4345	0.0000	-8.9910	17.2613

ZBUS

AREA 1

-2.0772	-2.2033	-2.1464	-2.2576	-2.0857
-2.2033	-2.1016	-2.1588	-2.3947	-2.2124
-2.1464	-2.1588	-2.1031	-2.3329	-2.1552
-2.2576	-2.3947	-2.3329	-1.5436	-2.1377
-2.0857	-2.2124	-2.1552	-2.1377	-1.9749

AREA 2

0.2796	0.0216	0.1565	0.1841
0.0216	0.1072	0.0669	0.0142
0.1565	0.0669	0.4861	0.1031
0.1841	0.0142	0.1031	0.1994

AREA 3

0.5846	0.2436	0.3595	0.4729
0.2436	0.2414	0.2446	0.2465
0.3595	0.2446	0.3610	0.3637
0.4729	0.2465	0.3637	0.4784

Z2 FOR AREA 1

2.2033	-2.0772	2.2576
2.1016	-2.2033	2.3947
2.1588	-2.1464	2.3329
2.3947	-2.2576	1.5436
2.2124	-2.0857	2.1377

Z2 FOR AREA 2

0.1841	0.0000	0.0000
0.0142	0.0000	0.0000
0.1031	0.0000	0.0000
0.1994	0.0000	0.0000

Z2 FOR AREA 3

0.0000	-0.4729	0.5846
0.0000	-0.2465	0.2436
0.0000	-0.3637	0.3595
0.0000	-0.4784	0.4729

Z4 MATRIX

-1.6797	2.2033	-2.3947
2.2033	-1.3763	1.7847
-2.3947	1.7847	-0.2473

**** Q-V **** PROBLEM

MODIFY JACOBIAN MATRICES

AREA 1

21.7568	0.0000	-8.9910	0.0000
0.0000	13.2278	-8.9638	0.0000
-8.9910	-8.9638	17.9023	0.0000
0.0000	0.0000	0.0000	1.2982

AREA 2

9.9042	0.0000	-1.4052
0.0000	10.2039	-1.4052
-1.4052	-1.4052	2.7033

AREA 3

8.5335	0.0000	0.0000
0.0000	13.2278	-8.9638
0.0000	-8.9638	17.9023

Z1 FOR AREA 1

0.0670	0.0345	0.0509	0.0000
0.0345	0.1322	0.0835	0.0000
0.0509	0.0835	0.1233	0.0000
0.0000	0.0000	0.0000	0.7703

Z1 FOR AREA 2

0.1097	0.0085	0.0614
0.0085	0.1062	0.0596
0.0614	0.0596	0.4328

Z1 FOR AREA 3

0.1172	0.0000	0.0000
0.0000	0.1144	0.0573
0.0000	0.0573	0.0845

Z2 FOR AREA 1

0.0000
0.0000
0.0000
-0.7703

Z2 FOR AREA 2

0.0000
0.0000
0.0000

Z2 FOR AREA 3

0.1172
0.0000
0.0000

Z4 MATRIX

1.5992

				BUS			BUS
ITE.	0	DEL P	1.030120	3	DEL Q	0.567165	3
ITE.	1	DEL P	0.208933	11	DEL Q	0.167347	11
ITE.	2	DEL P	0.134342	11	DEL Q	0.104824	11
ITE.	3	DEL P	0.077973	11	DEL Q	0.062375	11
ITE.	4	DEL P	0.049114	11	DEL Q	0.038823	11
ITE.	5	DEL P	0.029628	11	DEL Q	0.023614	11
ITE.	6	DEL P	0.018397	11	DEL Q	0.014594	11
ITE.	7	DEL P	0.011233	11	DEL Q	0.008938	11
ITE.	8	DEL P	0.006933	11	DEL-Q	0.005507	11
ITE.	9	DEL P	0.004252	11	DEL Q	0.003381	11
ITE.	10	DEL P	0.002618	11	DEL Q	0.002080	11
ITE.	11	DEL P	0.001608	11	DEL Q	0.001278	11
ITE.	12	DEL P	0.000989	11	DEL Q	0.000786	11

**** OUT PUT ****

BUS NO.	VOLT		ANGLE	GENERATION		DEMAND		SHUNT
	PU.	KV	(DEGREE)	MW	MVAR	MW	MVAR	MVAR
1	1.0200	102.00	6.5767	200.00	38.08	100.00	50.00	0.00
2	1.0075	100.75	5.2074	0.00	0.00	0.00	0.00	0.00
3	1.0128	101.28	9.7964	200.00	56.20	100.00	50.00	0.00
4	1.0000	100.00	8.8165	0.00	2.83	0.00	0.00	0.00
5	1.0200	102.00	8.5151	200.00	67.75	100.00	50.00	0.00
6	0.9995	99.95	7.7188	0.00	0.00	0.00	0.00	0.00
7	1.0400	104.00	0.0000	62.98	112.15	100.00	50.00	0.00
8	0.9996	99.96	-0.4117	0.00	0.00	0.00	0.00	0.00
9	0.9748	97.48	4.0577	0.00	0.00	50.00	25.00	19.01
10	0.9735	97.35	5.6997	0.00	0.00	50.00	25.00	0.00
11	0.9303	93.03	0.3289	0.00	0.00	25.00	20.00	8.66
12	0.9274	92.74	6.1838	0.00	0.00	25.00	20.00	8.60
13	0.9875	98.75	0.1486	0.00	0.00	50.00	25.00	19.51
14	0.9823	98.23	3.1402	0.00	0.00	50.00	25.00	0.00

**** LINE FLOW ****

LINE NO.	FROM BUS P	TO BUS Q	FLOW FROM P		FLOW TO Q		LOSS	
			MW	MVAR	MW	MVAR	MW	MVAR
1	1	7	52.598	-26.515	-50.435	28.515	2.163	6.456
2	1	9	26.731	12.383	-26.134	-14.782	0.597	1.782
3	2	11	20.704	1.714	-19.211	-0.581	1.493	1.791
4	3	5	9.331	-8.781	-9.245	4.697	0.086	0.255
5	3	10	38.044	6.276	-37.052	-7.460	0.992	2.960
6	3	10	38.044	6.276	-37.052	-7.460	0.992	2.960
7	4	12	14.606	5.007	-13.759	-4.641	0.847	1.017
8	5	14	48.647	2.948	-47.106	-2.560	1.541	4.600
9	5	14	48.647	2.948	-47.106	-2.560	1.541	4.600
10	6	12	11.977	6.928	-11.289	-6.753	0.688	0.826
11	7	13	7.018	22.653	-6.603	-25.733	0.415	1.240
12	8	11	6.430	10.801	-5.850	-10.757	0.580	0.696
13	9	10	-23.867	8.787	24.105	-10.080	0.238	0.700
14	13	14	-43.398	20.238	44.212	-19.881	0.814	2.395

**** SYSTEM TOTAL ****

	MW	MVAR
GENERATION	662.98	277.01
LOAD	650.00	340.00
LINE CHARGING	0.00	40.65
STATIC CAPACITOR	0.00	55.77
LOSS	12.99	33.44
MISMATCH	0.01	0.02

Example 3 The EGAT network data is as below:

```
208 302 0 69 5 0100 0
0.00100 100.00 0
 14 182 0.001298 0.03344 0.00418
 14 182 0.001220 0.03567 0.00439
 16 17 0.70 0.00503 0.01109
 16 21 0.00184 0.01445 0.02660
 16 22 0.00194 0.01393 0.03077
 17 18 0.00104 0.00748 0.01647
 17 18 0.00104 0.00748 0.01647
 17 22 0.00177 0.01271 0.02807
 18 19 0.00205 0.01472 0.03251
 18 19 0.00205 0.01472 0.03251
 18 23 0.00134 0.01408 0.05740
 18 23 0.00134 0.01408 0.05740
 19 20 0.00159 0.01142 0.02522
 19 20 0.00159 0.01142 0.02522
 19 179 0.00440 0.03166 0.06992
 19 179 0.00440 0.03166 0.06992
 20 21 0.00232 0.01666 0.03679
 20 21 0.00232 0.01666 0.03679
 21 159 0.01 0.07185 0.35993
 21 202 0.00178 0.02325 1.19161
 22 23 0.00200 0.02100 0.08568
 22 23 0.00200 0.02100 0.08568
 22 158 0.00756 0.05444 0.42043
 22 158 0.00756 0.05444 0.42043
 22 159 0.00949 0.06822 0.35180
 22 202 0.00158 0.02619 1.12353
 23 179 0.00211 0.02221 0.09061
 23 179 0.00211 0.02221 0.09061
 23 179 0.00211 0.02214 0.09093
 23 179 0.00211 0.02214 0.09093
 24 25 0.0089443 0.072929 0.00954
 25 26 0.0076953 0.062698 0.00820
 26 27 0.0035026 0.028489 0.00373
 27 28 0.0084401 0.068797 0.00900
 27 29 0.0069636 0.077741 0.01150
 30 32 0.007495 0.021587 0.019293
 30 146 0.004408 0.012685 0.019205
 31 33 0.003901 0.011225 0.01508
 31 146 0.008867 0.025551 0.03439
 32 33 0.001189 0.03421 0.00460
 32 38 0.019263 0.054495 0.07706
 33 34 0.0015785 0.033573 0.04104
 33 36 0.0028501 0.035902 0.03841
 33 60 0.004766 0.013382 0.01875
 34 35 0.006623 0.014053 0.01714
 36 37 0.005494 0.016165 0.02061
 36 38 0.0018895 0.023751 0.02538
 38 39 0.710 0.01991 0.00280
 38 39 0.710 0.01991 0.00280
```

38	40	0.0022191	0.027912	0.02984
38	49	0.008724	0.025827	0.03261
38	50	0.0014093	0.017702	0.01891
38	52	0.0011283	0.031750	0.04461
38	60	0.0013815	0.038929	0.05479
38	61	0.002983	0.08373	0.01173
39	42	0.007535	0.021139	0.02974
39	42	0.007535	0.021139	0.02974
40	41	0.0027759	0.034794	0.03759
41	42	0.0010822	0.030434	0.04279
41	43	0.007010	0.019686	0.02763
41	44	0.008965	0.025164	0.03543
41	45	0.0024658	0.030882	0.03335
42	43	0.003814	0.010702	0.01501
44	45	0.009086	0.025532	0.03587
45	46	0.016392	0.19049	0.02386
45	46	0.016392	0.19049	0.02386
45	47	0.0040769	0.051563	0.05529
48	49	0.005150	0.15233	0.01921
50	51	0.0030903	0.038953	0.04169
51	52	0.001106	0.03118	0.00433
51	56	0.012591	0.037142	0.04752
51	57	0.011610	0.14579	0.01557
51	58	0.007343	0.020632	0.02894
52	53	0.009337	0.027529	0.03508
52	55	0.0021607	0.046799	0.05556
52	58	0.007898	0.022195	0.03113
52	61	0.008321	0.023387	0.03281
53	54	0.0011082	0.032656	0.04177
53	55	0.005211	0.015345	0.01953
57	58	0.006664	0.08364	0.00893
58	59	0.007404	0.020803	0.02918
58	59	0.007404	0.020803	0.02918
58	59	0.0018921	0.023784	0.02542
62	133	0.001838	0.013351	0.09567
62	133	0.001838	0.013351	0.09567
63	64	0.0017662	0.049874	0.07050
63	64	0.0017662	0.049874	0.07050
63	200	0.0017613	0.049734	0.07030
63	200	0.0017613	0.049734	0.07030
64	65	0.001180	0.02047	0.00214
64	68	0.0021605	0.037616	0.03943
64	74	0.0028970	0.043230	0.04582
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66	69	0.007363	0.020696	0.02901
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67	68	0.016706	0.035834	0.04310
68	69	0.008537	0.014551	0.01580
69	70	0.007686	0.021799	0.03001
69	70	0.007686	0.021799	0.03001
69	71	0.0015591	0.027970	0.03139
69	72	0.0018486	0.031872	0.03400
70	71	0.002321	0.05275	0.00685

