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XLF1 - A PROGRAM FOR COMPLEX LOAD FLOW ANALYSIS BY CONJUGATE ELIMINATION

J.W. Bandler, M.A. El-Kady and H. Gupta

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Abstract

XLF1 is a package of five compiled library subroutines for solving steady-state power flow equations in the compact complex mode. A user-supplied main program provides the necessary dimensional storage and system data. The program implements the recently developed algorithm for practical complex solution of power flow equations presented by Bandler, El-Kady and Gupta. Sensitivities of system states with respect to system control variables can also be evaluated by the program using a perturbation method. The program is written in Fortran IV, documented and tested on a CYBER 170 computer. The report includes a listing of the program, a user's guide and some illustrative examples.

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I. INTRODUCTION

The computer program package called XLF1 implements the practical complex solution of power flow equations presented by Bandler, El-Kady and Gupta [1], which uses the complex notation introduced by Bandler and El-Kady [2]. The user has to provide the main program which assigns the necessary dimensional storage and reads system data if the solution of the load flow equations is required. For sensitivity analysis using a perturbation method, a different main program is needed in which the package XLF1 is called an appropriate number of times. The user can also assess transmission contingencies by the same approach, where one line at a time is taken out. Some examples of these problems are included in this report to illustrate the versatility of the program.

This package is particularly designed to solve problems of moderate size. Its 501 Fortran statements require about 7.2 K bytes of storage on the CYBER 170/730 machine when compiled using the Fortran compiler with OPT = 1. The total number of lines in the program is 839.

Fig. 1, with arrows emanating from calling subprograms and leading to called subroutines, highlights the overall organization of the program units.

II. SUBROUTINES AND VARIABLES

This section describes all the subroutines and variables that could be of interest to the user. The essential information regarding the dimensions and initialization is also provided in Table I in a condensed form. In addition, a more comprehensive explanation of various features

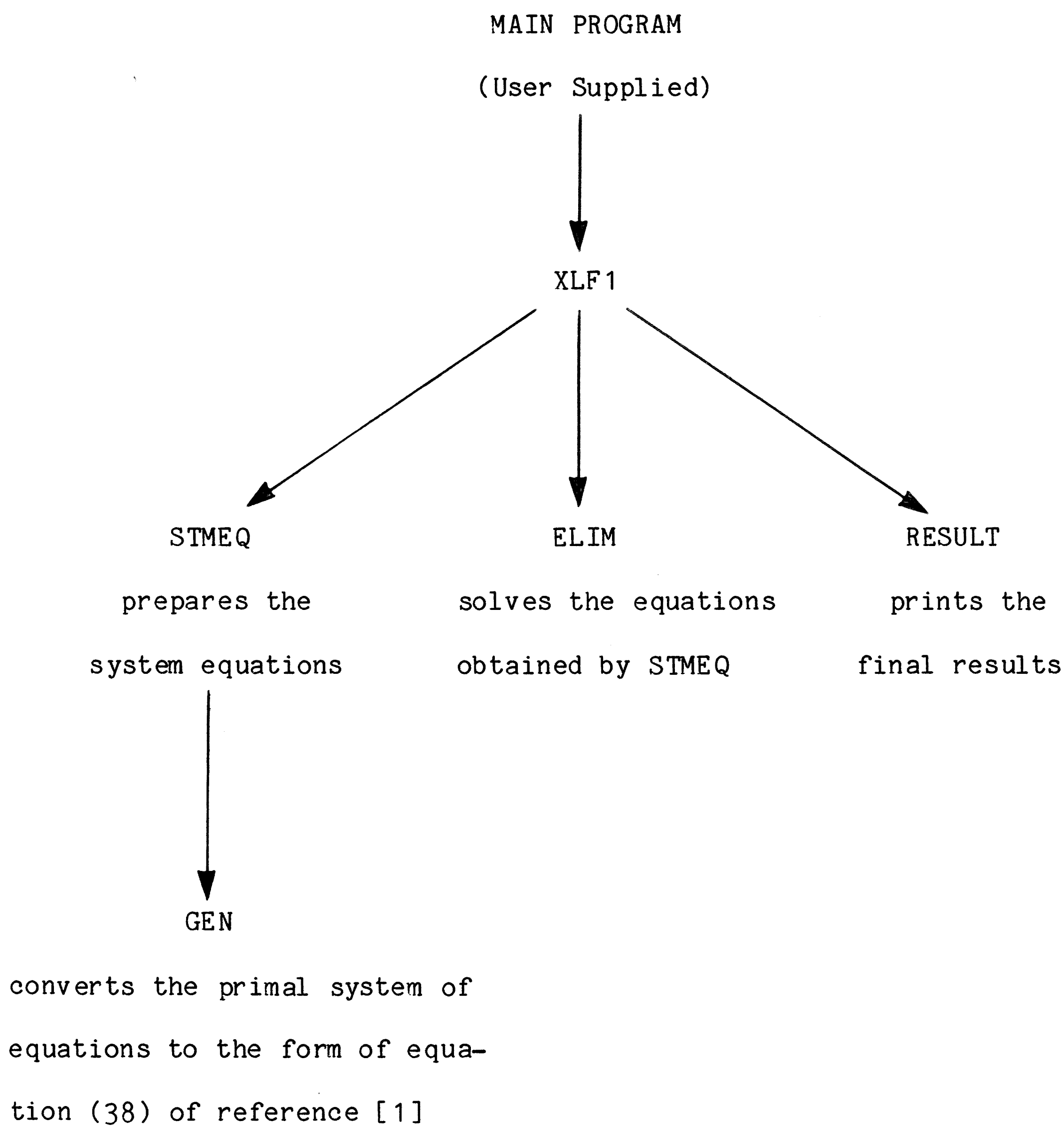

Fig. 1 Overall organization of the XLF1 package

is included in the comment statements in the program listing.

Subroutines

XLF1 — This is the main subroutine of the XLF1 package, which is called by the user's main program. This subroutine solves the load flow problem by calling subroutines, STMEQ, ELIM and RESULT.

ELIM — This subroutine solves equations obtained by STMEQ using conjugate reduction combined with forward Gaussian elimination as introduced by Bandler and El-Kady [2].

RESULT — This subroutins prints the final results in an appropriate format.

STMEQ — This subroutine reads line data (from tape 3) and prepares the system equations to the form of equation (38) of the paper by Bandler, El-Kady and Gupta [1]. Subroutine GEN is called for this purpose.

GEN — This subroutine is called by subroutine STMEQ to convert the primal system of equations to the form of equation (38) of the paper by Bandler, El-Kady and Gupta [1].

Integer Variables

IA,JA — (IA,JA) represents a transmission line connecting buses IA and JA.

IAC,JAC — (IAC,JAC) is the transmission line whose parameters have been altered by the user.

ICHTL = 0 — if there is no alteration in the line data file required by the user. Normally, it is zero for load flow analysis.

= 1 if parameters of one line have been altered by the user (i.e., the parameters of one line differ from the line data file and the user does not want to change the line data file). Normally, it is 1 for performing sensitivity analysis by a perturbation method.

= 2 if one line is to be removed for contingency analysis.

IG NGB dimensional array which stores the generator bus indices. IG(I) is the bus number of the Ith generator bus, where I = 1, ..., NGB.

IT current iteration number.

ITMAX maximum number of iterations after which program will stop.

IWRITE variable to control printouts.

= 0 prints the final load flow solution only.

= 1 prints results iteration-wise as well as the final load flow solution. Iteration wise results include bus currents, mismatches, bus voltages and correction voltage vector.

= 2 suppresses all printouts.

IZ N dimensional array.

IZ(I) = 0 if the modulus of the bus current of the Ith bus is $>10^{-6}$.

= I if the modulus of the bus current of the Ith bus is $\leq 10^{-6}$.

IZB an array to identify the zero current buses during the iteration. IZB(I) is the bus number of the Ith zero current bus (modulus of the bus current $\leq 10^{-6}$), where I = 1,...,NIZ. As NIZ is not known at the beginning, the dimension of IZB is taken as equal to the number of expected zero current buses during the solution process. This dimension can be equal to or slightly larger than the number of dummy buses.

KA — N dimensional array identifying the type of bus.

KA(I) = 0 if the Ith bus is a load bus.

= 1 if the Ith bus is a generator bus.

(Note: The NBth bus is taken as the slack bus.)

N — NB-1

NB — total number of buses.

NGB — number of generator buses.

NIZ — number of zero current buses.

Real Variables

CC — altered transformer tap between buses IAC and JAC.

SHTLC — altered value of half shunt susceptance of the transmission line (IAC,JAC).

TOLV — tolerance over bus voltages to the accuracy the final solution is required.

Complex Variables

AI — NB dimensional array of bus currents.

AK — NxN matrix which is denoted by $\underset{\sim}{K}_{SM}$ in equation (20) of SOC-270 [1].

BGK — NGBxN matrix which is denoted by $[\bar{\underset{\sim}{K}}_{GL}\ \bar{\underset{\sim}{K}}_{GD}\ \bar{\underset{\sim}{K}}_{GG}]$ in equation (32) of SOC-270 [1]. These are coefficients of the conjugate of the bus voltages in the equations of the generator buses.

CV NB dimensional array of the conjugate of V.

DS NB dimensional array which represents mismatches as well as correction voltages.

S N dimensional array of load bus powers, and generator bus active power and modulus of the voltage, which is represented as $P_G + j|V_G|$. See equation (15) of SOC-270 [1].

V NB dimensional array of bus voltages, i.e., bus voltage vector.

Y line admittance.

YL half leakage admittance of the line.

ZC altered impedance of line (IAC,JAC).

III. HOW TO USE THE PROGRAM

In order to use the XLF1 package, the user has to prepare the following programs and data.

Main Program

The main program must provide the dimensions and execute reading of all the system data except line data, i.e., the number of buses, the number of generator buses, the tolerance over bus voltage to the accuracy the final solution is required, the maximum number of iterations, specified bus powers, initial bus voltages, type of buses, and parameters of the transmission line where parameters have been altered by the user.

Line Data File

The line data file must be available on tape (unit) 3 arranged in free format and in the following sequence.