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73	74	0.009391	0.016163	0.01721
73	77	0.0012065	0.020573	0.02235
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77	78	0.0015526	0.026493	0.02880
78	79	0.001136	0.02421	0.05292
78	79	0.001136	0.02421	0.05292
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79	80	0.002090	0.05863	0.00822
79	82	0.0016805	0.035939	0.04350
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89	90	0.00971	0.07048	0.05372
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90	91	0.00892	0.06472	0.04110
91	92	0.00808	0.05826	0.02846
91	92	0.00808	0.05826	0.02846
93	94	0.0027505	0.058647	0.00930
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124	125	0.007990	0.023450	0.03037
127	128	0.00545	0.04175	0.08110
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130	158	0.001462	0.010555	0.03455
131	132	0.01832	0.08764	0.07804
131	132	0.01832	0.08764	0.07804
132	133	0.01231	0.08909	0.09622
132	133	0.01231	0.08909	0.09622
132	134	0.001608	0.011664	0.05775
132	134	0.001608	0.011664	0.05775
135	136	0.00261	0.03445	1.81021
137	138	0.0024483	0.032293	0.0434
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139	140	0.0018347	0.024676	0.0318
142	144	0.003332	0.09588	0.01288
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143	144	0.003363	0.09859	0.01275
144	145	0.193	0.00568	0.73
144	146	0.003586	0.010319	0.01387
144	146	0.003586	0.010319	0.01387
144	148	0.002263	0.06636	0.00850
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152	155	0.03854	0.010813	0.01517
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153	154	0.008260	0.024313	0.03105
155	156	0.00593	0.07522	0.07486
159	160	0.00827	0.05970	0.03129
159	160	0.00827	0.05970	0.03129
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168	169	0.002205	0.06615	0.0816
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170	172	0.002683	0.08055	0.0992
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173	174	0.001869	0.06051	0.0781
173	175	0.005747	0.016143	0.02262
173	175	0.005747	0.016143	0.02262
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175	176	0.005687	0.016714	0.02136
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182	183	0.001148	0.03445	0.00425
182	186	0.001342	0.04024	0.00496
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185	194	0.003880	0.011828	0.01413
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190	191	0.001281	0.03841	0.00474
191	192	0.004624	0.013565	0.01739
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194	195	0.333	0.01591	0.00201
194	195	0.333	0.01591	0.00201
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202	205	0.001085	0.07847	0.07282
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1 1.04 0.00 0.00 0.00 0.00 115.00 -30.00
1 1.00 79.03 48.98 0.00 0.00 115.00 -30.00
1 1.00 31.35 19.43 0.00 0.00 115.00 -30.00
1 1.02 82.62 51.21 0.00 0.00 115.00 0.00
2 1.04 49.80 30.87 75.00 0.00 115.00 0.00
1 1.00 28.09 17.41 0.00 0.00 115.00 -20.00
1 1.00 28.31 17.54 0.00 0.00 115.00 -20.00
1 1.00 17.89 11.09 0.00 0.00 115.00 -30.0
1 1.00 17.64 10.93 0.00 0.00 115.00 12.60
1 1.04500 14.65 9.08 0.00 0.00 115.00 -10.00
1 1.00 14.43 8.94 0.00 0.00 115.00 -10.00
1 1.00 12.99 8.05 0.00 0.00 115.00 0.00
1 1.00 30.38 18.82 0.00 0.00 115.00 18.90
1 1.00 55.27 34.26 0.00 0.00 115.00 18.90
1 1.00 37.24 23.08 0.00 0.00 115.00 0.00
1 1.02 0.00 0.00 0.00 0.00 230.00 0.00
1 1.05 0.00 0.00 0.00 0.00 230.00 -30.00
1 1.05 0.00 0.00 0.00 0.00 230.00 120.00
1 1.01500 44.59 27.64 0.00 0.00 115.00 12.60
1 1.00 30.71 19.04 0.00 0.00 115.00 6.30
1 1.00 18.87 11.70 0.00 0.00 115.00 0.00
1 1.00 0.00 0.00 0.00 0.00 115.00 0.00
1 1.00 56.94 35.29 0.00 0.00 115.00 12.60
1 1.00 14.38 8.91 0.00 0.00 115.00 0.00
1 1.00 14.97 9.28 0.00 0.00 115.00 0.00
1 1.00 31.47 19.51 0.00 0.00 115.00 0.00
1 1.00 59.16 36.67 0.00 0.00 115.00 0.00
1 1.00 5.89 3.65 0.00 0.00 115.00 0.00
1 1.00 12.53 7.77 0.00 0.00 115.00 0.00
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1 1.00 17.29 10.72 0.00 0.00 115.00 0.00
2 1.05 9.26 5.74 60.00 0.00 115.00 0.00
1 1.00 41.59 25.78 0.00 0.00 115.00 11.25
1 1.00 12.47 7.73 0.00 0.00 115.00 0.00
1 1.00 36.03 22.33 0.00 0.00 115.00 22.05
1 1.00 14.52 9.00 0.00 0.00 115.00 6.30
2 1.02 0.50 0.31 10.00 0.00 115.00 0.00
3 1.05 74.00 45.86 1820.00 0.00 230.00 0.00
2 1.05 0.00 0.00 100.00 0.00 230.00 0.00
2 1.05 0.00 0.00 200.00 0.00 230.00 0.00
1 1.00 85.14 52.77 0.00 0.00 115.00 6.30
1 1.00 54.94 34.05 0.00 0.00 115.00 9.00
1 1.00 25.26 15.66 0.00 0.00 115.00 0.00
1 1.00 25.35 15.71 0.00 0.00 115.00 0.00
1 1.01 66.90 41.46 0.00 0.00 115.00 6.30
1 1.04 43.81 27.15 0.00 0.00 115.00 0.00
1 1.05 48.54 30.08 0.00 0.00 115.00 -25.00
1 1.00 20.69 12.82 0.00 0.00 115.00 -15.00
1 1.00 11.35 7.04 0.00 0.00 115.00 0.00
1 1.00 22.08 13.68 0.00 0.00 115.00 0.00
2 1.05 0.50 0.31 38.00 0.00 115.00 0.00
1 1.00 0.30 0.19 0.00 0.00 115.00 0.00
1 1.00 13.83 8.57 0.00 0.00 115.00 0.00
1 1.04 13.66 8.46 0.00 0.00 115.00 0.00
1 1.01 17.46 10.82 0.00 0.00 115.00 0.00
1 1.00 26.05 16.14 0.00 0.00 115.00 4.80
2 1.02 0.20 0.12 13.50 0.00 115.00 0.00
1 1.02 16.61 10.30 0.00 0.00 115.00 4.50
1 1.05 15.30 9.48 0.00 0.00 115.00 0.00
1 1.00 3.42 2.12 0.00 0.00 115.00 0.00
1 1.04 0.00 0.00 0.00 0.00 230.00 0.00
1 1.04 0.00 0.00 0.00 0.00 230.00 -120.00
1 1.04 0.00 0.00 0.00 0.00 230.00 -120.00
2 1.05 1.00 0.62 400.00 0.00 230.00 0.00
2 1.05500 1.00 0.62 300.00 0.00 230.00 0.00
1 1.05 0.00 0.00 0.00 0.00 230.00 60.00
2 1.05500 0.00 0.00 0.00 0.00 500.00 -240.00
1 16 0.06580 1.00 0.00 0.00
2 17 0.04240 1.00 0.00 0.00
8 17 0.04290 1.00 0.00 0.00
3 18 0.07960 1.02500 0.00 0.00
3 18 0.07970 1.02500 0.00 0.00
9 18 0.05920 1.00 0.00 0.00
12 19 0.05630 0.98750 0.00 0.00
4 19 0.04240 1.00 0.00 0.00
5 20 0.06520 0.98750 0.00 0.00
5 20 0.06560 0.98750 0.00 0.00
10 20 0.04010 1.00 0.00 0.00
13 20 0.05900 0.98750 0.00 0.00
7 22 0.06180 0.98750 0.00 0.00
7 22 0.06580 0.98750 0.00 0.00
15 22 0.05630 1.00 0.00 0.00
6 21 0.01995 0.98 0.00 0.00
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6 21 0.01970 0.98 0.00 0.00
14 21 0.01082 0.95 0.00 0.00
14 21 0.01057 0.95 0.00 0.00
14 21 0.01082 0.95 0.00 0.00
11 21 0.05860 0.97500 0.00 0.00
38 62 0.05830 1.00 0.00 0.00
38 62 0.05860 1.00 0.00 0.00
24 40 0.04227 1.00 0.00 0.00
27 55 0.02658 0.98750 0.00 0.00
76 89 0.01183 1.01250 0.00 0.00
66 87 0.01182 1.00 0.00 0.00
64 88 0.01240 1.00 0.00 0.00
64 88 0.01240 1.00 0.00 0.00
75 90 0.01183 1.00 0.00 0.00
77 91 0.01183 0.97500 0.00 0.00
79 92 0.01619 0.98750 0.00 0.00
79 92 0.01619 0.98750 0.00 0.00
101 127 0.01596 1.00 0.00 0.00
110 131 0.01457 1.00 0.00 0.00
110 131 0.01440 1.00 0.00 0.00
97 129 0.02175 1.00 0.00 0.00
126 129 0.01146 1.00 0.00 0.00
105 132 0.01270 1.00 0.00 0.00
109 133 0.01185 1.00 0.00 0.00
96 122 0.02658 1.00 0.00 0.00
114 134 0.01183 1.01250 0.00 0.00
114 134 0.01183 1.01250 0.00 0.00
114 134 0.01183 1.01250 0.00 0.00
137 158 0.01601 1.00 0.00 0.00
143 158 0.01469 1.00 0.00 0.00
143 158 0.01510 1.00 0.00 0.00
142 158 0.05630 0.97500 0.00 0.00
152 159 0.05630 0.97500 0.00 0.00
146 160 0.01604 0.95 0.00 0.00
146 160 0.01604 0.95 0.00 0.00
141 150 0.02821 1.00 0.00 0.00
164 179 0.04630 1.00 0.00 0.00
168 180 0.05950 0.97500 0.00 0.00
173 181 0.01617 0.93750 0.00 0.00
173 181 0.01656 0.93750 0.00 0.00
188 202 0.01618 0.98750 0.00 0.00
195 203 0.01619 1.00 0.00 0.00
200 204 0.01230 1.00 0.00 0.00
200 204 0.01230 1.00 0.00 0.00
193 205 0.01197 1.01250 0.00 0.00
201 206 0.01516 1.01250 0.00 0.00
134 135 0.02170 1.00 0.00 0.00
130 136 0.02170 0.97500 0.00 0.00
43 207 0.01617 0.95 0.00 0.00
43 207 0.01617 0.95 0.00 0.00
23 208 0.01027 1.01250 0.00 0.00
23 208 0.01027 1.01250 0.00 0.00
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**** OUT PUT ****

BUS NO.	VOLT PU.	VOLT KV	ANGLE (DEGREE)	GENERATION MW	GENERATION MVAR	DEMAND MW	DEMAND MVAR	SHUNT MVAR
1	0.9505	65.58	-11.7004	0.00	0.00	256.54	125.34	18.07
2	1.0036	69.25	-5.7279	0.00	0.00	149.88	72.59	0.00
3	0.9933	68.54	-5.2234	0.00	0.00	136.77	66.24	29.60
4	1.0265	70.83	-3.8386	0.00	0.00	120.87	58.54	36.67
5	1.0106	69.73	-5.3668	0.00	0.00	305.01	147.72	30.64
6	1.0258	70.78	-1.3765	0.00	0.00	136.88	66.29	21.04
7	1.0179	70.23	-5.6221	0.00	0.00	241.75	117.09	20.72
8	1.0168	70.16	-5.7235	0.00	0.00	149.88	72.59	31.01
9	1.0044	69.30	-6.5778	0.00	0.00	136.77	66.24	20.18
10	1.0173	70.19	-3.3038	0.00	0.00	152.50	73.86	20.70
11	1.0119	69.82	-5.0313	0.00	0.00	136.88	66.29	30.72
12	1.0168	116.93	-4.5776	0.00	0.00	115.74	56.05	0.00
13	1.0346	118.98	-3.8635	0.00	0.00	124.76	60.42	32.11
14	1.0400	119.60	-0.8148	0.00	-563.22	0.00	0.00	0.00
15	1.0043	115.50	-6.7327	0.00	0.00	169.10	81.90	30.26
16	1.0400	239.20	-1.8680	225.00	478.98	0.00	0.00	0.00
17	1.0362	238.34	-2.2247	0.00	0.00	0.00	0.00	128.86
18	1.0347	237.98	-2.1094	0.00	0.00	339.16	164.26	128.47
19	1.0367	238.44	-1.0781	0.00	0.00	0.00	0.00	0.00
20	1.0400	239.20	0.0099	1200.00	652.07	65.00	40.30	0.00
21	1.0096	232.22	-0.6409	0.00	0.00	0.00	0.00	0.00
22	1.0376	238.66	-1.4914	0.00	0.00	0.00	0.00	64.60
23	1.0437	240.05	-0.6367	0.00	0.00	0.00	0.00	0.00
24	1.0368	68.43	-0.6253	0.00	0.00	0.00	0.00	-10.75
25	1.0343	68.27	-0.9386	0.00	0.00	11.92	7.39	3.37

26	1.0350	68.31	-0.8211	5.00	-46.75	1.81	1.12	0.00
27	1.0482	69.18	-0.9038	0.00	0.00	0.00	0.00	0.00
28	1.0480	69.17	-1.1111	0.00	0.00	5.73	3.55	3.46
29	1.0508	69.35	-1.3468	0.00	0.00	10.55	6.54	10.43
30	1.0506	120.82	-1.3100	0.00	0.00	17.70	10.97	13.91
31	1.0487	120.61	-1.2337	0.00	0.00	20.56	12.74	0.00
32	1.0517	120.94	-1.3354	0.00	0.00	43.09	26.71	59.72
33	1.0500	120.75	-1.1633	40.00	29.32	41.44	25.56	0.00
34	1.0494	120.68	-1.2349	0.00	0.00	25.21	15.62	47.52
35	1.0440	120.06	-0.8542	0.00	0.00	26.15	16.20	16.84
36	1.0489	120.63	-1.0341	0.00	0.00	24.89	15.42	6.93
37	1.0476	120.47	-1.1718	0.00	0.00	17.23	10.68	6.91
38	1.0505	120.81	-0.4347	0.00	0.00	39.02	24.18	88.28
39	1.0464	120.34	-0.3344	0.00	0.00	10.43	6.47	32.85
40	1.0420	119.82	-0.4382	0.00	0.00	23.00	14.25	10.26
41	1.0366	119.21	0.1167	0.00	0.00	23.32	14.45	45.18
42	1.0400	119.60	-0.0315	30.00	-127.58	19.39	12.02	0.00
43	1.0478	120.49	-0.1255	0.00	0.00	22.01	13.64	-21.96
44	1.0250	117.88	0.5962	120.00	-217.81	26.45	16.40	0.00
45	1.0330	118.79	0.3842	0.00	0.00	40.02	24.80	37.67
46	1.0500	120.75	4.1558	80.00	14.42	3.83	2.37	0.00
47	1.0352	119.05	0.0332	0.00	0.00	12.27	7.60	10.13
48	1.0500	120.75	0.3033	40.00	-2.53	0.59	0.37	0.00
49	1.0473	120.44	-0.5431	0.00	0.00	21.91	13.58	0.00
50	1.0500	120.75	-0.1808	14.00	-7.79	0.50	0.31	0.00
51	1.0498	120.73	-0.4848	0.00	0.00	31.14	19.30	22.04
52	1.0503	120.79	-0.1498	0.00	0.00	25.48	15.79	44.13
53	1.0468	120.39	-0.5954	0.00	0.00	14.12	8.75	6.90
54	1.0462	120.31	-0.7078	0.00	0.00	6.64	4.11	0.00
55	1.0457	120.26	-0.6738	0.00	0.00	16.22	10.05	35.65
56	1.0479	120.50	-0.9419	0.00	0.00	22.86	14.17	13.83
57	1.0472	120.42	-0.8016	0.00	0.00	18.22	11.29	6.91
58	1.0493	120.67	-0.1993	0.00	0.00	25.65	15.90	0.00
59	1.0500	120.75	0.0232	58.00	-8.61	1.00	0.62	0.00
60	1.0506	120.82	-0.9951	0.00	0.00	4.75	2.94	-3.31

61	1.0550	121.32	1.4390	200.00	1.38	32.71	20.20	0.00
62	1.0500	241.50	0.3486	100.00	33.87	0.00	0.00	0.00
63	1.0400	119.60	4.3669	0.00	12.05	23.02	14.27	0.00
64	1.0400	119.60	4.9407	30.00	-173.24	3.50	1.10	0.00
65	1.0355	119.09	4.5905	0.00	0.00	33.35	20.67	0.00
66	1.0495	120.69	6.1483	0.00	0.00	1.37	0.85	0.00
67	1.0374	119.30	5.2130	0.00	0.00	13.03	8.08	0.00
68	1.0415	119.77	5.4095	0.00	0.00	5.24	3.24	0.00
69	1.0459	120.28	5.7015	0.00	0.00	4.81	2.98	0.00
70	1.0434	119.99	5.5572	0.00	0.00	29.16	18.07	0.00
71	1.0439	120.05	5.5347	0.00	0.00	12.50	7.74	0.00
72	1.0500	120.75	5.7530	80.00	-5.08	11.14	6.91	0.00
73	1.0460	120.29	4.6309	0.00	0.00	24.74	15.33	14.33
74	1.0415	119.78	4.6983	0.00	0.00	30.32	18.79	0.00
75	1.0408	119.70	4.7287	0.00	0.00	35.74	22.15	0.00
76	1.0450	120.17	6.4746	0.00	0.00	14.77	9.15	0.00
77	1.0546	121.28	4.2512	75.00	79.69	16.03	9.93	0.00
78	1.0400	119.60	3.3203	0.00	0.00	45.37	27.26	0.00
79	1.0487	120.60	2.8266	60.00	-110.05	14.12	8.75	0.00
80	1.0397	119.57	1.7699	0.00	0.00	34.81	21.58	0.00
81	1.0388	119.46	3.2003	0.00	0.00	10.99	6.81	6.81
82	1.0306	118.52	2.4763	0.00	0.00	24.37	15.11	3.40
83	1.0282	118.24	2.2630	0.00	0.00	22.45	13.91	12.43
84	1.0279	118.21	2.3240	0.00	0.00	28.58	17.71	9.99
85	1.0300	118.45	2.7058	0.00	0.00	5.17	3.20	3.33
86	1.0550	121.32	2.9764	60.00	-35.86	10.24	6.35	0.00
87	1.0500	241.50	6.6794	45.00	43.54	1.00	0.62	0.00
88	1.0500	241.50	5.0942	250.00	-23.59	0.00	0.00	0.00
89	1.0500	241.50	6.0979	100.00	340.39	3.50	2.17	0.00
90	1.0427	239.83	4.9711	75.00	-70.96	0.00	0.00	0.00
91	1.0400	239.20	4.5744	0.00	0.00	0.00	0.00	0.00
92	1.0438	240.07	2.6643	150.00	68.00	0.00	0.00	0.00
93	1.0289	71.00	-3.2588	0.00	0.00	0.00	0.00	0.00
94	1.0287	70.98	-3.2581	0.00	0.00	9.50	5.89	0.00
95	1.0299	71.06	-3.2040	0.00	0.00	9.50	5.89	0.00

96	1.0405	71.79	-2.2410	0.00	0.00	11.40	7.07	0.00
97	1.0415	71.86	0.6331	0.00	0.00	0.00	0.00	0.00
98	1.0320	71.21	-0.2295	0.00	0.00	23.82	14.76	0.00
99	1.0106	69.73	-1.7032	0.00	0.00	9.02	5.59	0.00
100	1.0150	70.03	-1.5028	0.00	0.00	7.67	4.75	0.00
101	1.0473	120.44	1.3067	0.00	0.00	1.02	0.63	0.00
102	1.0439	120.05	1.3617	0.00	0.00	15.34	9.51	0.00
103	1.0411	119.73	1.2199	0.00	0.00	18.15	11.25	0.00
104	1.0444	120.11	1.7910	0.00	0.00	18.42	11.42	0.00
105	1.0459	120.28	1.6472	0.00	0.00	4.14	2.57	0.00
106	1.0461	120.30	1.3157	0.00	0.00	35.54	22.03	10.29
107	1.0442	120.09	0.9479	0.00	0.00	26.36	16.34	6.87
108	1.0447	120.15	0.5718	0.00	0.00	17.47	10.83	0.00
109	1.0471	120.42	0.4815	0.00	0.00	8.87	5.50	0.00
110	1.0503	120.78	3.4927	0.00	0.00	1.50	0.93	0.00
111	1.0452	120.20	2.6215	0.00	0.00	23.23	14.40	0.00
112	1.0419	119.82	2.0936	0.00	0.00	23.89	14.81	0.00
113	1.0414	119.76	1.8158	0.00	0.00	16.40	10.17	6.83
114	1.0429	119.93	1.9253	0.00	0.00	0.00	0.00	0.00
115	1.0500	120.75	1.1347	150.00	190.46	71.38	44.24	0.00
116	1.0481	120.53	-0.2873	0.00	0.00	24.24	15.02	17.30
117	1.0474	120.46	-0.9761	0.00	0.00	50.23	31.13	44.11
118	1.0424	119.88	-0.0051	0.00	0.00	16.33	10.12	0.00
119	1.0423	119.86	-0.3205	0.00	0.00	19.79	12.26	21.73
120	1.0412	119.73	-0.3809	0.00	0.00	8.97	5.56	0.00
121	1.0398	119.58	-0.9048	0.00	0.00	24.43	15.14	10.22
122	1.0451	120.18	-1.8149	0.00	0.00	45.60	28.26	56.96
123	1.0500	120.75	1.8238	80.00	8.69	7.58	4.70	0.00
124	1.0476	120.47	1.1910	0.00	0.00	4.10	2.54	0.00
125	1.0482	120.55	1.0961	0.00	0.00	17.46	10.82	0.00
126	1.0412	119.74	0.7371	0.00	0.00	51.31	31.80	0.00
127	1.0500	241.50	1.4073	400.00	273.15	1.00	0.62	0.00
128	1.0439	240.11	0.9508	0.00	0.00	37.76	23.40	0.00
129	1.0447	240.29	1.0468	0.00	0.00	0.00	0.00	65.49
130	1.0300	236.90	-0.1729	0.00	-190.95	0.00	0.00	0.00

131	1.0500	241.50	4.2075	300.00	-26.19	1.00	0.62	0.00
132	1.0478	241.00	1.6465	0.00	0.00	0.00	0.00	0.00
133	1.0496	241.41	0.5059	0.00	0.00	0.00	0.00	0.00
134	1.0500	241.50	2.1351	450.00	33.03	40.00	24.80	0.00
135	1.0400	520.00	2.0286	300.00	-373.56	20.00	12.40	0.00
136	1.0326	516.32	0.6109	0.00	0.00	0.00	0.00	-426.53
137	1.0311	71.14	-0.6056	0.00	0.00	7.67	4.75	0.00
138	1.0318	71.19	-0.6086	0.00	0.00	0.00	0.00	0.00
139	1.0318	71.20	-0.6199	0.00	0.00	0.00	0.00	0.00
140	1.0317	71.18	-0.6295	0.00	0.00	2.38	1.47	0.00
141	1.0097	69.67	-1.5974	0.00	0.00	0.00	0.00	-20.39
142	1.0236	117.72	-1.5245	0.00	0.00	0.00	0.00	-31.43
143	1.0280	118.22	-0.5780	0.00	0.00	0.00	0.00	-31.71
144	1.0354	119.07	-1.3728	0.00	0.00	79.03	48.98	-32.16
145	1.0325	118.74	-1.4630	0.00	0.00	31.35	19.43	-31.98
146	1.0501	120.76	-1.1670	0.00	0.00	82.62	51.21	0.00
147	1.0400	119.60	-0.9109	75.00	-29.54	49.80	30.87	0.00
148	1.0100	116.15	-2.3478	0.00	0.00	28.09	17.41	-20.40
149	1.0091	116.05	-2.3066	0.00	0.00	28.31	17.54	-20.37
150	1.0138	116.59	-1.5267	0.00	0.00	17.89	11.09	-30.84
151	1.0149	116.71	-2.4911	0.00	0.00	17.64	10.93	12.98
152	1.0216	117.48	-5.6303	0.00	0.00	14.65	9.08	-10.44
153	1.0196	117.26	-5.6951	0.00	0.00	14.43	8.94	-10.40
154	1.0170	116.96	-5.8402	0.00	0.00	12.99	8.05	0.00
155	1.0165	116.90	-6.0425	0.00	0.00	30.38	18.82	19.53
156	1.0140	116.61	-6.4463	0.00	0.00	55.27	34.26	19.43
157	1.0165	116.89	-5.8260	0.00	0.00	37.24	23.08	0.00
158	1.0297	236.83	-0.5188	0.00	0.00	0.00	0.00	0.00
159	1.0257	235.91	-0.6517	0.00	0.00	0.00	0.00	-31.56
160	1.0225	235.18	-0.1829	0.00	0.00	0.00	0.00	125.46
161	1.0186	117.14	-5.6936	0.00	0.00	44.59	27.64	13.07
162	1.0109	116.26	-6.2221	0.00	0.00	30.71	19.04	6.44
163	1.0055	115.64	-6.5226	0.00	0.00	18.87	11.70	0.00
164	1.0367	119.22	-2.9721	0.00	0.00	0.00	0.00	0.00
165	1.0352	119.05	-4.0992	0.00	0.00	56.94	35.29	13.50

166	1.0433	119.98	-3.0863	0.00	0.00	14.38	8.91	0.00	
167	1.0381	119.38	-3.8600	0.00	0.00	14.97	9.28	0.00	
168	1.0458	120.27	-2.6462	0.00	0.00	31.47	19.51	0.00	
169	1.0325	118.73	-3.3142	0.00	0.00	59.16	36.67	0.00	
170	1.0385	119.43	-1.9734	0.00	0.00	5.89	3.65	0.00	
171	1.0366	119.21	-2.1938	0.00	0.00	12.53	7.77	0.00	
172	1.0460	120.29	0.4788	0.00	0.00	17.29	10.72	0.00	
173	1.0500	120.75	1.0001	60.00	-851.61	9.26	5.74	0.00	
174	1.0447	120.14	0.5108	0.00	0.00	41.59	25.78	12.28	
175	1.0458	120.27	0.7030	0.00	0.00	12.47	7.73	0.00	
176	1.0400	119.60	0.4076	0.00	0.00	36.03	22.33	23.85	
177	1.0390	119.48	0.2693	0.00	0.00	14.52	9.00	6.80	
178	1.0200	117.30	0.8250	10.00	-33.28	0.50	0.31	0.00	
179	1.0500	241.50	0.0000	253.13	250.60	74.00	45.86	0.00	
180	1.0500	241.50	0.6924	100.00	43.67	0.00	0.00	0.00	
181	1.0500	241.50	1.4792	200.00	939.17	0.00	0.00	0.00	
182	1.0231	117.66	-1.6530	0.00	0.00	85.14	52.77	6.59	
183	1.0129	116.48	-1.9442	0.00	0.00	54.94	34.05	9.23	
184	1.0116	116.34	-1.1976	0.00	0.00	25.26	15.66	0.00	
185	1.0219	117.51	1.4232	0.00	0.00	25.35	15.71	0.00	
186	1.0151	116.74	-1.4658	0.00	0.00	66.90	41.46	6.49	
187	1.0295	118.39	1.7186	0.00	0.00	43.81	27.15	0.00	
188	1.0409	119.71	2.5280	0.00	0.00	48.54	30.08	-27.09	
189	1.0225	117.59	1.8363	0.00	0.00	20.69	12.82	-15.68	
190	1.0419	119.82	3.8394	0.00	0.00	11.35	7.04	0.00	
191	1.0449	120.16	4.5666	0.00	0.00	22.08	13.68	0.00	
192	1.0500	120.75	4.9323	38.00	32.75	0.50	0.31	0.00	
193	1.0386	119.44	5.9540	0.00	0.00	0.30	0.19	0.00	
194	1.0285	118.28	1.9406	0.00	0.00	13.83	8.57	0.00	
195	1.0301	118.46	2.5184	0.00	0.00	13.66	8.46	0.00	
196	1.0277	118.18	2.5712	0.00	0.00	17.46	10.82	0.00	
197	1.0224	117.57	3.5444	0.00	0.00	26.05	16.14	5.02	
198	1.0200	117.30	3.7169	13.50	-26.16	0.20	0.12	0.00	
199	1.0285	118.27	3.7325	0.00	0.00	16.61	10.30	4.76	
200	1.0371	119.27	4.1032	0.00	0.00	15.30	9.48	0.00	

201	1.0417	119.79	4.6882	0.00	0.00	3.42	2.12	0.00
202	1.0394	239.07	3.0871	0.00	0.00	0.00	0.00	0.00
203	1.0367	238.45	3.7997	0.00	0.00	0.00	0.00	-128.98
204	1.0384	238.84	4.2437	0.00	0.00	0.00	0.00	-129.40
205	1.0500	241.50	6.0894	400.00	-0.22	1.00	0.62	0.00
206	1.0550	242.65	4.7156	300.00	230.57	1.00	0.62	0.00
207	1.0076	231.75	-0.0028	0.00	0.00	0.00	0.00	60.91
208	1.0550	527.50	-0.0445	0.00	184.67	0.00	0.00	-267.13

**** LINE FLOW ****

LINE NO.	FROM BUS P	TO BUS Q	FLOW FROM P MW	FLOW FROM P MVAR	FLOW TO Q MW	FLOW TO Q MVAR	LOSS MW	LOSS MVAR
1	14	182	48.521	50.690	-48.461	-49.605	0.059	1.529
2	14	182	45.275	47.712	-45.226	-46.745	0.049	1.434
3	16	17	141.513	57.792	-141.361	-57.898	0.152	1.090
4	16	21	-125.536	234.781	126.754	-228.015	1.217	9.560
5	16	22	-47.509	22.809	47.560	-25.762	0.051	0.368
6	17	18	-25.373	24.003	25.386	-25.681	0.012	0.088
7	17	18	-25.373	24.003	25.386	-25.681	0.012	0.088
8	17	22	-107.659	2.868	107.850	-4.512	0.191	1.374
9	18	19	-130.413	3.619	130.739	-4.764	0.326	2.342
10	18	19	-130.413	3.619	130.739	-4.764	0.326	2.342
11	18	23	-201.325	-47.343	201.857	46.732	0.532	5.588
12	18	23	-201.325	-47.343	201.857	46.732	0.532	5.588
13	19	20	-179.720	-4.651	180.198	5.365	0.478	3.433
14	19	20	-179.720	-4.651	180.198	5.365	0.478	3.433
15	19	179	-69.323	-37.087	69.565	31.219	0.242	1.743
16	19	179	-69.323	-37.087	69.565	31.219	0.242	1.743
17	20	21	96.169	174.599	-95.302	-172.236	0.867	6.228
18	20	21	96.169	174.599	-95.302	-172.236	0.867	6.228
19	21	159	-2.813	-40.522	2.862	3.596	0.049	0.352
20	21	202	-300.899	-157.619	302.644	55.303	1.745	22.792
21	22	23	-78.993	-26.406	79.118	18.437	0.125	1.310
22	22	23	-78.993	-26.406	79.118	18.437	0.125	1.310
23	22	158	-30.583	-2.970	30.676	-41.283	0.093	0.668
24	22	158	-30.583	-2.970	30.676	-41.283	0.093	0.668
25	22	159	-19.927	2.159	20.001	-39.070	0.074	0.534
26	22	202	-327.183	-34.800	328.764	-60.180	1.581	26.200

:	27:	23:	179:	-57.110:	-28.903:	57.185:	19.756:	0.074:	0.782:
:	28:	23:	179:	-57.110:	-28.903:	57.185:	19.756:	0.074:	0.782:
:	29:	23:	179:	-57.296:	-28.979:	57.371:	19.799:	0.075:	0.785:
:	30:	23:	179:	-57.296:	-28.979:	57.371:	19.799:	0.075:	0.785:
:	31:	24:	25:	8.343:	1.951:	-8.337:	-2.922:	0.006:	0.051:
:	32:	25:	26:	-3.583:	-1.097:	3.584:	0.227:	0.001:	0.008:
:	33:	26:	27:	-0.394:	-48.093:	0.469:	48.298:	0.075:	0.610:
:	34:	27:	28:	5.733:	-0.878:	-5.730:	-0.090:	0.003:	0.021:
:	35:	27:	29:	10.558:	-5.069:	-10.550:	3.895:	0.008:	0.093:
:	36:	30:	32:	0.374:	-6.525:	-0.372:	4.400:	0.002:	0.006:
:	37:	30:	146:	-18.050:	9.453:	18.067:	-11.522:	0.017:	0.050:
:	38:	31:	33:	-14.398:	-7.557:	14.407:	5.922:	0.009:	0.026:
:	39:	31:	146:	-6.162:	-5.182:	6.166:	1.406:	0.004:	0.011:
:	40:	32:	33:	-9.505:	5.228:	9.506:	-5.699:	0.001:	0.037:
:	41:	32:	38:	-27.537:	7.992:	27.695:	-16.058:	0.158:	0.448:
:	42:	33:	34:	4.177:	-0.633:	-4.177:	-3.883:	0.000:	0.006:
:	43:	33:	36:	-6.623:	1.586:	6.625:	-5.797:	0.001:	0.019:
:	44:	33:	60:	-22.908:	2.580:	22.931:	-4.583:	0.023:	0.065:
:	45:	34:	35:	-26.742:	52.211:	26.955:	-53.637:	0.213:	0.452:
:	46:	36:	37:	17.245:	1.546:	-17.230:	-3.766:	0.015:	0.045:
:	47:	36:	38:	-48.760:	-4.237:	48.801:	1.955:	0.041:	0.515:
:	48:	38:	39:	-8.883:	21.765:	8.886:	-21.972:	0.004:	0.101:
:	49:	38:	39:	-8.883:	21.765:	8.886:	-21.972:	0.004:	0.101:
:	50:	38:	40:	2.779:	30.284:	-2.759:	-33.291:	0.021:	0.260:
:	51:	38:	49:	11.216:	7.551:	-11.199:	-11.088:	0.017:	0.050:
:	52:	38:	50:	-27.203:	4.123:	27.213:	-6.086:	0.010:	0.123:
:	53:	38:	52:	-17.234:	-1.264:	17.237:	-3.573:	0.003:	0.086:
:	54:	38:	60:	27.691:	-4.109:	-27.681:	-1.667:	0.010:	0.271:
:	55:	38:	61:	-43.399:	-4.045:	43.450:	4.183:	0.051:	1.438:
:	56:	39:	42:	-14.101:	35.163:	14.208:	-38.100:	0.107:	0.300:
:	57:	39:	42:	-14.101:	35,163:	14.208:	-38.100:	0.107:	0.300:
:	58:	40:	41:	-28.585:	16.510:	28.615:	-20.198:	0.030:	0.372:
:	59:	41:	42:	8.738:	-14.286:	-8.736:	9.736:	0.002:	0.062:
:	60:	41:	43:	2.065:	-61.186:	-1.832:	58.839:	0.233:	0.654:
:	61:	41:	44:	-16.244:	51.683:	16.506:	-54.714:	0.262:	0.734:

62	41	45	-15.124	11.517	15.134	-14.971	0.009	0.117
63	42	43	-9.071	-73.132	9.258	72.022	0.187	0.526
64	44	45	3.518	-35.120	-3.421	31.594	0.097	0.271
65	45	46	-37.861	-6.014	38.085	6.025	0.224	2.599
66	45	46	-37.861	-6.014	38.085	6.025	0.224	2.599
67	45	47	12.277	-8.352	-12.270	2.527	0.007	0.087
68	48	49	10.717	0.541	-10.711	-2.492	0.005	0.162
69	50	51	14.962	-2.986	-14.955	-1.530	0.006	0.079
70	51	52	-20.706	-1.133	20.710	0.777	0.004	0.122
71	51	56	22.921	-4.714	-22.860	-0.335	0.061	0.179
72	51	57	4.296	0.738	-4.294	-2.422	0.002	0.028
73	51	58	-22.696	9.381	22.738	-12.450	0.042	0.119
74	52	53	31.946	0.675	-31.859	-4.275	0.087	0.256
75	52	55	21.899	6.397	-21.887	-12.259	0.011	0.241
76	52	58	5.388	1.376	-5.385	-4.799	0.003	0.008
77	52	61	-122.660	22.686	123.840	-23.005	1.180	3.317
78	53	54	6.640	-0.450	-6.640	-4.110	0.000	0.014
79	53	55	11.099	2.880	-11.092	-4.998	0.007	0.019
80	57	58	-13.926	-1.960	13.938	1.128	0.012	0.150
81	58	59	-19.405	1.673	19.431	-4.815	0.026	0.073
82	58	59	-19.405	1.673	19.431	-4.815	0.026	0.073
83	58	59	-18.132	-3.129	18.137	0.400	0.006	0.072
84	62	133	-21.817	0.807	21.826	-11.288	0.009	0.062
85	62	133	-21.817	0.807	21.826	-11.288	0.009	0.062
86	63	64	-21.690	-2.936	21.698	-4.472	0.008	0.217
87	63	64	-21.690	-2.936	21.698	-4.472	0.008	0.217
88	63	200	10.180	1.823	-10.178	-9.344	0.002	0.062
89	63	200	10.180	1.823	-10.178	-9.344	0.002	0.062
90	64	65	33.367	20.733	-33.350	-20.670	0.017	0.293
91	64	68	-23.713	-4.813	23.724	0.741	0.011	0.198
92	64	74	10.313	-6.820	-10.309	1.907	0.003	0.050
93	64	74	10.313	-6.820	-10.309	1.907	0.003	0.050
94	66	69	42.526	1.687	-42.404	-4.530	0.122	0.342
95	66	69	42.526	1.687	-42.404	-4.530	0.122	0.342
96	67	68	-13.030	-8.080	13.062	3.491	0.032	0.068

97	68	69	-42.027	-7.472	42.169	5.993	0.142	0.243
98	69	70	14.981	5.096	-14.962	-8.317	0.019	0.054
99	69	70	14.981	5.096	-14.962	-8.317	0.019	0.054
100	69	71	11.739	5.052	-11.736	-8.432	0.003	0.047
101	69	72	-3.871	-15.154	3.874	11.476	0.003	0.056
102	70	71	0.764	-1.437	-0.764	0.692	0.000	0.001
103	72	73	64.986	-23.468	-64.301	21.406	0.685	1.181
104	73	74	6.689	24.213	-6.631	-25.988	0.058	0.100
105	73	77	32.874	-46.616	-32.839	44.741	0.035	0.591
106	74	75	-3.074	3.373	3.074	-5.402	0.000	0.005
107	77	78	70.451	52.875	-70.340	-54.145	0.111	1.889
108	78	79	36.986	-41.789	-36.956	36.663	0.030	0.645
109	78	79	36.986	-41.789	-36.956	36.663	0.030	0.645
110	78	81	10.999	0.419	-10.990	-3.411	0.009	0.025
111	79	80	34.837	14.642	-34.810	-14.769	0.027	0.768
112	79	82	20.817	49.530	-20.769	-53.209	0.048	1.023
113	79	86	-34.652	-38.762	34.761	37.188	0.109	0.318
114	82	83	22.492	1.628	-22.450	-3.920	0.042	0.090
115	82	84	28.618	12.905	-28.580	-14.382	0.038	0.111
116	82	85	-27.356	17.994	27.415	-19.528	0.060	0.120
117	82	85	-27.356	17.994	27.415	-19.528	0.060	0.120
118	87	88	81.290	-14.619	-80.978	7.908	0.312	2.245
119	87	88	81.290	-14.619	-80.978	7.908	0.312	2.245
120	88	89	-34.297	3.903	34.381	-5.579	0.083	0.602
121	88	89	-34.297	3.903	34.381	-5.579	0.083	0.602
122	89	90	31.484	3.816	-31.393	-9.035	0.091	0.663
123	89	90	31.484	3.816	-31.393	-9.035	0.091	0.663
124	90	91	11.987	0.569	-11.975	-4.936	0.012	0.090
125	90	91	11.987	0.569	-11.975	-4.936	0.012	0.090
126	91	92	60.153	-15.605	-59.868	14.571	0.285	2.056
127	91	92	60.153	-15.605	-59.868	14.571	0.285	2.056
128	93	94	0.000	0.000	0.000	-0.984	0.000	0.000
129	94	95	-9.499	-4.906	9.506	4.689	0.007	0.015
130	95	96	-19.006	-10.579	19.021	10.848	0.014	0.429
131	97	98	36.119	15.300	-36.065	-21.329	0.054	0.711

132	98	100	12.245	6.568	-12.214	-8.984	0.030	0.402
133	99	100	-4.542	-5.377	4.544	4.234	0.003	0.037
134	99	141	-4.478	-0.213	4.479	-5.521	0.001	0.011
135	101	102	0.882	23.776	-0.856	-25.657	0.027	0.078
136	101	124	10.204	-6.588	-10.196	3.989	0.008	0.022
137	102	103	18.175	8.790	-18.150	-11.251	0.025	0.072
138	102	104	-32.658	7.360	32.740	-10.326	0.082	0.241
139	104	105	16.563	-19.235	-16.540	17.617	0.023	0.067
140	104	111	-67.723	18.140	68.052	-20.154	0.329	0.969
141	105	106	12.284	-4.344	-12.282	-2.806	0.002	0.071
142	106	107	48.932	-3.594	-48.828	1.950	0.105	0.309
143	106	123	-72.192	-5.345	72.421	3.988	0.229	0.659
144	107	108	22.467	-11.420	-22.416	7.702	0.052	0.152
145	108	109	4.946	-18.534	-4.929	16.367	0.016	0.048
146	110	111	94.233	-3.206	-93.739	2.009	0.494	1.417
147	110	111	94.233	-3.206	-93.739	2.009	0.494	1.417
148	111	112	56.424	-1.764	-56.239	-0.436	0.184	0.517
149	111	114	39.771	3.498	-39.754	-8.148	0.018	0.496
150	112	113	16.403	-1.044	-16.400	-3.338	0.003	0.080
151	112	114	15.946	-13.328	-15.926	10.981	0.021	0.058
152	114	115	78.052	-79.193	-77.476	80.588	0.576	1.614
153	114	115	78.052	-79.193	-77.476	80.588	0.576	1.614
154	115	116	75.294	-20.917	-74.673	18.009	0.621	1.825
155	115	118	42.250	0.304	-41.951	-0.259	0.299	0.840
156	115	119	104.651	-6.861	-103.725	5.453	0.926	2.601
157	115	125	11.379	12.515	-11.369	-14.028	0.010	0.030
158	116	117	50.432	-15.728	-50.230	12.975	0.203	0.596
159	118	119	25.621	-9.861	-25.571	6.808	0.050	0.140
160	119	120	8.975	3.448	-8.970	-5.560	0.005	0.014
161	119	121	24.439	4.490	-24.430	-4.922	0.009	0.260
162	119	122	38.046	-5.367	-38.010	5.239	0.036	1.006
163	119	122	38.046	-5.367	-38.010	5.239	0.036	1.006
164	124	125	6.096	-6.530	-6.092	3.208	0.004	0.013
165	127	128	22.534	7.892	-22.501	-16.532	0.033	0.250
166	127	129	48.160	26.218	-48.099	-31.239	0.062	0.448

167	127	129	48.160	26.218	-48.099	-31.239	0.062	0.448	
168	128	129	-15.259	-6.870	15.263	2.149	0.004	0.029	
169	129	130	70.674	30.860	-70.398	-37.154	0.276	1.985	
170	129	130	70.674	30.860	-70.398	-37.154	0.276	1.985	
171	129	132	-111.465	-8.010	111.714	7.882	0.249	1.192	
172	129	132	-111.465	-8.010	111.714	7.882	0.249	1.192	
173	129	159	37.562	16.141	-37.366	-17.021	0.197	1.416	
174	129	159	37.562	16.141	-37.366	-17.021	0.197	1.416	
175	130	158	59.951	-6.934	-59.901	3.630	0.050	0.360	
176	130	158	59.951	-6.934	-59.901	3.630	0.050	0.360	
177	131	132	54.518	-11.850	-54.015	5.672	0.503	2.408	
178	131	132	54.518	-11.850	-54.015	5.672	0.503	2.408	
179	132	133	23.863	-10.426	-23.796	-0.327	0.067	0.484	
180	132	133	23.863	-10.426	-23.796	0.327	0.067	0.484	
181	132	134	-81.523	-11.040	81.621	5.399	0.098	0.713	
182	132	134	-81.523	-11.040	81.621	5.399	0.098	0.713	
183	135	136	78.434	-80.647	-78.278	-111.710	0.156	2.054	
184	137	138	0.000	-4.615	0.000	0.000	0.000	0.002	
185	137	139	0.772	-4.859	-0.772	1.053	0.000	0.002	
186	139	140	0.772	-1.054	-0.772	-2.331	0.000	0.000	
187	142	144	-3.356	-13.089	3.362	11.876	0.005	0.151	
188	142	144	-3.356	-13.089	3.362	11.876	0.005	0.151	
189	142	150	40.417	53.479	-40.032	-54.182	0.385	0.519	
190	143	144	14.702	-8.726	-14.693	7.631	0.009	0.262	
191	144	145	31.357	51.524	-31.350	-51.409	0.007	0.193	
192	144	146	-79.486	-120.550	80.178	121.031	0.692	1.990	
193	144	146	-79.486	-120.550	80.178	121.031	0.692	1.990	
194	144	148	28.139	38.346	-28.090	-37.813	0.048	1.422	
195	144	149	28.414	38.707	-28.310	-37.906	0.104	1.446	
196	146	147	-25.176	58.560	25.200	-60.412	0.023	0.686	
197	150	151	17.662	-2.678	-17.640	2.048	0.022	0.300	
198	152	153	13.732	10.373	-13.719	-12.108	0.013	0.037	
199	152	153	13.732	10.373	-13.719	-12.108	0.013	0.037	
200	152	155	17.456	-15.276	-17.266	13.754	0.190	0.053	
201	152	157	45.619	16.383	-45.449	-17.262	0.170	0.240	

202	153	154	13.007	4.879	-12.990	-8.050	0.017	0.049
203	155	156	9.870	-1.197	-9.864	-6.444	0.006	0.076
204	159	160	-13.353	5.732	13.371	-8.881	0.018	0.132
205	159	160	-13.353	5.732	13.371	-8.881	0.018	0.132
206	161	162	49.832	17.840	-49.632	-20.019	0.200	0.601
207	161	164	-94.422	-32.406	94.590	30.459	0.168	5.044
208	162	163	18.921	7.418	-18.870	-11.700	0.051	0.150
209	164	165	27.308	-3.799	-27.290	-5.911	0.018	0.539
210	165	166	-29.650	-15.876	29.671	7.798	0.021	0.617
211	166	167	14.978	0.561	-14.970	-9.280	0.008	0.227
212	166	168	-59.028	-17.269	59.045	15.831	0.016	0.494
213	168	169	19.718	16.116	-19.702	-24.436	0.016	0.491
214	169	170	-39.458	-12.234	39.491	4.737	0.032	0.974
215	170	171	12.532	3.371	-12.530	-7.770	0.002	0.059
216	170	172	-57.913	-11.758	57.997	3.518	0.084	2.535
217	172	173	-75.287	-14.237	75.455	12.701	0.168	0.738
218	173	174	15.753	4.475	-15.747	-12.864	0.006	0.179
219	173	175	39.866	11.675	-39.774	-13.902	0.092	0.257
220	173	175	39.866	11.675	-39.774	-13.902	0.092	0.257
221	174	175	-25.843	-0.638	25.872	-1.247	0.029	0.086
222	175	176	41.207	21.323	-41.092	-23.309	0.115	0.337
223	176	177	14.532	-0.298	-14.520	-2.199	0.012	0.036
224	176	178	-9.470	25.126	9.500	-33.588	0.030	0.642
225	179	180	-34.649	0.442	34.707	-9.201	0.058	0.419
226	179	180	-34.649	0.442	34.707	-9.201	0.058	0.419
227	180	181	-39.824	1.279	39.900	-9.804	0.076	0.547
228	180	181	-39.824	1.279	39.900	-9.804	0.076	0.547
229	182	183	16.288	29.712	-16.275	-29.770	0.013	0.382
230	182	186	-7.741	20.464	7.747	-20.791	0.006	0.188
231	183	184	-38.665	4.954	38.682	-4.865	0.017	0.510
232	184	185	-63.942	-10.796	64.042	12.924	0.100	3.047
233	185	194	-89.392	-28.635	89.718	28.143	0.326	0.993
234	186	187	-74.647	-14.177	74.817	17.532	0.170	4.377
235	187	188	-44.653	-32.402	44.687	32.936	0.034	0.994
236	187	188	-42.913	-30.868	42.950	31.337	0.037	0.952

237	187	194	-31.062	18.587	31.108	-19.878	0.046	0.138
238	188	189	20.716	28.380	-20.690	-28.504	0.026	0.757
239	188	190	-24.822	-0.561	24.841	-0.208	0.019	0.569
240	190	191	-36.191	-6.833	36.207	6.795	0.016	0.479
241	191	192	-58.288	-20.474	58.448	19.036	0.160	0.470
242	192	193	-20.947	13.405	20.965	-14.150	0.018	0.524
243	194	195	-67.327	-8.417	67.342	8.896	0.014	0.692
244	194	195	-67.327	-8.417	67.342	8.896	0.014	0.692
245	195	196	-0.841	14.550	0.853	-16.622	0.012	0.037
246	196	197	-18.313	5.802	18.324	-6.707	0.011	0.344
247	197	198	-13.254	24.833	13.300	-26.280	0.046	0.099
248	197	199	-31.120	-29.251	31.212	27.368	0.092	0.270
249	199	200	-47.823	-32.909	48.019	30.950	0.197	0.579
250	202	203	-42.500	11.950	42.579	-18.486	0.079	0.569
251	202	203	-42.500	11.950	42.579	-18.486	0.079	0.569
252	202	205	-73.535	-15.007	73.590	11.186	0.055	3.988
253	202	205	-73.535	-15.007	73.590	11.186	0.055	3.988
254	202	205	-73.001	-14.995	73.056	11.006	0.055	3.959
255	202	205	-73.001	-14.995	73.056	11.006	0.055	3.959
256	203	204	-59.838	-4.669	59.903	3.821	0.065	0.471
257	203	204	-59.838	-4.669	59.903	3.821	0.065	0.471
258	205	206	42.221	-15.668	-42.073	13.398	0.148	1.080
259	205	206	42.221	-15.668	-42.073	13.398	0.148	1.080
260	62	207	15.020	47.322	-14.718	-53.824	0.302	2.183
261	62	207	15.020	47.322	-14.718	-53.824	0.302	2.183
262	88	204	141.688	73.673	-141.288	-83.282	0.400	2.970
263	88	204	141.688	73.673	-141.288	-83.282	0.400	2.970
264	135	136	82.155	-38.777	-81.983	-71.205	0.172	2.149
265	130	159	43.597	10.968	-43.538	-18.796	0.058	0.427
266	130	159	43.597	10.968	-43.538	-18.796	0.058	0.427
267	130	160	1.230	6.497	-1.222	-8.562	0.008	0.055
268	130	160	1.230	6.497	-1.222	-8.562	0.008	0.055
269	136	208	45.747	-193.088	-45.536	10.763	0.210	2.749
270	35	44	-53.105	54.276	53.503	-54.536	0.398	2.350
271	41	45	-15.124	11.517	15.134	-14.971	0.009	0.117