READ (3,*) ICODE, IA, JA, A1, A2, A3, A4, A5

where

ICODE		code to identify data card.
	= 4	for a transmission line without a transformer.
	= 7	for a transmission line having a transformer.
IA, JA		(IA,JA) represents a transmission line connecting buses IA and JA.
A1		identifies the circuit number if ICODE = 4.
		identifies the type of transformation ratio if ICODE = 7.
	= 0	for fixed tap.
	= 1	for real transformation ratio.
	= 2	for complex transformation ratio.
A2		denotes the branch type if ICODE = 4.
		series resistance of the line if ICODE = 7.
A3		series resistance of the line if ICODE = 4.
		series reactance of the line if ICODE = 7.
A4		series reactance of the line if ICODE = 4.
		real part of the transformation ratio if ICODE = 7.
A5		half shunt susceptance of the line if ICODE = 4.
		imaginary part of the transformation ratio if ICODE = 7.

This program does not use A1 or A2 if ICODE = 4 and A5 if ICODE = 7 as the program solves the load flow equations with real transformation ratios. Line data is read by subroutine STMEQ and used for preparing the system equations.

Dimensions and Initialization

For the purpose of dimensioning and initializations, Table I should be consulted. Note that the last bus is taken as the slack bus. Some illustrative examples have been included in this report.

TABLE I

ESSENTIAL INFORMATION ON DIMENSIONS AND INITIALIZATION
FOR THE MAIN PROGRAM

Variable Name	Initialized by User	Dimensions In Main Program
IAC,JAC	Yes if ICHTL = 1 or 2	
ICHTL	Yes	
IG	No	NGB
IWRITE	Yes	
ITMAX	Yes	
IZ	No	N = NB - 1
IZB	No	Equal to or slightly greater than the number of dummy buses
KA	Yes	N
NB	Yes	
NGB	Yes	
Real Variables		
CC	Yes if ICHTL = 1	
SHTLC	Yes if ICHTL = 1	
TOLV	Yes	
Complex Variables		
AI	No	NB
AK	No	NxN
BGK	No	NGBxN
CV	No	NB
DS	No	N
S	Yes	N
V	Yes	NB
ZC	Yes if ICHTL = 1	

IV. EXAMPLES

Six examples are presented in this section to illustrate the flexibility and power of XLF1. For each example, a complete listing of the main program and the output has been provided. The listing of XLF1 is given in the Appendix.

We consider 6-bus and 26-bus power systems in the examples to be described in this report. The structure and line diagrams of these power systems are shown in Figs. 2 and 3, respectively. The detailed data of the 6-bus and 26-bus power systems are tabulated by Tables II-V. All the values shown are in per unit. The computations have been performed on a CYBER 170 computer. TOLV for all examples is taken as 10^{-6} which gives an accuracy over mismatches of 10^{-12}.

Examples 1 and 2 determine the load flow solution of the 6-bus and 26-bus power systems, respectively. Example 3 deals with contingency analysis of the 26-bus power system.

The sensitivities of state variables with respect to the control variables for the 26-bus power system are determined in Examples 4-6 by perturbation. The basic formula used is

$$\frac{dF}{dt} \simeq \frac{\Delta F}{\Delta t} = \frac{F\,(t + \frac{\Delta t}{2}) - F(t - \frac{\Delta t}{2})}{\Delta t}\ , \qquad (1)$$

where Δt is very small.

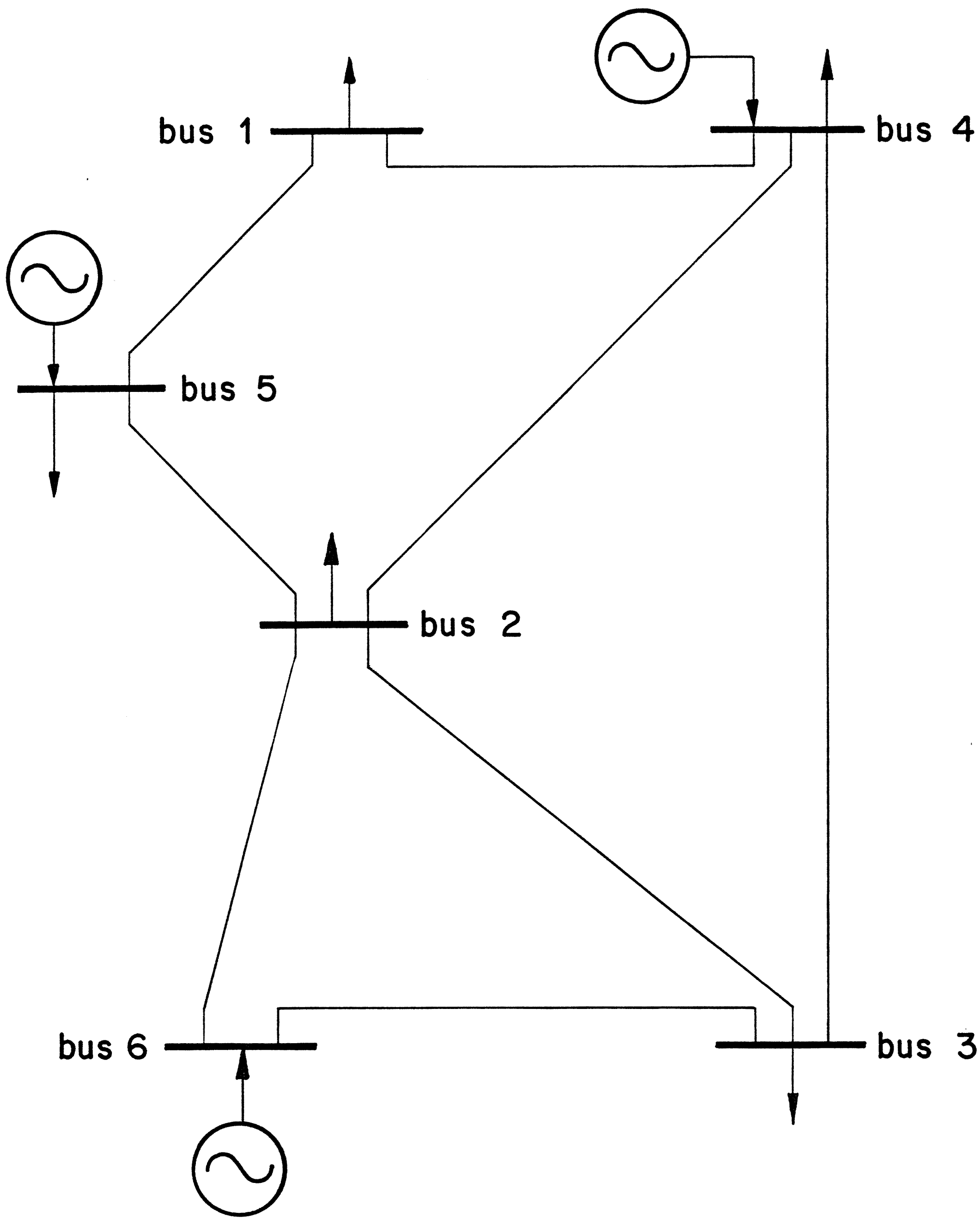

Fig. 2 6-bus power system

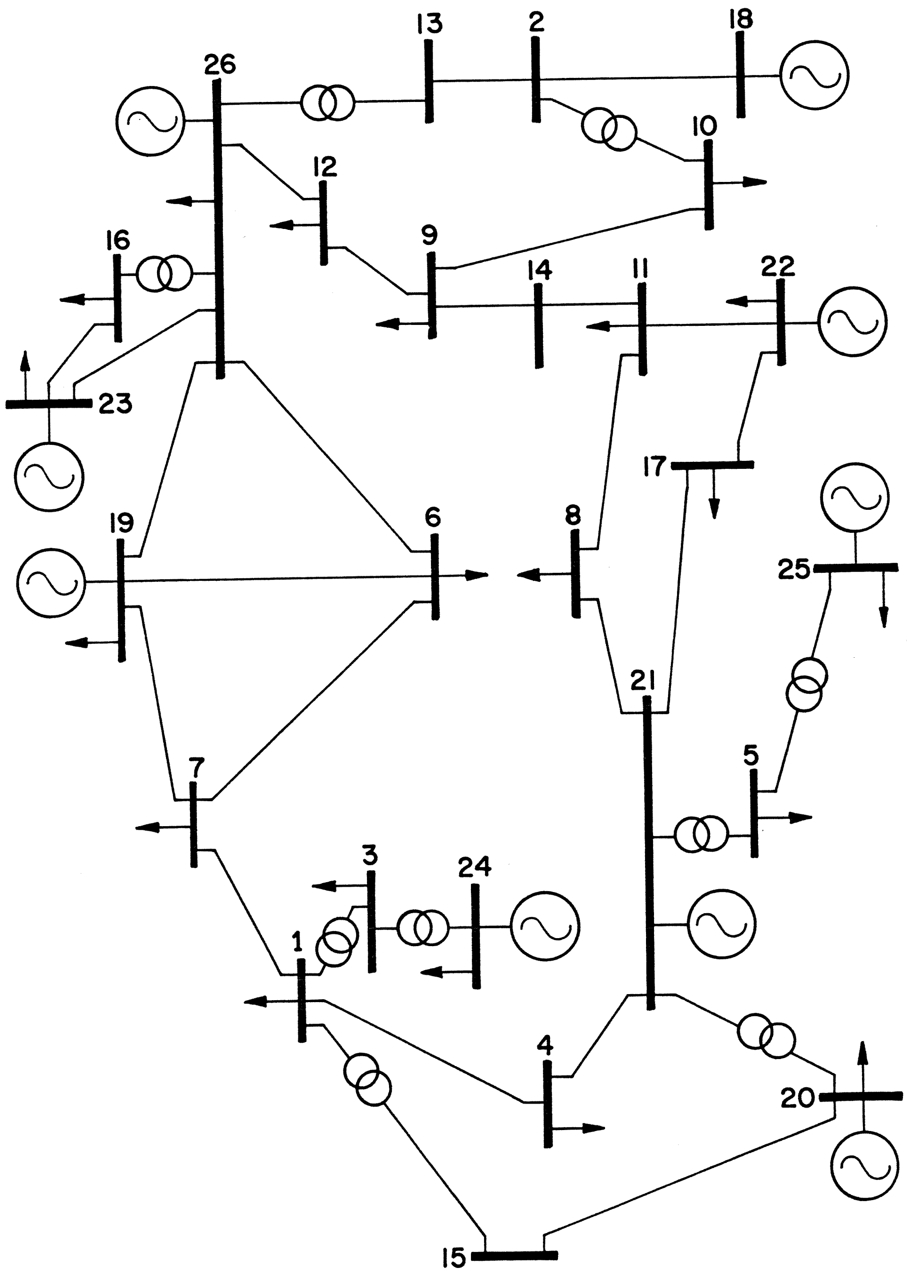

Fig. 3 26-bus power system

TABLE II

LINE DATA FOR 6-BUS POWER SYSTEM

Line No.	Terminal Buses	Resistance R_t (pu)	Reactance X_t (pu)	Number of Lines
1	1,4	0.05	0.20	1
2	1,5	0.025	0.10	2
3	2,3	0.10	0.40	1
4	2,4	0.10	0.40	1
5	2,5	0.05	0.20	1
6	2,6	0.01875	0.075	4
7	3,4	0.15	0.60	1
8	3,6	0.0375	0.15	2