272	44	45	3.518	-35.120	-3.421	31.594	0.097	0.271
273	41	44	-16.244	51.683	16.506	-54.714	0.262	0.734
274	32	34	-2.848	7.701	2.856	-8.213	0.008	0.022
275	32	34	-2.848	7.701	2.856	-8.213	0.008	0.022
276	62	179	30.999	-30.482	-30.973	-22.044	0.026	0.189
277	62	179	30.999	-30.482	-30.973	-22.044	0.026	0.189
278	23	179	-57.110	-25.178	57.185	23.526	0.074	0.782
279	23	179	-57.110	-25.178	57.185	23.526	0.074	0.782
280	202	203	-42.500	11.950	42.579	-18.486	0.079	0.569
281	202	203	-42.500	11.950	42.579	-18.486	0.079	0.569
282	203	204	-59.838	-4.669	59.903	3.821	0.065	0.471
283	203	204	-59.838	-4.669	59.903	3.821	0.065	0.471
284	136	208	45.747	-193.088	-45.536	10.763	0.210	2.749
285	127	160	134.016	97.157	-133.168	-97.063	0.848	6.286
286	127	160	134.016	97.157	-133.168	-97.063	0.848	6.286
287	92	134	79.263	-68.795	-79.105	67.166	0.158	1.135
288	92	134	79.263	-68.795	-79.105	67.166	0.158	1.135
289	134	179	147.599	-15.495	-147.068	12.991	0.531	5.491
290	134	179	147.599	-15.495	-147.068	12.991	0.531	5.491
291	202	206	-150.203	-67.575	150.553	64.880	0.350	5.259
292	202	206	-150.203	-67.575	150.553	64.880	0.350	5.259
293	203	206	-39.233	-40.377	39.310	35.631	0.077	1.292
294	203	206	-39.233	-40.377	39.310	35.631	0.077	1.292
295	137	140	1.609	-4.241	-1.609	0.861	0.000	0.002
296	152	156	45.653	4.331	-45.406	-8.384	0.247	0.696
297	155	157	-8.200	-1.743	8.207	-5.817	0.007	0.031
298	152	155	14.816	2.327	-14.787	-10.105	0.028	0.137
299	48	50	28.693	-3.436	-28.675	0.971	0.019	0.242
300	135	208	42.920	-72.873	-42.614	-23.505	0.306	1.911
301	135	208	42.920	-72.873	-42.614	-23.505	0.306	1.911
302	135	208	42.920	-72.873	-42.614	-23.505	0.306	1.911

**** SYSTEM TOTAL ****

	MW	MVAR
GENERATION	6166.63	1015.86
LOAD	6125.34	3433.31
LINE CHARGING	0.00	2612.66
STATIC CAPACITOR	0.00	500.51
LOSS	41.27	695.68
MISMATCH	0.01	0.04

Appendix G

The Computer Program

A computer program of Diakoptics in FDLF is written in Fortran-77 on mini-computer PDP-11/24, VAX-11/750 and micro-computer IBM-PC. The program has a top-down structure design (67). The function of the subroutines in the module can be described as follows:

Routine Name	Function
------	Main Program
COMB	Combine Solution of Diakoptics Method
CUT	Automatic Tearing
FACTOR	Factorization of [A]
FDLF	Solve Load-Flow
ICT	Calculate Tie-Line' s Current
INPUT	Input Data
INVE	Inverse Matrix
LIST	Print The Input Data
OUT	Print The Out Put Data
PC	Calculate Pi
PCD	Solve P- Iteration
PRE1	Build Tables
PRE2	Form [Y-Bus]

PRE3	Form [B']
PRE4	Form [B"]
QC	Calculate Qi
QCV	Solve Q-V Iteration
SOLV	Forward and Backward Substitution
X1	Look Up Table
X2	Look Up Table
ZZ24	Form [Z'_4] and [Z''_4]