TABLE III

BUS DATA FOR 6-BUS POWER SYSTEM

Bus No.	Bus Type	P_m (pu)	Q_m (pu)	$\|V_m\|\angle\delta_m$ (pu)
1	load	-2.40	0	- $\angle$-
2	load	-2.40	0	- $\angle$-
3	load	-1.60	-0.40	- $\angle$-
4	generator	-0.30	-	1.02 $\angle$-
5	generator	1.25	-	1.04 $\angle$-
6	slack	-	-	1.04 $\angle$-

TABLE IV

LINE DATA FOR 26-BUS POWER SYSTEM

Line No.	Terminal Buses	Resistance R_t (pu)	Reactance X_t (pu)	1/2 Shunt Susceptance
1	13,26	0.0	0.0131	0.0
2	26,16	0.0	0.0392	0.0
3	16,23	0.0	0.4320	0.0
4	23,26	0.0	0.3140	0.0
5	2,10	0.0	0.0150	0.0
6	9,10	0.1494	0.3392	0.4120
7	9,12	0.0658	0.1494	0.0182
8	12,26	0.0533	0.1210	0.0147
9	9,14	0.0618	0.2397	0.0319
10	11,14	0.0676	0.2620	0.0349
11	19,26	0.0610	0.2521	0.0295
12	6,26	0.0513	0.1986	0.0265
13	6,19	0.0129	0.0532	0.0074
14	7,19	0.0906	0.3742	0.0437
15	6,7	0.0921	0.3569	0.0475
16	11,22	0.0513	0.2118	0.0248
17	8,11	0.0865	0.3355	0.0447
18	17,22	0.0281	0.1869	0.0237
19	8,21	0.0735	0.2847	0.0379
20	17,21	0.0459	0.3055	0.0387
21	1,4	0.0619	0.2401	0.0319
22	4,21	0.0610	0.2365	0.0315
23	20,21	0.0	0.0305	0.0
24	15,1	0.0	0.0147	0.0
25	2,13	0.0086	0.0707	0.3017
26	1,7	0.0199	0.0785	0.0404
27	15,20	0.0107	0.0617	0.4471
28	2,18	0.0074	0.0608	0.2593
29	1,3	0.0	0.0392	0.0
30	24,3	0.0	0.1450	0.0
31	5,21	0.0	0.1750	0.0
32	5,25	0.0	0.154	0.0

TABLE V

BUS DATA FOR 26-BUS POWER SYSTEM

Bus No.	Injected Power		Bus Voltage	
	P_m	Q_m	$\lvert V_m \rvert$	δ_m
1	-0.82	-0.21	-	-
2	0.0	0.0	-	-
3	-0.57	-0.17	-	-
4	-0.48	-0.21	-	-
5	-0.43	-0.11	-	-
6	-0.40	-0.10	-	-
7	-1.11	-0.27	-	-
8	-0.23	-0.06	-	-
9	-0.67	-0.21	-	-
10	-1.02	-0.27	-	-
11	-0.43	-0.14	-	-
12	-0.43	-0.12	-	-
13	0.0	0.0	-	-
14	0.0	0.0	-	-
15	0.0	0.0	-	-
16	-1.31	-0.30	-	-
17	-0.03	-0.01	-	-
18	2.80	-	1.07	-
19	1.45	-	1.05	-
20	2.80	-	1.00	-
21	1.10	-	1.02	-
22	-0.56	-	0.89	-
23	-0.04	-	1.00	-
24	-0.05	-	1.00	-
25	0.63	-	1.00	-
26	0.0	-	1.01	0.0

Transformer tap ($a_{mm'}$) between buses m and m'

$a_{13,26} = 1.03$, $a_{26,16} = 0.96$, $a_{2,10} = 1.03$,

$a_{20,21} = 0.97$, $a_{15,1} = 0.98$, $a_{1,3} = 0.98$,

$a_{24,3} = 0.98$, $a_{5,21} = 0.99$, $a_{5,25} = 1.03$

Bus Type

$n_L = 17$, $n_G = 8$

Example 1

In this example the load flow solution of the 6-bus power system is determined by the package XLF1. The listing of the main program is given on page 18. Two input data files TL6 and BUS6 are created:

1) TL6 transmission line data file.

2) BUS6 bus data file.

Input data files TL6 and BUS6 are listed on page 19. The program output is reported on pages 20-25. The final load flow solution is reported on page 25.

```
      PROGRAM MAIN( INPUT,OUTPUT,TL6,BUS6,TAPE5=BUS6,TAPE6=OUTPUT,TAPE3=
     1TL6)
C
      COMPLEX V(6),CV(6),AI(6),S(5),DS(5),AK(5,5),BGK(2,5)
      DIMENSION KA(5),IG(2),IZ(5),IZB(2)
C
C     THIS IS THE MAIN PROGRAM FOR SOLVING THE POWER FLOW EQUATIONS
C
C     USING THE COMPUTER PROGRAM PACKAGE CALLED XLF1
C
C     ******************************************************************
C
      READ (5,20) NB,NGB,ITMAX,ICHTL,IWRITE
      READ (5,30) TOLV
      N=NB-1
      DO 10 I=1,N
      READ (5,40) S(I),V(I),KA(I)
10    CONTINUE
      READ (5,50) V(NB)
      CALL XLF1 (V,CV,AI,S,DS,AK,BGK,KA,IG,IZ,IZB,NB,N,NGB,ITMAX,TOLV,IC
     1HTL,IAC,JAC,ZC,SHTLC,CC,IWRITE)
      STOP
C
20    FORMAT (10I5)
30    FORMAT (E15.5)
40    FORMAT (4F10.5,I5)
50    FORMAT (2F10.5)
      END
```

Data File TL6 for Example 1

```
4,1,4,1,1,0.05,.2,0.0
4,1,5,1,1,0.025,0.1,0.0
4,2,3,1,1,0.1,0.4,0.0
4,2,4,1,1,0.1,0.4,0.0
4,2,5,1,1,0.05,0.2,0.0
4,3,4,1,1,0.15,0.6,0.0
4,3,6,1,1,0.0375,0.15,0.0
4,2,6,1,1,0.01875,0.075,0.0
```

Data File BUS6 for Example 1

```
   6    2     7     0     1
          .1E-5
 -2.4     0.0         1.0       0.0          0
 -2.4     0.0         1.0       0.0          0
 -1.6     -0.4        1.0       0.0          0
 -0.3     1.02        1.02      0.0          1
 1.25     1.04        1.04      0.0          1
 1.04     0.0
```

ITERATION NO. 1 OF XLF1

BUS NO.	BUS CURRENT(AI)		MISMATCHES(DS)	
	REAL	IMAGINARY	REAL	IMAGINARY
1	-.11765E+00	.47059E+00	-.22824E+01	-.47059E+00
2	-.18431E+00	.73725E+00	-.22157E+01	-.73725E+00
3	-.70588E-01	.28235E+00	-.15294E+01	.11765E+00
4	.43137E-01	-.17255E+00	-.34400E+00	0.
5	.14118E+00	-.56471E+00	.11032E+01	0.

BUS NO.	VOLTAGE		VOLTAGE CORRECTION VECTOR	
	REAL	IMAGINARY	REAL	IMAGINARY
1	.99310E+00	-.58403E+00	-.68966E-02	-.58403E+00
2	.10029E+01	-.26520E+00	.29450E-02	-.26520E+00
3	.95323E+00	-.26781E+00	-.46769E-01	-.26781E+00
4	.10200E+01	-.49117E+00	.89623E-13	-.49117E+00
5	.10400E+01	-.41966E+00	.19307E-12	-.41966E+00

ITERATION NO. 2 OF XLF1

BUS NO.	BUS CURRENT(AI)		MISMATCHES(DS)	
	REAL	IMAGINARY	REAL	IMAGINARY
1	-.21260E+01	.71955E-01	-.24666E+00	.11702E+01
2	-.22039E+01	.46709E-01	-.17719E+00	.53764E+00
3	-.15277E+01	.43211E+00	-.28041E-01	.39723E+00
4	-.37721E+00	-.38270E+00	-.10322E+00	-.11210E+00
5	.97405E+00	-.41073E+00	.64619E-01	-.81480E-01

BUS NO.	VOLTAGE		VOLTAGE CORRECTION VECTOR	
	REAL	IMAGINARY	REAL	IMAGINARY
1	.79592E+00	-.60185E+00	-.19718E+00	-.17818E-01
2	.92797E+00	-.27936E+00	-.74973E-01	-.14162E-01
3	.87047E+00	-.26886E+00	-.82765E-01	-.10505E-02
4	.87793E+00	-.52783E+00	-.14207E+00	-.36657E-01
5	.93494E+00	-.46229E+00	-.10506E+00	-.42625E-01

ITERATION NO. 3 OF XLF1

BUS NO.	BUS CURRENT(AI)		MISMATCHES(DS)	
	REAL	IMAGINARY	REAL	IMAGINARY
1	-.20854E+01	.12788E+01	.29499E-01	.23725E+00
2	-.23814E+01	.66430E+00	-.45576E-02	.48816E-01
3	-.15587E+01	.89675E+00	-.20810E-02	.38489E-01
4	-.57253E+00	-.44051E+00	-.29869E-01	-.43835E-02
5	.78797E+00	-.12280E+01	-.54385E-01	-.29843E-02

BUS NO.	VOLTAGE		VOLTAGE CORRECTION VECTOR	
	REAL	IMAGINARY	REAL	IMAGINARY
1	.77345E+00	-.60028E+00	-.22472E-01	.15732E-02
2	.92099E+00	-.28255E+00	-.69778E-02	-.31901E-02
3	.86204E+00	-.26994E+00	-.84248E-02	-.10791E-02
4	.86636E+00	-.53857E+00	-.11572E-01	-.10741E-01
5	.92560E+00	-.47443E+00	-.93334E-02	-.12143E-01