PROGRAM LIST

```
      CALL INPUT
      CALL LIST
      CALL PRE1
      CALL PRE2
      CALL PRE3
      CALL PRE4
      CALL FDLF
      CLOSE(8)
      CLOSE(9)
      STOP
      END

      SUBROUTINE COMB(N)
      COMMON NA,NB,NL
      COMMON/G1/ TJ(60,60),DV(60)
      COMPLEX ZSE
      COMMON/LINE/ NSB(500),NEB(500)
      COMMON/TRA/ N1A(200),NTA(200)
      COMPLEX VG,CTI
      COMMON/Z24/ VM(400),AG(400),VG(400),CTI(60),E0(50,10),
     1PCAL(400),Y1(50,50,10),NBC(400),NAC(400)
      DO 15 I=1,N
      J=NBC(I)
```

```
      CALL X2(J,L,K)
      CALL X1(K,M,N1)
      DV(I)=E0(M,N1)
      CALL X1(L,M,N1)
      DV(I)=DV(I)-E0(M,N1)
15    CONTINUE
C      WRITE(*,579)
C579   FORMAT(/,25X,'STEP2 EC1')
C      DO 781 I=1,N
C      WRITE(*,782) I,DV(I)
C782   FORMAT(5X,'TIE LINE NO',5X,I3,5X,'EC1',5X,F10.6)
C781   CONTINUE
      CALL SOLV(N)
C      WRITE(*,476)
C476   FORMAT(/,25X,'STEP 3  IC')
C      DO 568 I=1,N
C      WRITE(*,577) I,DV(I)
C577   FORMAT(5X,'TIE LINE NO.',5X,I3,5X,'CURRENT',5X,F10.6)
C568   CONTINUE
      DO 20 I=1,N
      PCAL(I)=DV(I)
20    CONTINUE
C      WRITE(*,683)
C683   FORMAT(/,25X,'STEP4 ET1')
      DO 25 I=1,NA
      J=NAC(I)
      IF(J.NE.0) THEN
      DO 30 L=1,J
      DV(L)=0.0
30    CONTINUE
      DO 35 J=1,N
      L=NBC(J)
      CALL X2(L,K,M)
      CALL X1(K,N1,K1)
      CALL X1(M,K,M1)
      IF(K1.EQ.I) DV(N1)=DV(N1)+PCAL(J)
      IF(M1.EQ.I) DV(K)=DV(K)-PCAL(J)
35    CONTINUE
C      WRITE(*,3988)
C3988  FORMAT(/)
      J=NAC(I)
C      DO 729 L=1,J
C      WRITE(*,726) I,DV(L)
C726   FORMAT(5X,'AREA',5X,I3,5X,'IT1',5X,F10.6)
C729   CONTINUE
C      WRITE(*,3988)
      DO 40 L=1,J
      DO 40 M=1,J
      TJ(L,M)=Y1(L,M,I)
40    CONTINUE
      CALL SOLV(J)
C      DO 7729 L=1,J
C      WRITE(*,7726) I,DV(L)
```

```
C7726   FORMAT(5X,'AREA',5X,I3,5X,'ET1',5X,F10.6)
C7729   CONTINUE
        DO 45 L=1,J
        E0(L,I)=E0(L,I)+DV(L)
45      CONTINUE
        ENDIF
25      CONTINUE
        RETURN
        END


        SUBROUTINE CUT
        COMMON NA,NB,NL,NC,NT,LNIT
        COMMON/LINE/ NSB(500),NEB(500)
        COMMON/BUS3/ NAB(400)
        COMMON/TRA/ N1A(200),NAT(200)
        COMMON/Z24/ NXX(10),NAA(10),NTT(10)
        J=NB/NA+1
        DO 5 I=1,NA
        L=I*J
        M=L-J+1
        IF(L.GT.NB) L=NB
        DO 5 K=M,L
        NAB(K)=I
5       CONTINUE
        KK=NB*NB
        K1=KK
        DO 10 L=0,LNIT
        DO 15 N=1,NB
        DO 20 K=1,NA
        NAB(N)=K
        NTT(K)=0
        DO 25 J=1,NL
        M=NSB(J)
        J2=NEB(J)
        IF(NAB(M).NE.NAB(J2)) NTT(K)=NTT(K)+1
25      CONTINUE
        DO 30 J=1,NT
        M=N1A(J)
        J2=NAT(J)
        IF(NAB(M).NE.NAB(J2)) NTT(K)=NTT(K)+1
30      CONTINUE
        DO 35 J=1,NA
        NXX(J)=0
35      CONTINUE
        DO 40 J=1,NB
        M=NAB(J)
        NXX(M)=NXX(M)+1
40      CONTINUE
        NAA(K)=NTT(K)*NTT(K)
        DO 45 M=1,NA
        NAA(K)=NAA(K)+NXX(M)*NXX(M)
C        NAA(K)=NAA(K)+2*NXX(M)*NXX(M)
```

```
45     CONTINUE
20     CONTINUE
       LL=1
       KK=NAA(1)
       DO 50 J=2,NA
       IF(KK.GT.NAA(J)) THEN
       LL=J
       KK=NAA(J)
       ENDIF
50     CONTINUE
       NAB(N)=LL
15     CONTINUE
C       DO 888 L1=1,NB
C       WRITE(*,*) '    BUS    ',L1,'    AREA    ',NAB(L1)
C888    CONTINUE
       IF(KK.EQ.K1) RETURN
       K1=KK
10     CONTINUE
       RETURN
       END


       SUBROUTINE FACTOR(L)
       COMMON/G1/ TJ(60,60)
       IF(L.EQ.1) RETURN
       DO 5 I=2,L
       TJ(1,I)=TJ(1,I)/TJ(1,1)
5      CONTINUE
       DO 10 I=2,L
       DO 10 J=2,L
       X=0.0
       K1=J-1
       IF(J.GT.I) K1=I-1
       DO 15 K2=1,K1
       X=X+TJ(I,K2)*TJ(K2,J)
15     CONTINUE
       TJ(I,J)=TJ(I,J)-X
       IF(J.GT.I) TJ(I,J)=TJ(I,J)/TJ(I,I)
10     CONTINUE
       RETURN
       END


       SUBROUTINE FDLF
       COMMON NA,NB,NL,NC,NT,LNIT,ERROR
       COMMON/AR1/ NBB(400),NK(50,10),NLOAD(10)
       COMMON/BUS3/ NAB(400)
       COMMON/BUS1/ NTB(400),VSPEC(400),PD(400),QD(400),PG(400)
      1,QG(400)
       COMMON/G1/ TJ(60,60),DV(60),A(60,60)
       COMPLEX ZSE
       COMMON/LINE/ NSB(500),NEB(500),YSH(500),ZSE(500)
       COMPLEX TAP
```

```
      COMMON/TRA/ N1A(200),NTA(200),ZT(200),TAP(200)
      COMMON/TIE/ NTL,NTT(60)
      COMMON/P/ NTP,NPT(60),Y1P(50,50,10),NBP(10),Z4P(60,60)
      COMPLEX VG
      COMMON/Z24/ VM(400),AG(400),VG(400)
C       COMMON/PQX/ EP0(50,10),EQ0(50,10),DPX,DQX
C       DPX=9999.99
C       DQX=9999.99
      WRITE(8,778)
778   FORMAT('1',//)
      DO 10 I=1,NB
      VM(I)=VSPEC(I)
      AG(I)=0.0
      PD(I)=PG(I)-PD(I)
      QD(I)=QG(I)-QD(I)
      VG(I)=CMPLX(VM(I),0.0)
10    CONTINUE
      D1=100.0
      D2=100.0
      K=0
      DO 15 I=1,NA
      K=K+NLOAD(I)
15    CONTINUE
      IF(K.EQ.0) D2=0.0
      DO 20 I=0,LNIT
      IF(D1.GT.ERROR) CALL PCD(D1,IXP)
      IF(D2.GT.ERROR) CALL QCV(D2,IXQ)
      TYPE 888,I,D1,IXP,D2,IXQ
      WRITE(8,888) I,D1,IXP,D2,IXQ
888   FORMAT(5X,'ITE.',3X,I3,2X,'DEL P',2X,F10.6,2X,I3,2X
     1,'DEL Q',2X,F10.6,2X,I3)
      IF(D1.LT.ERROR.AND.D2.LT.ERROR) THEN
      CALL OUT
      RETURN
      ENDIF
20    CONTINUE
      WRITE(8,9999)
9999  FORMAT(5X,'NOT CONVERGENCE PLEASE CHECK YOUR DATA')
      CALL OUT
      RETURN
      END


      SUBROUTINE ICT
      COMMON NA,NB,NL
      COMPLEX ZSE
      COMMON/LINE/ NSB(500),NEB(500),YSH(500),ZSE(500)
      COMPLEX TAP
      COMMON/TRA/ N1A(200),NTA(200),ZT(200),TAP(200)
      COMMON/TIE/ NTL,NTT(60)
      COMPLEX VG,CTI
      COMMON/Z24/ VM(400),AG(400),VG(400),CTI(60)
      DO 10 I=1,NTL
```

```
      J=NTT(I)
      CALL X2(J,L,M)
      IF(J.GT.NL) THEN
      J=J-NL
      CTI(I)=(VG(L)-VG(M))*CMPLX(0.0,ZT(J)/REAL(TAP(J)))
      ELSE
      CTI(I)=(VG(L)-VG(M))*ZSE(J)
      ENDIF
10    CONTINUE
C      DO 533 I=1,NTL
C      J=NTT(I)
C      CALL X2(J,L,M)
C      WRITE(*,786) I,L,M,CTI(I)
C786   FORMAT(5X,'CURRENT IN TIE LINE NO.',5X,I3,5X,I3,'-',I3
C     1,5X,F10.6,' J',F10.6)
C533   CONTINUE
      RETURN
      END


      SUBROUTINE INPUT
      COMMON NA,NB,NL,NC,NT,LNIT,ERROR,PBASE,REF
      COMMON/BUS3/ NAB(400)
      COMMON/BUS1/ NTB(400),VSPEC(400),PD(400),QD(400),PG(400)
     1,QG(400)
      COMPLEX ZSE
      COMMON/LINE/ NSB(500),NEB(500),YSH(500),ZSE(500)
      COMPLEX TAP
      COMMON/TRA/ N1A(200),NTA(200),ZT(200),TAP(200)
      COMMON/BUS2/ VBASE(400)
      COMMON/QC1/ QCX(400)
      COMMON/CAP/ NCB(400),ZC(400)
      CHARACTER*80 X,Y
      TYPE 8888
8888  FORMAT(25X,'INPUT FROM      ',5X,$)
      ACCEPT 9999,X
9999  FORMAT(A80)
      TYPE 7777
7777  FORMAT(25X,'OUTPUT TO       ',5X,$)
      ACCEPT 9999,Y
      IR=9
C      OPEN(UNIT=9,FILE='DATA.DAT',STATUS='OLD')
      OPEN(UNIT=9,FILE=X,STATUS='OLD')
      OPEN(UNIT=8,FILE=Y,STATUS='NEW')
      READ(IR,*) NB,NL,NC,NT,NA,LNIT,IN
      IF(LNIT.LE.0) LNIT=10
      READ(IR,*) ERROR,PBASE,REF
      IF(ERROR.LE.0.0) ERROR=0.0001
      IF(PBASE.EQ.0.0) PBASE=1.0
      DO 15 I=1,NL
      READ(IR,*) NSB(I),NEB(I),Z1,Z2,YSH(I)
      ZSE(I)=CMPLX(Z1,Z2)
15    CONTINUE
```

```
      DO 20 I=1,NB
      READ(IR,*) NTB(I),VSPEC(I),PD(I),QD(I),PG(I),QG(I),
     1VBASE(I),QCX(I)
      IF(VBASE(I).LE.0.0) VBASE(I)=1.0
      IF(VSPEC(I).LE.0.0) VSPEC(I)=1.0
20    CONTINUE
      IF(PBASE.NE.1.0) THEN
      DO 25 I=1,NB
      PD(I)=PD(I)/PBASE
      QD(I)=QD(I)/PBASE
      PG(I)=PG(I)/PBASE
      QG(I)=QG(I)/PBASE
      QCX(I)=QCX(I)/PBASE
25    CONTINUE
      ENDIF
      DO 35 I=1,NT
      READ(IR,*) N1A(I),NTA(I),ZT(I),Z1,Z2
      TAP(I)=CMPLX(Z1,Z2)
35    CONTINUE
      DO 40 I=1,NC
      READ(IR,*) NCB(I),ZC(I)
40    CONTINUE
      IF(IN.EQ.0) CALL CUT
      IF(IN.NE.0) READ(IR,*) (NAB(I),I=1,NB)
      CLOSE(9)
      RETURN
      END


      SUBROUTINE INVE(N)
      COMMON/G1/ TJ(60,60),DV(60),A(60,60)
      IF(N.EQ.1) THEN
      A(1,1)=1.0/TJ(1,1)
      RETURN
      ENDIF
      CALL FACTOR(N)
      DO 10 I=1,N
      DO 15 J=1,N
      DV(J)=0.0
15    CONTINUE
      DV(I)=1.0
      CALL SOLV(N)
      DO 10 J=1,N
      A(J,I)=DV(J)
10    CONTINUE
      RETURN
      END


      SUBROUTINE LIST
      COMMON NA,NB,NL,NC,NT,LNIT,ERROR,PBASE
      COMMON/BUS3/ NAB(400)
      COMMON/BUS1/ NTB(400),VSPEC(400),PD(400),QD(400),PG(400)
```

```
      1,QG(400)
       COMPLEX ZSE
       COMMON/LINE/ NSB(500),NEB(500),YSH(500),ZSE(500)
       COMPLEX TAP
       COMMON/TRA/ N1A(200),NTA(200),ZT(200),TAP(200)
       COMMON/TIE/ NTL,NTT(60)
       COMMON/BUS2/ VBASE(400)
       COMMON/QC1/ QCX(400)
       COMMON/CAP/ NCB(400),ZC(400)
       WRITE(8,108)
108    FORMAT('1',//,10X,'*** LINES LISTING ***',//)
       WRITE(8,118)
118    FORMAT(10X,':------:-----:-----:-----------------:
      1---------:')
       WRITE(8,128)
128    FORMAT(10X,': LINE : NSB : NEB :        ZSER       :
      1   YSHT  :')
       WRITE(8,118)
       DO 10 I=1,NL
       WRITE(8,138) I,NSB(I),NEB(I),ZSE(I),YSH(I)
138    FORMAT(10X,':  ',2(I3,' : '),I3,' :',F7.3,' J ',
      12(F7.3,' : '))
10     CONTINUE
       WRITE(8,118)
       IF(NT.NE.0) THEN
       WRITE(8,148)
148    FORMAT('1',//,10X,'*** TRANSFORMERS LISTING ***',//)
       WRITE(8,158)
158    FORMAT(10X,':-------:-----:-----:-----------------:
      1---------:')
       WRITE(8,168)
168    FORMAT(10X,': TRANS : N1A : NAB :        A        :
      1    ZT   :')
       WRITE(8,158)
       DO 20 I=1,NT
       WRITE(8,178) I,N1A(I),NTA(I),TAP(I),ZT(I)
178    FORMAT(10X,':  ',I3,'  : ',2(I3,' : '),F7.3,' J',
      12(F7.3,' : '))
20     CONTINUE
       WRITE(8,158)
       ENDIF
       IF(NC.NE.0) THEN
       WRITE(8,358)
358    FORMAT('1',//,10X,'*** CAPACITORS LISTING ***',//)
       WRITE(8,188)
188    FORMAT(10X,':-----:-----:---------:')
       WRITE(8,198)
198    FORMAT(10X,': CAP : NBC :    ZC   :')
       WRITE(8,188)
       DO 30 I=1,NC
       WRITE(8,208) I,NCB(I),ZC(I)
208    FORMAT(10X,':',2(' ',I3,' :'),1X,F7.3,' :')
30     CONTINUE
```

```
      WRITE(8,188)
      ENDIF
      WRITE(8,218) ERROR,PBASE
218   FORMAT(//,15X,'ERROR',T40,F8.5,/,15X,'BASE MVA',
     1T40,F8.4)
      WRITE(8,228)
228   FORMAT('1',//,10X,'*** BUSES LISTING (LOAD AND
     1 GENERATION IN PER UNIT) ***',//)
      WRITE(8,238)
238   FORMAT(10X,':-----:---------:---------:------:
     1--------:--------:--------:--------:--------:')
      WRITE(8,248)
248   FORMAT(10X,': BUS :  VSPEC  :  VBASE  : TYPE :
     1   PD   :   QD   :   PG   :   QG   : SHUNT :')
      WRITE(8,238)
      DO 35 I=1,NB
      WRITE(8,258) I,VSPEC(I),VBASE(I),NTB(I),PD(I),
     1QD(I),PG(I),QG(I),QCX(I)
258   FORMAT(10X,': ',I3,' : ',2(F7.2,' : '),I3,'  :',
     15(1X,F5.2,1X,' :'))
35    CONTINUE
      WRITE(8,238)
      DO 40 I=1,NL
      ZSE(I)=1.0/ZSE(I)
      YSH(I)=YSH(I)/2.0
40    CONTINUE
      DO 50 I=1,NT
      ZT(I)=-1.0/ZT(I)
50    CONTINUE
      DO 55 I=1,NC
      ZC(I)=-1.0/ZC(I)
55    CONTINUE
      NTL=0
      DO 60 I=1,NL
      J=NSB(I)
      K=NEB(I)
      IF(NAB(J).NE.NAB(K)) THEN
      NTL=NTL+1
      NTT(NTL)=I
      ENDIF
60    CONTINUE
      DO 65 I=1,NT
      J=N1A(I)
      K=NTA(I)
      IF(NAB(J).NE.NAB(K)) THEN
      NTL=NTL+1
      NTT(NTL)=I+NL
      ENDIF
65    CONTINUE
      WRITE(8,398)
398   FORMAT('1',//,15X,'TEARING SYSTEM')
      DO 885 I=1,NB
      WRITE(8,408) I,NAB(I)
```

```
408   FORMAT(5X,'BUS',5X,I3,5X,'AREA',5X,I3)
885   CONTINUE
      WRITE(8,418) NTL
418   FORMAT('1',//,15X,'TOTAL TIE LINES IN SYSTEM',5X,I3)
      DO 70 I=1,NTL
      J=NTT(I)
      IF(J.GT.NL) K=J-NL
      IF(J.GT.NL) WRITE(8,348) K
      IF(J.LE.NL) WRITE(8,388) J
348   FORMAT(5X,'TIE TRANSFORMER AT NO.',5X,I3)
388   FORMAT(5X,'TIE LINE        AT NO.',5X,I3)
70    CONTINUE
      RETURN
      END


      SUBROUTINE OUT
      COMMON NA,NB,NL,NC,NT,LNIT,ERROR,PBASE,REF
      COMMON/BUS1/ NTB(400),VSPEC(400),PD(400),QD(400),PG(400)
     1,QG(400)
      COMPLEX ZSE
      COMMON/LINE/ NSB(500),NEB(500),YSH(500),ZSE(500)
      COMPLEX TAP
      COMMON/TRA/ N1A(200),NTA(200),ZT(200),TAP(200)
      COMMON/TIE/ NTL,NTT(60)
      COMMON/BUS2/ VBASE(400)
      COMMON/QC1/ QCX(400)
      COMMON/CAP/ NCB(400),ZC(400)
      COMPLEX VG,CTI,S,R,SUM,A3
      COMMON/Z24/ VM(400),AG(400),VG(400),CTI(60),E0(50,10),
     1PCAL(400),S(500),R(500),PLL(500),QLL(500)
      CALL ICT
      DO 5 I=1,NC
      J=NCB(I)
      QCX(J)=QCX(J)+ZC(I)
5     CONTINUE
      DO 10 I=1,NB
      PD(I)=PG(I)-PD(I)
      QD(I)=QG(I)-QD(I)
      QCX(I)=QCX(I)*PBASE*VM(I)*VM(I)
      IF(NTB(I).EQ.3) IS=I
      IF(NTB(I).NE.1) THEN
      CALL QC(I,Q)
      QG(I)=QD(I)+Q
      ENDIF
10    CONTINUE
      CALL PC(IS,P)
      PG(IS)=PD(IS)+P
      WRITE(8,38)
38    FORMAT('1',//,15X,'**** OUT PUT ****',//)
      WRITE(8,48)
48    FORMAT(10X,':',5('-'),':',3(8('-'),':'),2(17('-'),':')
     1,8('-'),':')
```

```
      WRITE(8,58)
58    FORMAT(10X,': BUS :',6X,'VOLT',6X,' :  ANGLE :',4X,
     1'GENERATION',3X,':',6X,'DEMAND',5X,':  SHUNT :')
      WRITE(8,68)
68    FORMAT(10X,': NO. : ',7(' '),':',8(' '),':',6(8X,':'))
      WRITE(8,78)
78    FORMAT(10X,':',5X,':   PU.  :   KV   :(DEGREE):',
     12(17('-'),':')8('-'),':')
      WRITE(8,88)
88    FORMAT(10X,':',5X,':',8X,':',2(8X,':'),2(3X,'MW    :
     1  MVAR  :'),'  MVAR  :')
      WRITE(8,48)
      DO 15 I=1,NB
      V1=VM(I)*VBASE(I)
      D1=AG(I)*57.29578+REF
      GP=PG(I)*PBASE
      GQ=QG(I)*PBASE
      DPP=PD(I)*PBASE
      DQQ=QD(I)*PBASE
      WRITE(8,98) I,VM(I),V1,D1,GP,GQ,DPP,DQQ,QCX(I)
98    FORMAT(10X,':',I4,' : ',F7.4,': ',F7.2,':',F8.4,':',
     15(F7.2,' :'))
15    CONTINUE
      WRITE(8,48)
      WRITE(8,17)
17    FORMAT('1',//,15X,'**** LINE FLOW ****',//)
      WRITE(8,27)
27    FORMAT(5X,':',3(4('-'),':'),3(18('-'),':'))
      WRITE(8,37)
37    FORMAT(5X,':LINE:FROM: TO :    FLOW FROM P    :',
     1'    FLOW TO Q       :',7X,'LOSS',7X,':')
      WRITE(8,47)
47    FORMAT(5X,':NO. :',2('BUS :'),3(8('-'),':',9('-'),':'))
      WRITE(8,57)
57    FORMAT(5X,':',4X,': P  : Q  :',3('   MW   :   MVAR  :'))
      WRITE(8,67)
67    FORMAT(5X,':',3(4('-'),':'),3(8('-'),':',9('-'),':'))
      DO 25 I=1,NL
      L=NSB(I)
      K=NEB(I)
      SUM=(VG(L)-VG(K))*ZSE(I)
      A3=CMPLX(0.0,YSH(I))
      S(I)=VG(L)*CONJG(A3*VG(L)+SUM)*PBASE
      R(I)=VG(K)*CONJG(A3*VG(K)-SUM)*PBASE
25    CONTINUE
      CL=0.0
      TQL=0.0
      TPL=0.0
      DO 35 I=1,NL
      SUM=S(I)+R(I)
      L=NSB(I)
      K=NEB(I)
      FF=YSH(I)*(VM(L)*VM(L)+VM(K)*VM(K))*PBASE
```

```
      CL=CL+FF
      PLL(I)=REAL(SUM)
      QLL(I)=AIMAG(SUM)+FF
      TPL=TPL+PLL(I)
      TQL=TQL+QLL(I)
 35   CONTINUE
      DO 45 I=1,NL
      D1=REAL(S(I))
      D2=AIMAG(S(I))
      F1=REAL(R(I))
      F2=AIMAG(R(I))
      WRITE(8,77) I,NSB(I),NEB(I),D1,D2,F1,F2,PLL(I),QLL(I)
 77   FORMAT(5X,':',I4,T11,2(':',I4),3(':',F8.3,':',F9.3),':')
 45   CONTINUE
      WRITE(8,67)
      GP=0.0
      DPP=0.0
      GQ=0.0
      DQQ=0.0
      V1=0.0
      DO 55 I=1,NB
      GP=GP+PG(I)
      DPP=DPP+PD(I)
      GQ=GQ+QG(I)
      V1=V1+QCX(I)
      DQQ=DQQ+QD(I)
 55   CONTINUE
      GP=GP*PBASE
      DPP=DPP*PBASE
      GQ=GQ*PBASE
      DQQ=DQQ*PBASE
C      V1=0.0
C      DO 65 I=1,NC
C      L=NCB(I)
C      V1=V1+ZC(I)*VM(L)*VM(L)
C65    CONTINUE
C      V1=V1*PBASE
      CX=0.0
      DO 70 I=1,NT
      L=N1A(I)
      K=NTA(I)
      A3=(VG(L)-VG(K)/TAP(I))*CMPLX(0.0,ZT(I))
      CX=CX+CABS(A3)**2/ABS(ZT(I))
 70   CONTINUE
      CX=CX*PBASE
      TQL=TQL+CX
      CX=0.0
      F1=ABS(GP-DPP-TPL)
      F2=ABS(GQ-DQQ+V1-TQL+CL)
      WRITE(8,19)
 19   FORMAT('1',//,25X,'**** SYSTEM TOTAL ****')
      WRITE(8,29)
 29   FORMAT(//,T34,'MW',T45,'MVAR')
```

```
      WRITE(8,39) GP,GQ
39    FORMAT(//,10X,'GENERATION',T30,2(F8.2,4X))
      WRITE(8,49) DPP,DQQ
49    FORMAT(//,10X,'LOAD',T30,2(F8.2,4X))
      WRITE(8,59) CX,CL
59    FORMAT(//,10X,'LINE CHARGING',T30,2(F8.2,4X))
      WRITE(8,69) CX,V1
69    FORMAT(//,10X,'STATIC CAPACITOR',T30,2(F8.2,4X))
      WRITE(8,79) TPL,TQL
79    FORMAT(//,10X,'LOSS',T30,2(F8.2,4X))
      WRITE(8,89) F1,F2
89    FORMAT(//,10X,'MISMATCH',T30,2(F8.2,4X))
      RETURN
      END


      SUBROUTINE PC(I,P)
      COMMON NA,NB,NL
      COMMON/AR1/ NBB(400),NK(50,10),NLOAD(10),NCON(10),NBA(10)
      COMMON/TIE/ NTL,NTT(60)
      COMPLEX Y
      COMMON/YBL/ Y(50,50,10)
      COMPLEX VG,CTI
      COMMON/Z24/ VM(400),AG(400),VG(400),CTI(60),E0(50,10)
     1,PCAL(400)
      CALL X1(I,J,K)
      N=NBA(K)
      P=0.0
      DO 10 L=1,N
      M=NK(L,K)
      X=AG(I)-AG(M)
      P=P+VM(M)*(REAL(Y(J,L,K))*COS(X)+AIMAG(Y(J,L,K))*SIN(X))
10    CONTINUE
      PCAL(J)=P*VM(I)
      P=PCAL(J)
      DO 25 L=1,NTL
      M=NTT(L)
      CALL X2(M,N,K)
      IF(N.EQ.I) PCAL(J)=PCAL(J)+REAL(VG(N)*CONJG(CTI(L)))
      IF(K.EQ.I) PCAL(J)=PCAL(J)-REAL(VG(K)*CONJG(CTI(L)))
25    CONTINUE
C      WRITE(*,678) I,P,PCAL(J)
C678   FORMAT(5X,'BUS',5X,I3,5X,'P WITHOUT TIE CURRENT',F10.6,
C     15X,'PCAL',5X,F10.6)
      P=PCAL(J)
      RETURN
      END


      SUBROUTINE PCD(D1,IXP)
      COMMON NA,NB,NL
      COMMON/BUS3/ NAB(400)
      COMMON/BUS1/ NTB(400),VSPEC(400),PD(400)
```

```
      COMMON/G1/ TJ(60,60),DV(60),A(60,60)
      COMPLEX ZSE
      COMMON/LINE/ NSB(500),NEB(500),YSH(500),ZSE(500)
      COMPLEX TAP
      COMMON/TRA/ N1A(200),NTA(200),ZT(200),TAP(200)
      COMMON/TIE/ NTL,NTT(60)
      COMMON/P/ NTP,NPT(60),Y1P(50,50,10),NBP(10),Z4P(60,60)
      COMPLEX VG,CTI
      COMMON/Z24/ VM(400),AG(400),VG(400),CTI(60),E0(50,10),
     1PCAL(400),Y1(50,50,10),NBC(400),NAC(400)