ITERATION NO. 4 OF XLF1

BUS NO.	BUS CURRENT(AI)		MISMATCHES(DS)	
	REAL	IMAGINARY	REAL	IMAGINARY
1	-.19421E+01	.15005E+01	.28715E-02	.52077E-02
2	-.23821E+01	.73029E+00	.20584E-03	.46258E-03
3	-.15582E+01	.95142E+00	.63372E-04	.46000E-03
4	-.65452E+00	-.49877E+00	-.15746E-02	-.11278E-03
5	.64489E+00	-.13834E+01	-.32222E-02	-.10848E-03

BUS NO.	VOLTAGE		VOLTAGE CORRECTION VECTOR	
	REAL	IMAGINARY	REAL	IMAGINARY
1	.77301E+00	-.60019E+00	-.43554E-03	.88604E-04
2	.92085E+00	-.28264E+00	-.14201E-03	-.87338E-04
3	.86189E+00	-.26998E+00	-.14641E-03	-.38698E-04
4	.86605E+00	-.53885E+00	-.30761E-03	-.28122E-03
5	.92532E+00	-.47475E+00	-.28624E-03	-.32061E-03

ITERATION NO. 5 OF XLF1

BUS NO.	BUS CURRENT(AI) REAL	BUS CURRENT(AI) IMAGINARY	MISMATCHES(DS) REAL	MISMATCHES(DS) IMAGINARY
1	-.19370E+01	.15040E+01	.19152E-05	.19341E-05
2	-.23819E+01	.73108E+00	.92743E-07	.97458E-07
3	-.15581E+01	.95216E+00	.40761E-07	.10501E-06
4	-.65711E+00	-.49937E+00	-.96561E-06	-.78917E-07
5	.64013E+00	-.13853E+01	-.19943E-05	-.83149E-07

BUS NO.	VOLTAGE REAL	VOLTAGE IMAGINARY	VOLTAGE CORRECTION VECTOR REAL	VOLTAGE CORRECTION VECTOR IMAGINARY
1	.77301E+00	-.60019E+00	-.18127E-06	.38893E-07
2	.92085E+00	-.28264E+00	-.73414E-07	-.44605E-07
3	.86189E+00	-.26998E+00	-.63943E-07	-.22760E-07
4	.86605E+00	-.53885E+00	-.17457E-06	-.13119E-06
5	.92532E+00	-.47475E+00	-.17070E-06	-.15056E-06

FINAL BUS CURRENTS AND MISMATCHES

BUS NO.	BUS CURRENT(AI) REAL	BUS CURRENT(AI) IMAGINARY	MISMATCHES(DS) REAL	MISMATCHES(DS) IMAGINARY
1	-.19370E+01	.15040E+01	.45475E-12	.19185E-12
2	-.23819E+01	.73108E+00	-.28422E-13	.35527E-14
3	-.15581E+01	.95216E+00	0.	.23093E-13
4	-.65711E+00	-.49937E+00	-.20961E-12	-.21316E-13
5	.64012E+00	-.13853E+01	-.40501E-12	-.21316E-13
6	.58940E+01	-.13025E+01		

LOAD FLOW SOLUTION OF 6-BUS POWER SYSTEM

LOAD BUSES:

V(1) = .77301 - J .60019   V(2) = .92085 - J .28264

V(3) = .86189 - J .26998

GENERATOR BUSES

Q(4) = .78656   V(4) = .86605 - J .53885

Q(5) = .97796   V(5) = .92532 - J .47475

SLACK BUS

P(6) = 6.12978   Q(6) = 1.35460

TOTAL NUMBER OF ITERATIONS TAKEN BY XLF1 = 5

TOTAL EXECUTION TIME TAKEN BY XLF1 = .639 SECONDS

Example 2

The 26-bus power system load flow problem is solved using the package XLF1. The listing of the main program is given on page 27. Two input data files TL26 and BUS26 are created:

1) TL26 transmission line data file.

2) BUS26 bus data file.

These files are found on page 28 and are also used as the input data files for Examples 3-6. The program output is presented on pages 29-36. The final load flow solution is reported on page 36.

```
      PROGRAM MAIN(INPUT,OUTPUT,TL26,BUS26,TAPE5=BUS26,TAPE6=OUTPUT,
     1TAPE3=TL26)
C
      COMPLEX V(26),CV(26),AI(26),S(25),DS(25),AK(25,25),BGK(8,25),ZC
      DIMENSION KA(25),  IG(8),  IZ(25),  IZB(6)
C
C     THIS IS THE MAIN PROGRAM FOR SOLVING THE POWER FLOW EQUATIONS
C
C     USING THE COMPUTER PROGRAM PACKAGE CALLED XLF1
C
C     ************************************************************************
C
      READ (5,20)  NB,NGB,ITMAX,ICHTL,IWRITE
      READ (5,30)  TOLV
      N=NB-1
      DO 10 I=1,N
      READ (5,40)  S(I),V(I),KA(I)
10    CONTINUE
      READ (5,50)  V(NB)
      CALL XLF1 (V,CV,AI,S,DS,AK,BGK,KA,IG,IZ,IZB,NB,N,NGB,ITMAX,TOLV,IC
     1HTL,IAC,JAC,ZC,SHTLC,CC,IWRITE)
      STOP
C
20    FORMAT (10I5)
30    FORMAT (E15.5)
40    FORMAT (4F10.5,I5)
50    FORMAT (2F10.5)
      END
```

Data File TL26 for Examples 2-6

```
4,16,23,1,1,0.0,0.432,0.0
7,2,10,1,0.0,0.0150,1.03,0.0
4,9,10,1,1,0.1494,0.3392,0.4120
4,9,12,1,1,0.0658,0.1494,0.0182
4,9,14,1,1,0.0618,0.2397,0.0319
4,11,14,1,1,0.0676,0.2620,0.0349
4,6,19,1,1,0.0129,0.0532,0.0074
4,7,19,1,1,0.0906,0.3742,0.0487
4,6,7,1,1,0.0921,0.3569,0.0475
4,11,22,1,1,0.0513,0.2118,0.0248
4,8,11,1,1,0.0865,0.3355,0.0447
4,17,22,1,1,0.0281,0.1869,0.0237
4,8,21,1,1,0.0735,0.2847,0.0379
4,17,21,1,1,0.0459,0.3055,0.0387
4,1,4,1,1,0.0619,0.2401,0.0319
4,4,21,1,1,0.0610,0.2365,0.0315
7,20,21,1,0.0,0.0305,0.97,0.0
7,15,1,1,0.0,0.0147,0.89,0.0
4,2,13,1,1,0.0086,0.0707,0.3017
4,1,7,1,1,0.0199,0.0785,0.0404
4,15,20,1,1,0.0107,0.0617,0.4471
4,2,18,1,1,0.0074,0.0608,0.2593
7,1,3,1,0.0,0.0392,.98,0.0
7,24,3,1,0.0,0.1450,0.98,0.0
7,5,21,1,0.0,0.1750,0.99,0.0
7,5,25,1,0.0,0.1540,1.03,0.0
7,13,26,1,0.0,0.0131,1.03,0.0
7,26,16,1,0.0,0.0392,0.96,0.
4,23,26,1,1,0.0,0.3140,0.0
4,12,26,1,1,0.0533,0.1210,0.0147
4,19,26,1,1,0.0610,0.2521,0.0295
4,6,26,1,1,0.0513,0.1986,0.0265
```

Data File BUS26 for Examples 2-6

```
  26     8      7      0      1
         0.1E-5
 -0.82     -0.21      1.0       0.0       0
 0.0       0.0        1.0       0.0       0
 -0.57     -0.17      1.0       0.0       0
 -0.48     -0.21      1.0       0.0       0
 -0.43     -0.11      1.0       0.0       0
 -0.40     -0.1       1.0       0.0       0
 -1.11     -0.27      1.0       0.0       0
 -0.23     -0.06      1.0       0.0       0
 -0.67     -0.21      1.0       0.0       0
 -1.02     -0.27      1.0       0.0       0
 -0.43     -0.14      1.0       0.0       0
 -0.43     -0.12      1.0       0.0       0
 0.0       0.0        1.0       0.0       0
 0.0       0.0        1.0       0.0       0
 0.0       0.0        1.0       0.0       0
 -1.31     -0.30      1.0       0.0       0
 -0.03     -0.01      1.0       0.0       0
 2.80      1.07       1.07      0.0       1
 1.45      1.05       1.05      0.0       1
 2.80      1.0        1.0       0.0       1
 1.10      1.02       1.02      0.0       1
 -0.56     0.89       0.89      0.0       1
 -0.04     1.0        1.0       0.0       1
 -0.05     1.0        1.0       0.0       1
 0.63      1.0        1.0       0.0       1
 1.01      0.0
```

ITERATION NO.   1 OF XLF1

BUS NO.	BUS CURRENT(AI) REAL	IMAGINARY	MISMATCHES(DS) REAL	IMAGINARY
1	0.	.79489E+01	-.82000E+00	-.77389E+01
2	-.13808E+00	.35807E+01	.13808E+00	-.35807E+01
3	0.	.66136E+00	-.57000E+00	-.49136E+00
4	-.20452E-01	.14269E+00	-.45955E+00	.67308E-01
5	0.	.24076E+00	-.43000E+00	-.13076E+00
6	-.22743E+00	.10163E+01	-.17257E+00	-.91626E+00
7	-.30560E-01	.25782E+00	-.10794E+01	.12181E-01
8	-.17003E-01	.14846E+00	-.21300E+00	-.83460E-01
9	0.	.46210E+00	-.67000E+00	-.25210E+00
10	0.	-.15297E+01	-.10200E+01	.17997E+01
11	.11882E+00	-.38618E+00	-.54882E+00	.52618E+00
12	-.30489E-01	.10211E+00	-.39951E+00	.17886E-01
13	0.	.32014E+01	0.	-.32014E+01
14	0.	.66800E-01	0.	-.66800E-01
15	0.	-.89999E+01	0.	.89999E+01
16	0.	.13287E+01	-.13100E+01	-.10287E+01
17	.76912E-01	-.44912E+00	-.10691E+00	.45912E+00
18	.13808E+00	-.85706E+00	.26523E+01	0.
19	.28207E+00	-.10791E+01	.11533E+01	0.
20	0.	.77729E-01	.28000E+01	0.
21	.47073E-01	.20281E+00	.10520E+01	0.
22	-.20535E+00	.11093E+01	-.37724E+00	0.
23	0.	.31847E-01	-.40000E-01	0.
24	0.	-.14362E+00	-.50000E-01	0.
25	0.	-.18913E+00	.63000E+00	0.