C      COMMON/PQX/ EP0(50,10),EQ0(50,10),DPX,DQX
C      WRITE(*,1577)
C1577  FORMAT(//,25X,'P-D ITTERATIVE',//)
C      DO 532 I=1,NB
C      WRITE(*,578) I,VM(I),AG(I)
C578   FORMAT(5X,'BUS',5X,I3,5X,'VOLT',5X,F10.5,5X,'ANGLE',F10.5)
C532   CONTINUE
C75    CONTINUE
C      DO 80 I=1,NB
C      IF(NTB(I).NE.3) THEN
C      CALL X1(I,L,M)
C      EP0(L,M)=EP0(L,M)/2.0
C      ENDIF
C80    CONTINUE
      D1=0.0
      CALL ICT
      DO 15 I=1,NA
      JJ=NBP(I)
      IF(JJ.NE.0) THEN
      DO 20 J=1,NB
      CALL X1(J,K,N)
      IF(N.EQ.I.AND.NTB(J).NE.3) THEN
      CALL PC(J,P)
      DV(K)=PCAL(K)-PD(J)
      IF(ABS(DV(K)).GT.D1) THEN
      D1=ABS(DV(K))
      IXP=J
      ENDIF
      DV(K)=DV(K)/VM(J)
      ENDIF
20    CONTINUE
      DO 25 L=1,JJ
      DO 25 N=1,JJ
      TJ(L,N)=Y1P(L,N,I)
25    CONTINUE
      CALL SOLV(JJ)
      DO 30 L=1,JJ
      E0(L,I)=DV(L)
30    CONTINUE
      ENDIF
15    CONTINUE
C      IF(D1.GT.DPX) THEN
C      WRITE(8,7898) DPX,D1
```

```
C       TYPE 7898,DPX,D1
C7898   FORMAT(5X,'DPX ',5X,F10.6,5X,'D1 ',5X,F10.6)
C       DO 605 J=1,NB
C       IF(NTB(J).NE.3) THEN
C       CALL X1(J,L,M)
C       AG(J)=AG(J)+EP0(L,M)
C       VG(J)=VM(J)*CMPLX(COS(AG(J)),SIN(AG(J)))
C       ENDIF
C605    CONTINUE
C       GOTO 75
C       ENDIF
C       DPX=D1
C       WRITE(*,677) D1
C677    FORMAT(5X,'**** ERROR MAXIMUM ****',5X,F10.6)
C       WRITE(*,673)
C673    FORMAT(/,5X,'STEP 1  ET0')
C       DO 763 I=1,NA
C       J=NBP(I)
C       WRITE(*,8873) I
C8873   FORMAT(/,5X,'AREA',5X,I3)
C       DO 763 L=1,J
C       WRITE(*,789) L,E0(L,I)
C789    FORMAT(5X,'BUS',5X,I3,5X,'ET0',5X,F10.6)
C763    CONTINUE
      IF(NTP.NE.0) THEN
      DO 35 I=1,NTP
      NBC(I)=NPT(I)
35    CONTINUE
      DO 40 I=1,NTP
      DO 40 J=1,NTP
      TJ(I,J)=Z4P(I,J)
40    CONTINUE
      DO 45 I=1,NA
      NAC(I)=NBP(I)
      DO 50 J=1,NBP(I)
      DO 50 L=1,NBP(I)
      Y1(J,L,I)=Y1P(J,L,I)
50    CONTINUE
45    CONTINUE
      CALL COMB(NTP)
      ENDIF
      DO 55 I=1,NB
      IF(NTB(I).NE.3) THEN
      CALL X1(I,L,M)
      AG(I)=AG(I)-E0(L,M)
C       EP0(L,M)=E0(L,M)
      VG(I)=VM(I)*CMPLX(COS(AG(I)),SIN(AG(I)))
      ENDIF
55    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PRE1
      COMMON NA,NB
      COMMON/AR1/ NBB(400),NK(50,10),NLOAD(10),NCON(10),NBA(10)
      COMMON/Z24/ NK1(60)
      COMMON/BUS3/ NAB(400)
      COMMON/BUS1/ NTB(400)
      DO 10 I=1,NA
      NLOAD(I)=0
      NBA(I)=0
10    CONTINUE
      DO 15 I=1,NB
      N=NAB(I)
      IF(NTB(I).EQ.1) NLOAD(N)=NLOAD(N)+1
      IF(NTB(I).EQ.2) NCON(N)=NCON(N)+1
      NBA(N)=NBA(N)+1
15    CONTINUE
      DO 20 I=1,NA
      K=0
      J=NLOAD(I)
      DO 25 L=1,NB
      IF(NAB(L).EQ.I) THEN
      IF(NTB(L).EQ.1) THEN
      K=K+1
      N=K
      ENDIF
      IF(NTB(L).EQ.2) THEN
      J=J+1
      N=J
      ENDIF
      IF(NTB(L).EQ.3) N=NBA(I)
      NBB(L)=N
      NK1(N)=L
      ENDIF
25    CONTINUE
C      WRITE(*,566) I,(NK1(J),J=1,NBA(I))
C566   FORMAT(5X,'AREA',I3,5X,'NK1 REFER ',12(2X,I3))
      DO 20 L=1,NBA(I)
      NK(L,I)=NK1(L)
20    CONTINUE
C      DO 877 I=1,NB
C      WRITE(*,544) I,NBB(I),NAB(I)
C544   FORMAT(5X,'BUS',5X,I3,5X,'REFER',5X,I3,5X,'AREA',5X,I2)
C877   CONTINUE
      WRITE(8,8)
8     FORMAT('1',//,5X,'SUMMARY TOTAL BUS IN EACH AREA',//)
      DO 30 I=1,NA
      WRITE(8,18) I,NLOAD(I),NCON(I),NBA(I)
18    FORMAT(5X,'AREA NUMBER',I3,' LOAD BUS ',I3,'  VOLTAGE
     1CONTROL BUS ',I3,' TOTAL BUS',I3)
30    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PRE2
      COMMON NA,NB,NL,NC,NT
      COMMON/AR1/ NBB(400),NK(50,10),NLOAD(10),NCON(10),NBA(10)
      COMMON/BUS3/ NAB(400)
      COMPLEX ZSE
      COMMON/LINE/ NSB(500),NEB(500),YSH(500),ZSE(500)
      COMPLEX TAP
      COMMON/TRA/ N1A(200),NTA(200),ZT(200),TAP(200)
      COMPLEX Y
      COMMON/YBL/ Y(50,50,10)
      COMMON/QC1/ QCX(400)
      COMMON/CAP/ NCB(400),ZC(400)
      DO 10 I=1,NA
      K=NBA(I)
      DO 15 J=1,K
      DO 15 L=1,K
      Y(J,L,I)=CMPLX(0.0,0.0)
15    CONTINUE
10    CONTINUE
      DO 20 I=1,NL
      J=NSB(I)
      CALL X1(J,L,K)
      Y(L,L,K)=Y(L,L,K)+CMPLX(0.0,YSH(I))
      J=NEB(I)
      CALL X1(J,L,K)
      Y(L,L,K)=Y(L,L,K)+CMPLX(0.0,YSH(I))
20    CONTINUE
      DO 25 I=1,NL
      J=NSB(I)
      L=NEB(I)
      IF(NAB(J).EQ.NAB(L)) THEN
      CALL X1(J,K,M)
      Y(K,K,M)=Y(K,K,M)+ZSE(I)
      CALL X1(L,J,M)
      Y(J,J,M)=Y(J,J,M)+ZSE(I)
      Y(K,J,M)=Y(K,J,M)-ZSE(I)
      Y(J,K,M)=Y(K,J,M)
      ENDIF
25    CONTINUE
      DO 30 I=1,NT
      J=N1A(I)
      L=NTA(I)
      IF(NAB(J).NE.NAB(L)) THEN
      X=REAL(TAP(I))
      CALL X1(J,K,M)
      Y(K,K,M)=Y(K,K,M)+CMPLX(0.0,ZT(I)*(X-1.0))/X
      CALL X1(L,K,M)
      Y(K,K,M)=Y(K,K,M)+CMPLX(0.0,ZT(I)*(1.0-X))/(X*X)
      ELSE
      CALL X1(J,K,M)
      Y(K,K,M)=Y(K,K,M)+CMPLX(0.0,ZT(I))
      CALL X1(L,J,M)
```

```
      Y(J,J,M)=Y(J,J,M)+CMPLX(0.0,ZT(I)/CABS(TAP(I))**2)
      Y(K,J,M)=Y(K,J,M)-CMPLX(0.0,ZT(I))/TAP(I)
      Y(J,K,M)=Y(J,K,M)-CMPLX(0.0,ZT(I))/CONJG(TAP(I))
      ENDIF
 30   CONTINUE
      DO 35 I=1,NC
      J=NCB(I)
      CALL X1(J,L,K)
      Y(L,L,K)=Y(L,L,K)+CMPLX(0.0,ZC(I))
 35   CONTINUE
      DO 40 I=1,NB
      J=I
      CALL X1(J,L,K)
      Y(L,L,K)=Y(L,L,K)+CMPLX(0.0,QCX(I))
 40   CONTINUE
C      DO 444 I=1,NA
C      N=NBA(I)
C      WRITE(*,765) I
C765   FORMAT(/,15X,'Y1 BLOCK FOR AREA',I3,/)
C      DO 444 J=1,N
C      WRITE(*,778) (Y(J,L,I),L=1,N)
C778   FORMAT(5X,10(F7.3,' J ',F7.3))
C444   CONTINUE
      RETURN
      END


      SUBROUTINE PRE3
      COMMON NA,NB,NL
      COMMON/AR1/ NBB(400),NK(50,10),NLOAD(10),NCON(10),NBA(10)
      COMMON/BUS3/ NAB(400)
      COMMON/BUS1/ NTB(400)
      COMMON/G1/ TJ(60,60),DV(60),A(60,60)
      COMPLEX ZSE
      COMMON/LINE/ NSB(500),NEB(500),YSH(500),ZSE(500)
      COMPLEX TAP
      COMMON/TRA/ N1A(200),NTA(200),ZT(200),TAP(200)
      COMMON/TIE/ NTL,NTT(60)
      COMPLEX Y
      COMMON/YBL/ Y(50,50,10)
      COMMON/P/ NTP,NPT(60),Y1P(50,50,10),NBP(10),Z4P(60,60)
      COMMON/Z24/ NZT(60),NAT(10),Z1(50,50,10),Z2(50,60,10)
C      WRITE(*,632)
C632   FORMAT(/,5X,'**** P-D PROBLEM ****')
      DO 10 I=1,NB
      IF(NTB(I).EQ.3) IS=I
10    CONTINUE
      DO 15 I=1,NA
      NBP(I)=NBA(I)
15    CONTINUE
      J=NAB(IS)
      NBP(J)=NBP(J)-1
      DO 20 I=1,NA
```

```
      J=NBP(I)
      DO 25 L=1,J
      DO 25 K=1,J
      Y1P(L,K,I)=-AIMAG(Y(L,K,I))
25    CONTINUE
20    CONTINUE
      NTP=0
      DO 30 I=1,NTL
      NTP=NTP+1
      J=NTT(I)
      NPT(NTP)=J
      CALL X2(J,L,K)
      IF(J.LE.NL) THEN
      IF(L.EQ.IS.OR.K.EQ.IS) THEN
      NTP=NTP-1
      N=L
      IF(L.EQ.IS) N=K
      CALL X1(N,L,K)
      Y1P(L,L,K)=Y1P(L,L,K)-AIMAG(ZSE(J))
      ENDIF
      ELSE
      J=J-NL
      IF(L.EQ.IS.OR.K.EQ.IS) THEN
      NTP=NTP-1
      N=L
      IF(L.EQ.IS) N=K
      CALL X1(N,L,K)
      Y1P(L,L,K)=Y1P(L,L,K)-ZT(J)/REAL(TAP(J))
      ENDIF
      ENDIF
30    CONTINUE
C      WRITE(*,456)
C456   FORMAT(/,25X,'MODIFIED JACOBIAN MATRICES',/)
C      DO 566 I=1,NA
C      J=NBP(I)
C      WRITE(*,769) I
C769   FORMAT(15X,'AREA',5X,I3)
C      DO 566 M=1,J
C      WRITE(*,788) (Y1P(M,K,I),K=1,J)
C788   FORMAT(5X,10(F8.4,2X))
C566   CONTINUE
      DO 35 I=1,NA
      J=NBP(I)
      IF(J.NE.0) THEN
      DO 40 L=1,J
      DO 40 M=1,J
      TJ(L,M)=Y1P(L,M,I)
40    CONTINUE
C      WRITE(*,4677)
C4677  FORMAT(15X,'JMAT L-U')
      CALL INVE(J)
      DO 45 L=1,J
      DO 45 M=1,J
```

```
      Z1(L,M,I)=A(L,M)
      Y1P(L,M,I)=TJ(L,M)
45    CONTINUE
C      DO 479 L=1,J
C      WRITE(*,788) (Y1P(L,M,I),M=1,J)
C479   CONTINUE
      ENDIF
35    CONTINUE
C      WRITE(*,463)
C463   FORMAT(/,25X,'ZBUS BLOCK')
C      DO 379 I=1,NA
C      J=NBP(I)
C      WRITE(*,769) I
C      DO 379 L=1,J
C      WRITE(*,788) (Z1(L,K,I),K=1,J)
C379   CONTINUE
      IF(NTP.EQ.0) RETURN
      DO 50 I=1,NA
      NAT(I)=NBP(I)
50    CONTINUE
      DO 55 I=1,NTP
C      WRITE(*,679) I,NPT(I)
C679   FORMAT(5X,'TIE LINE IN P-PROBLEM',3X,I3,3X,'IS LINE',3X,I3)
      NZT(I)=NPT(I)
55    CONTINUE
      CALL ZZ24(NTP)
      DO 60 I=1,NTP
      DO 60 J=1,NTP
      Z4P(I,J)=TJ(I,J)
60    CONTINUE
C      WRITE(*,511)
C511   FORMAT(/,5X,'L-U Z4')
C      DO 562 I=1,NTP
C      WRITE(*,788) (Z4P(I,J),J=1,NTP)
C562   CONTINUE
      RETURN
      END

      SUBROUTINE PRE4
      COMMON NA,NB,NL
      COMMON/AR1/ NBB(400),NK(50,10),NLOAD(10),NCON(10),NBA(10)
      COMMON/BUS3/ NAB(400)
      COMMON/BUS1/ NTB(400)
      COMMON/G1/ TJ(60,60),DV(60),A(60,60)
      COMPLEX ZSE
      COMMON/LINE/ NSB(500),NEB(500),YSH(500),ZSE(500)
      COMPLEX TAP
      COMMON/TRA/ N1A(200),NTA(200),ZT(200),TAP(200)
      COMMON/TIE/ NTL,NTT(60)
      COMPLEX Y
      COMMON/YBL/ Y(50,50,10)
      COMMON/Q/ NTQ,NQT(60),Y1Q(50,50,10),Z4Q(60,60)
```

```
      COMMON/Z24/ NZT(60),NAT(10),Z1(50,50,10),Z2(50,60,10)
      K=0
      DO 20 I=1,NA
      J=NLOAD(I)
      K=K+J
      DO 25 L=1,J
      DO 25 N=1,J
      Y1Q(L,N,I)=-AIMAG(Y(L,N,I))
25    CONTINUE
20    CONTINUE
      IF(K.EQ.0) RETURN
C      WRITE(*,342)
C342   FORMAT(/,25X,'**** Q-V **** PROBLEM')
      NTQ=0
      DO 30 I=1,NTL
      NTQ=NTQ+1
      J=NTT(I)
      NQT(NTQ)=J
      CALL X2(J,L,K)
      IF(J.LE.NL) THEN
      IF(NTB(L).NE.1.AND.NTB(K).NE.1) NTQ=NTQ-1
      IF(NTB(L).NE.1.AND.NTB(K).NE.1) GOTO 30
      IF(NTB(L).EQ.1.AND.NTB(K).EQ.1) GOTO 30
      NTQ=NTQ-1
      N=L
      IF(NTB(K).EQ.1) N=K
      CALL X1(N,L,K)
      Y1Q(L,L,K)=Y1Q(L,L,K)-AIMAG(ZSE(J))
      ELSE
      J=J-NL
      IF(NTB(L).NE.1.AND.NTB(K).NE.1) NTQ=NTQ-1
      IF(NTB(L).NE.1.AND.NTB(K).NE.1) GOTO 30
      IF(NTB(L).EQ.1.AND.NTB(K).EQ.1) GOTO 30
      N=L
      IF(NTB(K).EQ.1) N=K
      CALL X1(N,L,K)
      Y1Q(L,L,K)=Y1Q(L,L,K)-ZT(J)/REAL(TAP(J))
      ENDIF
30    CONTINUE
C      WRITE(*,376)
C376   FORMAT(/,5X,'MODIFY JACOBIAN MATRICES')
C      DO 264 I=1,NA
C      J=NLOAD(I)
C      WRITE(*,364) I
C364   FORMAT(5X,'AREA',5X,I3)
C      DO 264 L=1,J
C      WRITE(*,321) (Y1Q(L,K,I),K=1,J)
C321   FORMAT(5X,10(F8.4,2X))
C264   CONTINUE
      DO 35 I=1,NA
      J=NLOAD(I)
      DO 40 L=1,J
      DO 40 M=1,J
```

```
      TJ(L,M)=Y1Q(L,M,I)
40    CONTINUE
      CALL INVE(J)
      DO 45 L=1,J
      DO 45 M=1,J
      Z1(L,M,I)=A(L,M)
      Y1Q(L,M,I)=TJ(L,M)
45    CONTINUE
35    CONTINUE
C      DO 357 I=1,NA
C      J=NLOAD(I)
C      WRITE(*,684) I
C684   FORMAT(/,5X,'Z1 FOR AREA',5X,I3)
C      DO 358 L=1,J
C      WRITE(*,321) (Z1(L,K,I),K=1,J)
C358   CONTINUE
C      WRITE(*,683) I
C683   FORMAT(/,5X,'Y1 L-U MATRIX',5X,I3)
C      DO 357 L=1,J
C      WRITE(*,321) (Y1Q(L,K,I),K=1,J)
C357   CONTINUE
      IF(NTQ.EQ.0) RETURN
      DO 50 I=1,NTQ
C      WRITE(*,679) I,NQT(I)
C679   FORMAT(5X,'TIE LINE IN Q-PROBLEM',3X,I3,3X,'IS LINE',3X,I4)
      NZT(I)=NQT(I)
50    CONTINUE
      DO 55 I=1,NA
      NAT(I)=NLOAD(I)
55    CONTINUE
      CALL ZZ24(NTQ)
      DO 60 I=1,NTQ
      DO 60 J=1,NTQ
      Z4Q(I,J)=TJ(I,J)
60    CONTINUE
C      WRITE(*,578)
C578   FORMAT(/,5X,'Z4 L-U')
C      DO 577 I=1,NTQ
C      WRITE(*,321) (Z4Q(I,J),J=1,NTQ)
C577   CONTINUE
      RETURN
      END


      SUBROUTINE QC(I,Q)
      COMMON NA,NB,NL
      COMMON/AR1/ NBB(400),NK(50,10),NLOAD(10),NCON(10),NBA(10)
      COMMON/BUS3/ NAB(400)
      COMPLEX ZSE
      COMMON/LINE/ NSB(500),NEB(500),YSH(500),ZSE(500)
      COMPLEX TAP
      COMMON/TRA/ N1A(200),NTA(200),ZT(200),TAP(200)
      COMMON/TIE/ NTL,NTT(60)
```

```
      COMPLEX Y
      COMMON/YBL/ Y(50,50,10)
      COMPLEX VG,CTI
      COMMON/Z24/ VM(400),AG(400),VG(400),CTI(60),E0(50,10),
     1QCAL(400)
      CALL X1(I,J,K)
      N=NBA(K)
      Q=0.0
      DO 10 L=1,N
      M=NK(L,K)
      X=AG(I)-AG(M)
      Q=Q-VM(M)*(AIMAG(Y(J,L,K))*COS(X)-REAL(Y(J,L,K))*SIN(X))
 10   CONTINUE
      QCAL(J)=Q*VM(I)
      Q=QCAL(J)
      DO 15 L=1,NTL
      M=NTT(L)
      CALL X2(M,N,K)
      IF(N.EQ.I) QCAL(J)=QCAL(J)+AIMAG(VG(N)*CONJG(CTI(L)))
      IF(K.EQ.I) QCAL(J)=QCAL(J)-AIMAG(VG(K)*CONJG(CTI(L)))
 15   CONTINUE
C      WRITE(*,678) I,Q,QCAL(J)
C678   FORMAT(5X,'BUS',I5,5X,'Q WITHOUT TIE CURRENT',5X,F10.6,
C     15X,'QCAL',F10.6)
      Q=QCAL(J)
      RETURN
      END


      SUBROUTINE QCV(D2,IXQ)
      COMMON NA,NB,NL
      COMMON/AR1/ NBB(400),NK(50,10),NLOAD(10),NCON(10),NBA(10)
      COMMON/BUS3/ NAB(400)
      COMMON/BUS1/ NTB(400),VSPEC(400),PD(400),QD(400)
      COMMON/G1/ TJ(60,60),DV(60),A(60,60)
      COMPLEX ZSE
      COMMON/LINE/ NSB(500),NEB(500),YSH(500),ZSE(500)
      COMPLEX TAP
      COMMON/TRA/ N1A(200),NTA(200),ZT(200),TAP(200)
      COMMON/TIE/ NTL,NTT(60)
      COMMON/Q/ NTQ,NQT(60),Y1Q(50,50,10),Z4Q(60,60)
      COMPLEX VG,CTI
      COMMON/Z24/ VM(400),AG(400),VG(400),CTI(60),E0(50,10),
     1QCAL(400),Y1(50,50,10),NBC(400),NAC(400)
C     COMMON/PQX/ EP0(50,10),EQ0(50,10),DOX,DQX
C     WRITE(*,1577)
C1577 FORMAT(//,15X,'Q-V ITERATIVE',//)
C     DO 532 I=1,NB
C     WRITE(*,578) I,VM(I),AG(I)
C578  FORMAT(5X,'BUS',I5,5X,'VOLT',5X,F10.6,5X,'ANGLE',5X,F10.6)
C532  CONTINUE
C75   CONTINUE
C     DO 95 I=1,NB
```

```
C        IF(NTB(I).EQ.1) THEN
C        CALL X1(I,L,M)
C        EQ0(L,M)=EQ0(L,M)/2.0
C        ENDIF
C95      CONTINUE
        D2=0.0
        CALL ICT
        DO 15 I=1,NA
        JJ=NLOAD(I)
        IF(JJ.NE.0) THEN
        DO 20 J=1,NB
        CALL X1(J,K,N)
        IF(N.EQ.I.AND.NTB(J).EQ.1) THEN
        CALL QC(J,Q)
        DV(K)=QCAL(K)-QD(J)
        IF(ABS(DV(K)).GT.D2) THEN
        D2=ABS(DV(K))
        IXQ=J
        ENDIF
        DV(K)=DV(K)/VM(J)
        ENDIF
20      CONTINUE
        DO 25 L=1,JJ
        DO 25 N=1,JJ
        TJ(L,N)=Y1Q(L,N,I)
25      CONTINUE
        CALL SOLV(JJ)
        DO 30 L=1,JJ
        E0(L,I)=DV(L)
30      CONTINUE
        ENDIF
15      CONTINUE
C        WRITE(*,677) D2
C677     FORMAT(15X,'**** ERROR MAXIMUM ****',5X,F10.6)
C        WRITE(*,673)
C673     FORMAT(5X,'STEP 1  ET0')
C        DO 763 I=1,NA
C        J=NLOAD(I)
C        WRITE(*,8873) I
C8873    FORMAT(5X,'AREA',5X,I3)
C        DO 763 L=1,J
C        WRITE(*,789) L,E0(L,I)
C789     FORMAT(5X,'BUS',5X,I3,5X,'ET0',5X,F10.6)
C763     CONTINUE
C        IF(D2.GT.DQX) THEN
C        WRITE(8,7898) DQX,D2
C        TYPE 7898,DQX,D2
C7898    FORMAT(5X,'DQX ',5X,F10.6,5X,'D2 ',5X,F10.6)
C        DO 85 J=1,NB
C        IF(NTB(J).EQ.1) THEN
C        CALL X1(J,L,M)
C        VG(J)=VG(J)/VM(J)
C        VM(J)=VM(J)+EQ0(L,M)
```

```
C        VG(J)=VG(J)*VM(J)
C        ENDIF
C85      CONTINUE
C        GOTO 75
C        ENDIF
C        DQX=D2
        IF(NTQ.NE.0) THEN
        DO 35 I=1,NTQ
        NBC(I)=NQT(I)
35      CONTINUE
        DO 40 I=1,NTQ
        DO 40 J=1,NTQ
        TJ(I,J)=Z4Q(I,J)
40      CONTINUE
        DO 45 I=1,NA
        NAC(I)=NLOAD(I)
        DO 50 J=1,NLOAD(I)
        DO 50 L=1,NLOAD(I)
        Y1(J,L,I)=Y1Q(J,L,I)
50      CONTINUE
45      CONTINUE
        CALL COMB(NTQ)
        ENDIF
        DO 55 I=1,NB
        IF(NTB(I).EQ.1) THEN
        CALL X1(I,L,M)
        VG(I)=VG(I)/VM(I)
        VM(I)=VM(I)-E0(L,M)
C        EQ0(L,M)=E0(L,M)
        VG(I)=VG(I)*VM(I)
        ENDIF
55      CONTINUE
        RETURN
        END

        SUBROUTINE SOLV(L)
        COMMON/G1/ TJ(60,60),DV(60)
        IF(L.EQ.1) THEN
        DV(1)=DV(1)/TJ(1,1)
        RETURN
        ENDIF
        K=L-1
        DO 5 I=1,K
        DV(I)=DV(I)/TJ(I,I)
        K1=I+1
        DO 5 J=K1,L
        DV(J)=DV(J)-DV(I)*TJ(J,I)
5       CONTINUE
        DV(L)=DV(L)/TJ(L,L)
        DO 10 I=1,K
        K1=L+1-I
        K2=K1-1
```

```
      DO 10 J=1,K2
      DV(J)=DV(J)-DV(K1)*TJ(J,K1)
10    CONTINUE
      RETURN
      END

      SUBROUTINE X1(I,J,K)
      COMMON/AR1/ NBB(400)
      COMMON/BUS3/ NAB(400)
      K=NAB(I)
      J=NBB(I)
      RETURN
      END


      SUBROUTINE X2(M,N,K)
      COMMON NA,NB,NL
      COMMON/LINE/ NSB(500),NEB(500)
      COMMON/TRA/ N1A(200),NTA(200)
      IF(M.LE.NL) THEN
      N=NSB(M)
      K=NEB(M)
      ELSE
      N=N1A(M-NL)
      K=NTA(M-NL)
      ENDIF
      RETURN
      END


      SUBROUTINE ZZ24(N)
      COMMON NA,NB,NL
      COMMON/BUS3/ NAB(400)
      COMMON/G1/ TJ(60,60)
      COMPLEX ZSE
      COMMON/LINE/ NSB(500),NEB(500),YSH(500),ZSE(500)
      COMPLEX TAP
      COMMON/TRA/ N1A(200),NTA(200),ZT(200),TAP(200)
      COMMON/Z24/ NZT(60),NAT(10),Z1(50,50,10),Z2(50,60,10)
      DO 10 I=1,NA
      K=NAT(I)
      DO 15 J=1,K
      DO 15 L=1,N
      Z2(J,L,I)=0.0
15    CONTINUE
10    CONTINUE
      DO 20 I=1,N
      J=NZT(I)
      CALL X2(J,L,K2)
      CALL X1(L,K1,M)
      K=NAT(M)
      DO 25 N1=1,K
      Z2(N1,I,M)=Z1(K1,N1,M)
```

```
25      CONTINUE
        CALL X1(K2,K1,M)
        K=NAT(M)
        DO 30 N1=1,K
        Z2(N1,I,M)=-Z1(K1,N1,M)
30      CONTINUE
20      CONTINUE
C        DO 352 I=1,NA
C        WRITE(*,567) I
C567     FORMAT(/,5X,'Z2 FOR AREA',5X,I3)
C        K=NAT(I)
C        DO 352 J=1,K
C        WRITE(*,346) (Z2(J,L,I),L=1,N)
C346     FORMAT(5X,10(F8.4,2X))
C352     CONTINUE
        DO 35 I=1,N
        J=NZT(I)
        CALL X2(J,L,K2)
        CALL X1(L,K,M)
        CALL X1(K2,I1,K1)
        DO 35 J=1,N
        TJ(I,J)=Z2(K,J,M)-Z2(I1,J,K1)
35      CONTINUE
        DO 40 I=1,N
        J=NZT(I)
        IF(J.LE.NL) X=-1.0/AIMAG(ZSE(J))
        IF(J.GT.NL) X=-REAL(TAP(J-NL))/ZT(J-NL)
        TJ(I,I)=TJ(I,I)+X
40      CONTINUE
C        WRITE(*,782)
C782     FORMAT(/,15X,'Z4 MATRIX')
C        DO 674 I=1,N
C        WRITE(*,346) (TJ(I,J),J=1,N)
C674     CONTINUE
        CALL FACTOR(N)
        RETURN
        END
```