BUS NO.	VOLTAGE REAL	IMAGINARY	VOLTAGE CORRECTION VECTOR REAL	IMAGINARY
1	.10911E+01	.11125E+00	.91134E-01	.11125E+00
2	.10893E+01	.10522E+00	.89329E-01	.10522E+00
3	.10902E+01	.87430E-01	.90207E-01	.87430E-01
4	.10237E+01	.13888E+00	.23677E-01	.13888E+00
5	.10112E+01	.30226E+00	.11166E-01	.30226E+00
6	.10407E+01	.68812E-01	.40694E-01	.68812E-01
7	.10556E+01	.45791E-01	.55594E-01	.45791E-01
8	.97005E+00	.85915E-01	-.29952E-01	.85915E-01
9	.99168E+00	-.93390E-01	-.83165E-02	-.93390E-01
10	.10591E+01	.81652E-01	.59099E-01	.81652E-01
11	.92594E+00	-.54603E-01	-.74064E-01	-.54603E-01
12	.98315E+00	-.67568E-01	-.16850E-01	-.67568E-01
13	.10522E+01	.17227E-01	.52159E-01	.17227E-01
14	.96810E+00	-.76881E-01	-.31902E-01	-.76881E-01
15	.97892E+00	.14122E+00	-.21975E-01	.14122E+00
16	.10388E+01	-.47073E-01	.38823E-01	-.47073E-01
17	.94734E+00	.85223E-01	-.52663E-01	.85223E-01
18	.10700E+01	.28787E+00	.23821E-13	.28787E+00
19	.10500E+01	.11543E+00	-.66919E-13	.11543E+00
20	.10000E+01	.28304E+00	-.15987E-12	.28304E+00
21	.10200E+01	.27365E+00	.11289E-12	.27365E+00
22	.89000E+00	-.31489E-01	.10458E-12	-.31489E-01
23	.10000E+01	-.26931E-01	-.16913E-13	-.26931E-01
24	.10000E+01	.80325E-01	-.23398E-12	.80325E-01
25	.10000E+01	.40219E+00	.97810E-14	.40219E+00

ITERATION NO. 2 OF XLF1

BUS NO.	BUS CURRENT(AI)		MISMATCHES(DS)	
	REAL	IMAGINARY	REAL	IMAGINARY
1	-.17043E+01	-.51442E+00	.10968E+01	.58170E+00
2	-.36443E+00	-.33439E+00	.43217E+00	.32591E+00
3	-.62782E+00	.11034E+00	.10481E+00	-.51841E-02
4	-.49933E+00	.20378E+00	.28543E-02	-.67955E-01
5	-.50277E+00	.10731E+00	.45950E-01	-.15048E+00
6	-.46068E+00	.42994E-01	.76465E-01	.23557E-01
7	-.11201E+01	.25427E+00	.60735E-01	-.49694E-01
8	-.24326E+00	.62986E-01	.56648E-03	-.21999E-01
9	-.62684E+00	.21384E+00	-.28398E-01	.56476E-01
10	-.89509E+00	.36041E+00	-.10144E+00	-.18479E+00
11	-.44229E+00	.10491E+00	-.14743E-01	.67010E-01
12	-.42361E+00	.12378E+00	-.51603E-02	.26928E-01
13	-.55151E-01	-.16698E+00	.60904E-01	.17474E+00
14	.51357E-02	.21310E-02	-.48089E-02	-.24579E-02
15	.12710E+01	-.19778E+00	-.12152E+01	.37293E+00
16	-.12475E+01	.24842E+00	-.24202E-02	.10066E+00
17	.12326E-01	-.70973E-02	-.41072E-01	.17774E-01
18	.28474E+01	.95101E+00	-.52048E+00	-.38046E-01
19	.14996E+01	.13157E+00	-.13975E+00	-.63259E-02
20	.27780E+01	.11892E+00	-.11659E-01	-.39284E-01
21	.10240E+01	.48196E+00	-.76389E-01	-.36071E-01
22	-.58997E+00	.43659E+00	-.21182E-01	-.55687E-03
23	-.39142E-01	.12171E+00	.24202E-02	-.36257E-03
24	-.38464E-01	.49120E+00	-.50991E-01	-.32208E-02
25	.70607E+00	-.11874E+00	-.28312E-01	-.77847E-01

BUS NO.	VOLTAGE		VOLTAGE CORRECTION VECTOR	
	REAL	IMAGINARY	REAL	IMAGINARY
1	.10355E+01	.77923E-01	-.55642E-01	-.33325E-01
2	.10646E+01	.94546E-01	-.24728E-01	-.10675E-01
3	.10446E+01	.55841E-01	-.45566E-01	-.31589E-01
4	.98733E+00	.99447E-01	-.36345E-01	-.39437E-01
5	.97364E+00	.26109E+00	-.37523E-01	-.41163E-01
6	.10327E+01	.55887E-01	-.79912E-02	-.12925E-01
7	.10152E+01	.18735E-01	-.40392E-01	-.27056E-01
8	.94518E+00	.42347E-01	-.24863E-01	-.43569E-01
9	.96252E+00	-.10840E+00	-.29164E-01	-.15009E-01
10	.10372E+01	.69525E-01	-.21900E-01	-.12127E-01
11	.90016E+00	-.97256E-01	-.25777E-01	-.42653E-01
12	.96761E+00	-.73915E-01	-.15539E-01	-.63472E-02
13	.10464E+01	.15751E-01	-.57856E-02	-.14754E-02
14	.94038E+00	-.10597E+00	-.27718E-01	-.29090E-01
15	.92996E+00	.98296E-01	-.48064E-01	-.42929E-01
16	.10353E+01	-.47118E-01	-.35476E-02	-.45460E-04
17	.93338E+00	.30755E-01	-.13954E-01	-.54468E-01
18	.10398E+01	.25357E+00	-.30171E-01	-.34300E-01
19	.10456E+01	.97181E-01	-.43577E-02	-.18250E-01
20	.97065E+00	.24250E+00	-.29353E-01	-.40541E-01
21	.99397E+00	.23148E+00	-.26032E-01	-.42171E-01
22	.88755E+00	-.84881E-01	-.24463E-02	-.53393E-01
23	.99965E+00	-.26551E-01	-.35248E-03	.37931E-03
24	.99936E+00	.48009E-01	-.63549E-03	-.32315E-01
25	.93595E+00	.35282E+00	-.64051E-01	-.49371E-01

ITERATION NO. 3 OF XLF1

BUS NO.	BUS CURRENT(AI)		MISMATCHES(DS)	
	REAL	IMAGINARY	REAL	IMAGINARY
1	-.86737E+00	.12985E+00	.68038E-01	.79575E-02
2	-.11058E-01	-.50874E-02	.12253E-01	.43706E-02
3	-.55663E+00	.13410E+00	.39943E-02	-.11663E-02
4	-.50098E+00	.16365E+00	-.16426E-02	-.13939E-02
5	-.44005E+00	.16961E-02	-.19938E-02	-.65449E-02
6	-.39240E+00	.76195E-01	.97474E-03	-.61716E-03
7	-.10986E+01	.24656E+00	.66109E-03	-.89363E-03
8	-.24517E+00	.52678E-01	-.49655E-03	-.17309E-03
9	-.66350E+00	.29002E+00	.74213E-04	.27719E-02
10	-.99258E+00	.19611E+00	-.41275E-02	-.24159E-02
11	-.45999E+00	.20162E+00	.36687E-02	.32478E-02
12	-.43251E+00	.15647E+00	.69234E-04	.56448E-03
13	-.52350E-03	-.84945E-03	.56116E-03	.88060E-03
14	.20239E-03	-.10938E-03	-.20191E-03	.81407E-04
15	.61949E-01	-.56564E-01	-.52050E-01	.58691E-01
16	-.12496E+01	.34632E+00	-.31521E-05	.34740E-03
17	-.32508E-01	.68183E-02	.13235E-03	.26362E-02
18	.24627E+01	.98481E+00	-.10449E-01	-.29870E-03
19	.13941E+01	-.42010E-01	-.36276E-02	-.14858E-03
20	.28975E+01	-.39174E-01	-.29033E-02	-.48085E-03
21	.10497E+01	.27862E+00	-.79053E-02	-.56601E-03
22	-.59539E+00	.26145E+00	-.93643E-02	-.16033E-02
23	-.36951E-01	.11544E+00	.31521E-05	-.68334E-07
24	-.48216E-01	.17510E+00	-.10221E-01	-.51703E-03
25	.64498E+00	.60618E-01	.49424E-02	-.23989E-03

BUS NO.	VOLTAGE		VOLTAGE CORRECTION VECTOR	
	REAL	IMAGINARY	REAL	IMAGINARY
1	.10328E+01	.77296E-01	-.27257E-02	-.62686E-03
2	.10644E+01	.94340E-01	-.23480E-03	-.20652E-03
3	.10424E+01	.54953E-01	-.22730E-02	-.88746E-03
4	.98591E+00	.97877E-01	-.14230E-02	-.15704E-02
5	.97408E+00	.25983E+00	.43886E-03	-.12683E-02
6	.10324E+01	.55420E-01	-.25775E-03	-.46682E-03
7	.10132E+01	.18063E-01	-.20112E-02	-.67208E-03
8	.94412E+00	.40274E-01	-.10625E-02	-.20724E-02
9	.96138E+00	-.10877E+00	-.11424E-02	-.36898E-03
10	.10370E+01	.69245E-01	-.22753E-03	-.28031E-03
11	.89823E+00	-.99212E-01	-.19335E-02	-.19559E-02
12	.96705E+00	-.74064E-01	-.56566E-03	-.14949E-03
13	.10463E+01	.15720E-01	-.44690E-04	-.31281E-04
14	.93882E+00	-.10713E+00	-.15560E-02	-.11553E-02
15	.92735E+00	.97015E-01	-.26157E-02	-.12809E-02
16	.10353E+01	-.47118E-01	-.12217E-04	-.48982E-07
17	.93177E+00	.27814E-01	-.16156E-02	-.29408E-02
18	.10397E+01	.25282E+00	-.12538E-03	-.74664E-03
19	.10455E+01	.96581E-01	-.93486E-04	-.59968E-03
20	.97058E+00	.24080E+00	-.70239E-04	-.17027E-02
21	.99384E+00	.22952E+00	-.12532E-03	-.19574E-02
22	.88560E+00	-.88477E-01	-.19545E-02	-.35954E-02
23	.99965E+00	-.26551E-01	-.57502E-07	.40871E-06
24	.99895E+00	.45852E-01	-.41400E-03	-.21570E-02
25	.93591E+00	.35223E+00	-.36650E-04	-.58286E-03