Table G.1 Number of Elementary Operation in Computing

	Substration and Addition	Multiplication and Division
Automatic Tearing	2 + 2A + B [A (L + T) + B + A]	1 + A + B [A (1 + A)]
Per Itearation		
Combine Solution	TL + A (B + 2TL + 4)	A (2TL + 4)
FDLF Per Iteration	B + A + 2 (2A + 4B + 7TL +2)	2 (2A + 9B + 7TL + 2) + 2B (4TL + 3F)
Building Tables	2B	None
Building [Y-Bus]	B + 10L +16T + 2C	27T
Building [B'] and [B"]	16B + 18TL - 4A	$4TL + 2A [2 (F - 1)^{2} (F + 1)]$
Building $[Z'_{4}]$, $[Z''_{4}]$ and Factorization Matrices	3TL (F + 4) - 3	$L + (TL - 1)^{2} (TL / 2 + 1)$
Output and Miscllaneous	9B + 18L + 5T + C + 10TL + 3F + 4	14B + 29L + 13T + 18TL + 5

B = Bus, A = Area, L = Line, T = Transformer, TL = Tie-Line, C = Shunt Element, F = B / A

Biographical Sketch

Songsak Kongnoi was born in Bangkok Thailand, on November 30, 1961. He received the B.Eng. (EE.) from Kasetsart University, Bangkok in 1983 and the M.Eng. form Chulalongkorn University, Bangkok in 1985. He worked as a teacher assistant in the Department of Electrical Engineering, Chulalongkorn University. He is a member staff of electrical engineers of Power System Analysis Section, Power System Planning Devision, Systems Planning Department, Electricity Generating Authority of Thailand (EGAT). Also, he is a student member of the Institude of Electrical and Electronics Engineers (IEEE), a member of the Engineering Institude of Thailand Under H.M. The King 's Patronage, and Technological Promotion Association (Thai-Japan).