ITERATION NO. 4 OF XLF1

BUS NO.	BUS CURRENT(AI)		MISMATCHES(DS)	
	REAL	IMAGINARY	REAL	IMAGINARY
1	-.80487E+00	.14310E+00	.17868E-03	-.30514E-05
2	-.34891E-05	.71321E-06	.36464E-05	-.10883E-05
3	-.55390E+00	.13389E+00	.60395E-05	-.28963E-05
4	-.50304E+00	.16306E+00	-.38624E-05	.24092E-05
5	-.44023E+00	-.45031E-02	-.77813E-05	.29550E-05
6	-.39150E+00	.75843E-01	.67263E-07	-.51076E-06
7	-.10999E+01	.24687E+00	-.25423E-05	.15432E-05
8	-.24588E+00	.53061E-01	.45574E-07	.18621E-05
9	-.66371E+00	.29352E+00	.10579E-05	.40760E-05
10	-.99658E+00	.19383E+00	-.15487E-05	.59871E-06
11	-.45596E+00	.20622E+00	.16788E-04	.10365E-05
12	-.43261E+00	.15722E+00	.55514E-07	.43878E-06
13	-.47431E-07	-.21343E-07	.49964E-07	.21586E-07
14	.15019E-06	-.44655E-06	-.18884E-06	.40314E-06
15	.12082E-03	-.23165E-03	-.89566E-04	.22654E-03
16	-.12496E+01	.34665E+00	-.11575E-10	.41517E-08
17	-.32497E-01	.97571E-02	.86592E-05	.47182E-05
18	.24543E+01	.98193E+00	-.31902E-05	-.22616E-06
19	.13915E+01	-.50496E-01	-.53301E-05	-.16489E-06
20	.29053E+01	-.82196E-01	-.72697E-04	-.13365E-05
21	.10443E+01	.27077E+00	-.16060E-04	-.17287E-05
22	-.60624E+00	.26094E+00	-.23059E-04	-.79644E-05
23	-.36949E-01	.11541E+00	.11565E-10	-.78160E-13
24	-.57460E-01	.16208E+00	-.31917E-04	-.22784E-05
25	.64919E+00	.63623E-01	.19057E-05	-.14176E-06

THE BUS CURRENT IS ZERO FOR THE FOLLOWING BUSES

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BUS NO.	VOLTAGE		VOLTAGE CORRECTION VECTOR	
	REAL	IMAGINARY	REAL	IMAGINARY
1	.10328E+01	.77289E-01	-.86757E-05	-.65399E-05
2	.10644E+01	.94339E-01	-.26058E-06	-.38691E-06
3	.10424E+01	.54945E-01	-.74236E-05	-.76573E-05
4	.98590E+00	.97867E-01	-.49306E-05	-.98786E-05
5	.97408E+00	.25981E+00	.21858E-05	-.12744E-04
6	.10324E+01	.55418E-01	-.66120E-06	-.28475E-05
7	.10132E+01	.18057E-01	-.68443E-05	-.58559E-05
8	.94412E+00	.40265E-01	-.29788E-05	-.95887E-05
9	.96137E+00	-.10877E+00	-.26970E-05	-.12666E-05
10	.10370E+01	.69245E-01	-.34396E-06	-.47334E-06
11	.89822E+00	-.99219E-01	-.59829E-05	-.65459E-05
12	.96704E+00	-.74065E-01	-.12836E-05	-.56266E-06
13	.10463E+01	.15720E-01	-.36344E-07	-.66894E-07
14	.93882E+00	-.10713E+00	-.43722E-05	-.38159E-05
15	.92734E+00	.97007E-01	-.84887E-05	-.77093E-05
16	.10353E+01	-.47118E-01	-.14589E-09	-.53359E-13
17	.93176E+00	.27204E-01	-.57954E-05	-.10182E-04
18	.10397E+01	.25282E+00	-.10729E-06	-.51593E-06
19	.10455E+01	.96578E-01	.12499E-06	-.31457E-05
20	.97058E+00	.24078E+00	.15666E-05	-.11865E-04
21	.99384E+00	.22951E+00	.10420E-05	-.12194E-04
22	.88559E+00	-.88488E-01	-.90720E-05	-.10691E-04

23	.99965E+00	-.26551E-01	-.66443E-13	.44219E-12
24	.99895E+00	.45841E-01	-.17549E-05	-.11455E-04
25	.93592E+00	.35222E+00	.42143E-05	-.11600E-04

ITERATION NO. 5 OF XLF1

BUS NO.	BUS CURRENT(AI)		MISMATCHES(DS)	
	REAL	IMAGINARY	REAL	IMAGINARY
1	-.80470E+00	.14312E+00	.15430E-08	-.94919E-09
2	-.71054E-12	.13642E-11	.62758E-12	-.15191E-11
3	-.55389E+00	.13389E+00	.38366E-10	-.31664E-11
4	-.50305E+00	.16307E+00	.49068E-10	.93181E-10
5	-.44024E+00	-.44966E-02	.10151E-09	.97775E-10
6	-.39150E+00	.75843E-01	.17799E-11	.24469E-12
7	-.11000E+01	.24688E+00	-.43983E-11	.11500E-09
8	-.24588E+00	.53065E-01	.43166E-10	.17438E-10
9	-.66371E+00	.29353E+00	.82636E-11	.15558E-10
10	-.99658E+00	.19383E+00	-.22737E-12	.47784E-12
11	-.45594E+00	.20623E+00	.13079E-09	-.91740E-10
12	-.43261E+00	.15722E+00	.58620E-13	.14264E-11
13	.71054E-14	.45475E-12	-.14583E-13	-.47570E-12
14	-.10658E-13	.28422E-13	.13051E-13	-.25541E-13
15	-.48766E-09	-.31759E-08	.76031E-09	.28978E-08
16	-.12496E+01	.34665E+00	0.	-.74607E-13
17	-.32488E-01	.97629E-02	.11084E-09	-.58604E-10
18	.24543E+01	.98193E+00	-.79581E-12	.14779E-11
19	.13915E+01	-.50531E-01	-.10824E-09	-.47038E-11
20	.29053E+01	-.82384E-01	-.21803E-08	-.70507E-10
21	.10443E+01	.27073E+00	-.46760E-09	-.72156E-10
22	-.60627E+00	.26096E+00	.32934E-10	-.74806E-10
23	-.36949E-01	.11541E+00	0.	0.
24	-.57488E-01	.16204E+00	-.50388E-09	-.64553E-10
25	.64920E+00	.63609E-01	-.17875E-09	-.76149E-10

THE BUS CURRENT IS ZERO FOR THE FOLLOWING BUSES

2 13 14 15

BUS NO.	VOLTAGE		VOLTAGE CORRECTION VECTOR	
	REAL	IMAGINARY	REAL	IMAGINARY
1	.10328E+01	.77289E-01	-.11111E-09	-.83945E-10
2	.10644E+01	.94339E-01	-.11839E-12	-.42640E-11
3	.10424E+01	.54945E-01	-.10363E-09	-.10389E-09
4	.98590E+00	.97867E-01	-.91219E-10	-.13754E-09
5	.97408E+00	.25981E+00	-.29597E-10	-.21064E-09
6	.10324E+01	.55418E-01	-.11046E-10	-.37867E-10
7	.10132E+01	.18057E-01	-.93329E-10	-.73284E-10
8	.94412E+00	.40265E-01	-.46850E-10	-.13962E-09
9	.96137E+00	-.10877E+00	-.20826E-10	-.18307E-10
10	.10370E+01	.69245E-01	-.72734E-12	-.49967E-11
11	.89822E+00	-.99219E-01	-.50889E-10	-.81280E-10
12	.96704E+00	-.74065E-01	-.98363E-11	-.81637E-11
13	.10463E+01	.15720E-01	.56674E-13	-.69793E-12
14	.93882E+00	-.10713E+00	-.35535E-10	-.43725E-10
15	.92734E+00	.97007E-01	-.11572E-09	-.87602E-10
16	.10353E+01	-.47118E-01	.26212E-14	-.32762E-17
17	.93176E+00	.27804E-01	-.55045E-10	-.12273E-09
18	.10397E+01	.25232E+00	.24848E-11	-.41402E-11
19	.10455E+01	.96578E-01	-.78912E-12	-.42597E-10
20	.97058E+00	.24078E+00	-.22368E-10	-.20266E-09
21	.99384E+00	.22951E+00	-.27511E-10	-.20154E-09
22	.88559E+00	-.88488E-01	-.84577E-10	-.94063E-10

23	.99965E+00	-.26551E-01	.72607E-18	.27336E-16
24	.99895E+00	.45841E-01	-.56971E-10	-.16670E-09
25	.93592E+00	.35222E+00	.15733E-11	-.22038E-09

FINAL BUS CURRENTS AND MISMATCHES

BUS NO.	BUS CURRENT(AI)		MISMATCHES(DS)	
	REAL	IMAGINARY	REAL	IMAGINARY
1	-.80470E+00	.14312E+00	.11369E-12	.98854E-12
2	0.	0.	0.	0.
3	-.55389E+00	.13389E+00	-.71054E-14	.39080E-13
4	-.50305E+00	.16307E+00	.35527E-14	.43521E-13
5	-.44024E+00	-.44966E-02	.88818E-14	.30198E-13
6	-.39150E+00	.75843E-01	.58620E-13	.90150E-13
7	-.11000E+01	.24688E+00	-.14211E-13	.44409E-13
8	-.24588E+00	.53065E-01	.88818E-15	-.82157E-14
9	-.66371E+00	.29353E+00	.21316E-13	-.25757E-13
10	-.99658E+00	.19383E+00	.28422E-13	-.99476E-13
11	-.45594E+00	.20623E+00	.71054E-14	-.26645E-13
12	-.43261E+00	.15722E+00	-.15987E-13	-.97700E-14
13	-.71054E-14	.45475E-12	.28594E-15	-.47593E-12
14	.35527E-14	-.14211E-13	-.48578E-14	.12961E-13
15	.56843E-13	.28422E-12	-.80284E-13	-.25805E-12
16	-.12496E+01	.34665E+00	.71054E-14	-.74607E-13
17	-.32488E-01	.97629E-02	.23315E-14	-.38858E-14
18	.24543E+01	.98193E+00	-.93792E-12	.42633E-13
19	.13915E+01	-.50531E-01	.35527E-13	0.
20	.29053E+01	-.82384E-01	-.42633E-13	0.
21	.10443E+01	.27073E+00	.71054E-14	0.
22	-.60627E+00	.26096E+00	0.	0.
23	-.36949E-01	.11541E+00	-.88818E-15	0.
24	-.57483E-01	.16204E+00	-.22204E-15	-.71054E-14
25	.64920E+00	.63609E-01	-.10658E-13	0.
26	.13209E+00	.50781E-01		

LOAD FLOW SOLUTION OF 26-BUS POWER SYSTEM

LOAD BUSES

V(1) = 1.03276 + J .07729	V(2) = 1.06437 + J .09434
V(3) = 1.04236 + J .05495	V(4) = .98590 + J .09787
V(5) = .97403 + J .25981	V(6) = 1.03244 + J .05542
V(7) = 1.01318 + J .01806	V(8) = .94412 + J .04026
V(9) = .96137 - J .10877	V(10) = 1.03697 + J .06924
V(11) = .89822 - J .09922	V(12) = .96704 - J .07406
V(13) = 1.04633 + J .01572	V(14) = .93882 - J .10713
V(15) = .92734 + J .09701	V(16) = 1.03526 - J .04712
V(17) = .93176 + J .02780	

GENERATOR BUSES

Q(18) = -.40042	V(18) = 1.03970 + J .25282
Q(19) = .18722	V(19) = 1.04555 + J .09658
Q(20) = .77951	V(20) = .97058 + J .24078
Q(21) = -.02939	V(21) = .99384 + J .22951
Q(22) = -.17746	V(22) = .88559 - J .08849
Q(23) = -.11439	V(23) = .99965 - J .02655
Q(24) = -.16451	V(24) = .99895 + J .04584
Q(25) = .16913	V(25) = .93592 + J .35222

SLACK BUS

P(26) = .13341	Q(26) = -.05129

TOTAL NUMBER OF ITERATIONS TAKEN BY XLF1 = 5

TOTAL EXECUTION TIME TAKEN BY XLF1 = 4.170 SECONDS

Example 3

Here we perform a contingency analysis of the 26-bus power system. For illustration purposes, the outage of lines (2,13) and (6,7) is considered.

The package XLF1 can handle only one line outage at a time without disturbing the line data file. The listing of the appropriate main program is found on pages 38-39. The data files TL26 and BUS26 reported on page 28 are used as the input data for this program. Other input data, i.e., information about line outages, is given after the main program on page 39.

The results of contingency analysis are reported on page 40.

```
      PROGRAM MAIN(INPUT,OUTPUT,TL26,BUS26,TAPE5=BUS26,TAPE6=OUTPUT,
     1TAPE3=TL26,TAPE2=INPUT)
C
      COMPLEX V(26),CV(26),AI(26),S(25),DS(25),AK(25,25),BGK(8,25),ZC,
     1VO(25)
      DIMENSION KA(25), IG(8), IZ(25), IZB(6)
C
C     THIS IS THE MAIN PROGRAM FOR CONTINGENCY ANALYSIS IN EXAMPLE 3
C
C     USING THE PACKAGE XLF1. EXAMPLE 3 CONSIDERS THE 26-BUS POWER
C
C     SYSTEM
C
C     A DESCRIPTION OF ALL THE NEW VARIABLES USED IN THE MAIN
C
C     PROGRAM NOW FOLLOWS
C
C     *************************** REAL VARIABLES ***************************
C
C     DDLT4     CHANGE IN THE ARGUMENT OF THE VOLTAGE V(4) DUE TO
C               THE LINE OUTAGE
C
C     DDLT20    CHANGE IN THE ARGUMENT OF THE VOLTAGE V(20) DUE TO
C               THE LINE OUTAGE
C
C     DLT4      DELTA(4), ARGUMENT OF VOLTAGE V(4) AT THE LOAD FLOW
C               SOLUTION OF THE ORIGINAL POWER SYSTEM
C
C     DLT20     DELTA(20), ARGUMENT OF VOLTAGE V(20) AT THE LOAD
C               FLOW SOLUTION OF THE ORIGINAL POWER SYSTEM
C
C     DQ20      CHANGE IN THE REACTIVE POWER OF BUS 20 DUE TO THE
C               LINE OUTAGE
C
C     DV6       CHANGE IN THE MODULUS OF THE VOLTAGE V(6) DUE TO THE
C               LINE OUTAGE
C
C     Q20       REACTIVE POWER SUPPLIED BY BUS 20 BEFORE A LINE OUTAGE
C
C     V6        MODULUS OF THE VOLTAGE V(6)
C
C     ******************************************************************
C
C     READING OF THE BUS DATA FROM TAPE 5
C
      READ (5,60) NB,NGB,ITMAX,ICHTL,IWRITE
      READ (5,70) TOLV
      N=NB-1
      DO 10 I=1,N
      READ (5,80) S(I),V(I),KA(I)
10    CONTINUE
      READ (5,90) V(NB)
      IWRITE=2
C
C     SOLUTION OF THE LOAD FLOW PROBLEM BEFORE THE LINE OUTAGE
C
      CALL XLF1 (V,CV,AI,S,DS,AK,BGK,KA,IG,IZ,IZB,NB,N,NGB,ITMAX,TOLV,
     1ICHTL,IAC,JAC,ZC,SHTLC,CC,IWRITE)
      DO 20 I=1,N
      VO(I)=V(I)
20    CONTINUE
      V6=CABS(V(6))
      DLT4=ATAN2(AIMAG(V(4)),REAL(V(4)))
      Q20=-AIMAG(CV(20)*AI(20))
      A1=AIMAG(V(20))
```

```
      A2=REAL(V(20))
      DLT20=ATAN2(A1,A2)
      ICHTL=2
      WRITE (6,100) NB
      WRITE (6,110)
C
C     READING OF THE DATA FOR THE LINE TO BE REMOVED
C
30    READ (2,*) IAC,JAC
      IF (EOF(2).NE.0) GO TO 50
C
C     SOLUTION OF THE LOAD FLOW PROBLEM AFTER A LINE OUTAGE
C
      CALL XLF1 (V,CV,AI,S,DS,AK,BCK,KA,IG,IZ,IZB,NB,N,NGB,ITMAX,TOLV,
     1ICHTL,IAC,JAC,ZC,SHTLC,CC,IWRITE)
C
C     CALCULATION OF THE VARIOUS CHANGES DUE TO THE LINE OUTAGE
C
      DV6=CABS(V(6))-V6
      DDLT4=ATAN2(AIMAG(V(4)),REAL(V(4)))-DLT4
      DQ20=-AIMAG(CV(20)*AI(20))-Q20
      DDLT20=ATAN2(AIMAG(V(20)),REAL(V(20)))-DLT20
      WRITE (6,120) IAC,JAC,DV6
      WRITE (6,130) DDLT4
      WRITE (6,140) DQ20
      WRITE (6,150) DDLT20
      DO 40 J=1,N
      V(J)=VO(J)
40    CONTINUE
      GO TO 30
50    WRITE (6,160)
      STOP
C
60    FORMAT (10I5)
70    FORMAT (E15.5)
80    FORMAT (4F10.5,I5)
90    FORMAT (2F10.5)
100   FORMAT (1H1,/,5X,*CONTINGENCY RESULTS FOR STATES OF *,I2,*-BUS POW
     1ER SYSTEM*,/,1X)
110   FORMAT (1X,59(*-*),//,1X,*   LINE OUTAGE          STATE VARIABLE
     1 CHANGE IN STATE  *,/,46X,*VARIABLE*,//,1X,59(*-*),/,1X)
120   FORMAT (6X,*(*,I2,*,*,I2,*)*,14X,*V(6)*,14X,F8.5,/)
130   FORMAT (27X,*DELTA(4)*,10X,F8.5,/)
140   FORMAT (27X,*Q(20)*,13X,F8.5,/)
150   FORMAT (27X,*DELTA(20)*,9X,F8.5,/)
160   FORMAT (1X,59(*-*))
      END
```

Input

2,13
6,7

CONTINGENCY RESULTS FOR STATES OF 26-BUS POWER SYSTEM

LINE OUTAGE	STATE VARIABLE	CHANGE IN STATE VARIABLE
(2,13)	V(6)	-.00027
	DELTA(4)	.06535
	Q(20)	.01739
	DELTA(20)	.06890
(6, 7)	V(6)	.00047
	DELTA(4)	-.03055
	Q(20)	.06165
	DELTA(20)	-.02989

Example 4

In this example, we determine by perturbation the sensitivities of $|V_6|$, δ_4, Q_{20} and δ_{20} in the 26-bus power system with respect to the line conductances and susceptances of the lines (1,3), (1,4), (2,13) and (6,7).

The listing of the main program is given on pages 42-44. The data files TL26 and BUS26 along with line data of lines (1,3), (1,4), (2,13) and (6,7) are used as input to this program. The extra input data is reported on page 44.

The output of the program is given on pages 45-46. The formula (1) is employed for determining sensitivities. In this program, the value of Δt is 0.01. The sensitivities thus obtained by this program are comparable with those obtained by the exact method [3].

```
      PROGRAM MAIN(INPUT,OUTPUT,TL26,BUS26,TAPE5=BUS26,TAPE6=OUTPUT,
     1TAPE3=TL26,TAPE2=INPUT)
C
      COMPLEX V(26),CV(26),AI(26),S(25),DS(25),AK(25,25),BGK(8,25),ZC,
     1VO(25),CPX
      DIMENSION KA(25), IG(8), IZ(25), IZB(6)
C
C     THIS IS THE MAIN PROGRAM FOR DETERMINING THE SENSITIVITIES OF
C
C     THE MODULUS OF V(6),DELTA(4),Q(20),DELTA(20) W.R.T. THE LINE
C
C     CONDUCTANCES AND SUSCEPTANCES OF THE LINES (1,3), (1,4),
C
C     (2,13) AND (6,7) USING THE PACKAGE XLF1 ALONG WITH PARAMETER
C
C     PERTURBATION
C
C     A DESCRIPTION OF ALL THE NEW VARIABLES USED IN THE MAIN
C
C     PROGRAM NOW FOLLOWS
C
C     ************************* INTEGER VARIABLES ************************
C
C     NS         TOTAL NUMBER OF THE LINE CONDUCTANCES (OR SUSCEPTANCES)
C                W.R.T. THEM SENSITIVITIES ARE TO BE DETERMINED
C
C     ************************** REAL VARIABLES **************************
C
C     DDLT4      SENSITIVITY OF DELTA(4)
C
C     DDLT20     SENSITIVITY OF DELTA(20)
C
C     DLT4       DELTA(4), ARGUMENT OF VOLTAGE V(4) AT THE LOAD FLOW
C                SOLUTION OF THE ORIGINAL POWER SYSTEM
C
C     DLT20      DELTA(20), ARGUMENT OF VOLTAGE V(20) AT THE LOAD
C                FLOW SOLUTION OF THE ORIGINAL POWER SYSTEM
C
C     DQ20       SENSITIVITY OF Q(20)
C
C     DV6        SENSITIVITY OF V(6)
C
C     Q20        REACTIVE POWER SUPPIED BY BUS 20 BEFORE A LINE OUTAGE
C
C     V6         MODULUS OF THE VOLTAGE V(6)
C
C     ********************************************************************
C
C     READING OF BUS DATA FROM TAPE 5
C
      READ (5,130) NB,NGB,ITMAX,ICHTL,IWRITE
      READ (5,140) TOLV
      N=NB-1
      DO 10 I=1,N
      READ (5,150) S(I),V(I),KA(I)
10    CONTINUE
      READ (5,160) V(NB)
      IWRITE=2
C
C     DETERMINATION OF THE SOLUTION OF THE LOAD FLOW PROBLEM WITH THE
C     GIVEN CONTROL VARIABLES
C
      CALL XLF1 (V,CV,AI,S,DS,AK,BGK,KA,IG,IZ,IZB,NB,N,NGB,ITMAX,TOLV,
     1ICHTL,IAC,JAC,ZC,SHTLC,CC,IWRITE)
      DO 20 I=1,N
```

```
      VO(I)=V(I)
20    CONTINUE
      ICHTL=1
C
C     DETERMINATION OF THE SOLUTION OF THE LOAD FLOW PROBLEM AFTER
C     DECREASING ONE OF THE LINE PARAMETERS BY A SMALL AMOUNT H
C
      H=0.005
      H1=0.5/H
      NS=4
      DO 120 K=1,2
      IF (K.EQ.2) GO TO 30
      WRITE (6,170)
      GO TO 40
30    WRITE (6,200)
40    WRITE (6,180)
      DO 110 I=1,NS
      READ (2,*) ICODE,IAC,JAC,A1,A2,A3,A4,A5
      IF (ICODE.EQ.7) GO TO 50
      ZC=CMPLX(A3,A4)
      SHTLC=A5 $ CC=0.0
      GO TO 60
50    ZC=CMPLX(A2,A3)
      CC=A4
60    IF (K.EQ.2) GO TO 70
      CPX=1.0/ZC+H
      ZC=1.0/ZC-H
      GO TO 80
70    CPX=1.0/ZC+CMPLX(0.0,H)
      ZC=1.0/ZC-CMPLX(0.0,H)
80    ZC=1.0/ZC
      CALL XLF1 (V,CV,AI,S,DS,AK,BGK,KA,IG,IZ,IZB,NB,N,NGB,ITMAX,TOLV,
     1ICHTL,IAC,JAC,ZC,SHTLC,CC,IWRITE)
      V6=CABS(V(6))
      A1=AIMAG(V(4))
      A2=REAL(V(4))
      DLT4=ATAN2(A1,A2)
      Q20=-AIMAG(CV(20)*AI(20))
      A1=AIMAG(V(20))
      A2=REAL(V(20))
      DLT20=ATAN2(A1,A2)
C
C     DETERMINATION OF THE SOLUTION OF THE LOAD FLOW PROBLEM AFTER
C     INCREASING ONE OF THE LINE PARAMETERS BY A SMALL AMOUNT H
C
      ZC=1.0/CPX
      DO 90 J=1,N
      V(J)=VO(J)
90    CONTINUE
      CALL XLF1 (V,CV,AI,S,DS,AK,BGK,KA,IG,IZ,IZB,NB,N,NGB,ITMAX,TOLV,
     1ICHTL,IAC,JAC,ZC,SHTLC,CC,IWRITE)
C
C     DETERMINATION OF SENSITIVITIES
C
      DV6=CABS(V(6))-V6
      A1=AIMAG(V(4))
      A2=REAL(V(4))
      DDLT4=ATAN2(A1,A2)-DLT4
      DQ20=-AIMAG(CV(20)*AI(20))-Q20
      A1=AIMAG(V(20))
      A2=REAL(V(20))
      DDLT20=ATAN2(A1,A2)-DLT20
      DV6=DV6*H1
      DDLT4=DDLT4*H1
      DQ20=DQ20*H1
```

```
      DDLT20=DDLT20*H1
      DO 100 J=1,N
      V(J)=VO(J)
100   CONTINUE
      WRITE (6,190) IAC,JAC,DV6,DDLT4,DQ20,DDLT20
110   CONTINUE
      WRITE (6,210)
120   CONTINUE
      STOP
C
130   FORMAT (10I5)
140   FORMAT (E15.5)
150   FORMAT (4F10.5,I5)
160   FORMAT (2F10.5)
170   FORMAT (1H1,/,2X,*SENSITIVITIES OF  V(6)  ,DELTA(4),Q(20),DELTA(20)
     1 W.R.T.*,//,21X,*LINE CONDUCTANCES*,/,1X)
180   FORMAT (1X,59(*-*),//,21X,*TOTAL DERIVATIVES*,//,4X,*LINE*,4X,48(*
     1-*),//,12X,*     V(6)       DELTA(4)       Q(20)       DELTA(20)*,//,1X
     2,59(*-*))
190   FORMAT (/,3X,*(*,I2,*,*,I2,*)    *,F9.6,3X,F9.6,3X,F9.6,3X,F9.6)
200   FORMAT (1H1,/,2X,*SENSITIVITIES OF  V(6)  ,DELTA(4),Q(20),DELTA(20)
     1 W.R.T.*,//,20X,*LINE SUSCEPTANCES*,/,1X)
210   FORMAT (/,1X,59(*-*))
      END
```

Input

```
7,1,3,1,0.0,0.0392,.98,0.0
4,1,4,1,1,0.0619,0.2401,0.0319
4,2,13,1,1,0.0086,0.0707,0.3017
4,6,7,1,1,0.0921,0.3569,0.0475
7,1,3,1,0.0,0.0392,0.98,0.0
4,1,4,1,1,0.0619,0.2401,0.0319
4,2,13,1,1,0.0086,0.0707,0.3017
4,6,7,1,1,0.0921,0.3569,0.0475
```

SENSITIVITIES OF V(6) ,DELTA(4),Q(20),DELTA(20) W.R.T.
LINE CONDUCTANCES

LINE	TOTAL DERIVATIVES			
	V(6)	DELTA(4)	Q(20)	DELTA(20)
(1, 3)	.000019	-.000230	-.002905	-.000230
(1, 4)	-.000063	.004666	.010103	.000448
(2,13)	.000000	-.000097	-.000020	-.000102
(6, 7)	.000938	.002793	.011300	.002757

SENSITIVITIES OF V(6) ,DELTA(4),Q(20),DELTA(20) W.R.T.

LINE SUSCEPTANCES

LINE	TOTAL DERIVATIVES			
	V(6)	DELTA(4)	Q(20)	DELTA(20)
(1, 3)	.000009	-.000017	-.001328	-.000018
(1, 4)	.000071	.004063	-.010808	.000296
(2,13)	-.000001	.000564	.000118	.000594
(6, 7)	.000891	-.005164	.012125	-.005050

Example 5

This example deals with the evaluation of the sensitivities of $|V_6|$, δ_4, Q_{20} and δ_{20} in the 26-bus power system with respect to the active and reactive powers of load buses 1, 2, 3 and 4.

The main program is found on pages 48-50. The data files TL26 and BUS26 are used as the input data. Other input data consists of the load bus indices, namely, 1, 2, 3 and 4, with respect to whose control variables the sensitivities are to be calculated.

The results are reported on pages 51-52. The formula (1) is employed, as before, for determining sensitivities. The value of Δt is taken as 0.002. The sensitivities thus obtained by this program are comparable with those obtained by the exact method [3].

```
      PROGRAM MAIN(INPUT,OUTPUT,TL26,BUS26,TAPE5=BUS26,TAPE6=OUTPUT,
     1TAPE3=TL26,TAPE2=INPUT)
C
      COMPLEX V(26),CV(26),AI(26),S(25),DS(25),AK(25,25),BGK(8,25),ZC,
     1VO(25),CPX
      DIMENSION KA(25), IG(8), IZ(25), IZB(6), INDEX(4)
C
C     THIS IS THE MAIN PROGRAM FOR DETERMINING THE SENSITIVITIES OF
C
C     THE MODULUS OF V(6),DELTA(4),Q(20),DELTA(20) W.R.T. THE
C
C     ACTIVE AND REACTIVE POWERS OF THE LOAD BUSES 1, 2, 3 AND 4
C
C     USING THE PACKAGE XLF1 ALONG WITH PARAMETER PERTURBATION
C
C     A DESCRIPTION OF ALL THE NEW VARIABLES USED IN THE MAIN
C
C     PROGRAM NOW FOLLOWS
C
C     ************************* INTEGER VARIABLES ***********************
C
C     INDEX,NS   NS DIMENSIONAL ARRAY. THE SENSITIVITIES ARE TO BE
C                DETERMINED W.R.T. THE CONTROL VARIABLES OF THESE
C                LOAD BUSES. NS IS THE NUMBER OF THESE BUSES
C
C     ************************** REAL VARIABLES *************************
C
C     VO         N DIMENSIONAL ARRAY. IT IS THE BUS VOLTAGE VECTOR
C                AT THE OPERATING POINT
C
C     *******************************************************************
C
C     READING OF BUS DATA FROM TAPE 5
C
      READ (5,120) NB,NGB,ITMAX,ICHTL,IWRITE
      READ (5,130) TOLV
      N=NB-1
      DO 10 I=1,N
      READ (5,140) S(I),V(I),KA(I)
10    CONTINUE
      READ (5,150) V(NB)
      IWRITE=2
C
C     DETERMINATION OF THE SOLUTION OF THE LOAD FLOW PROBLEM WITH
C     THE GIVEN CONTROL VARIABLES
C
      CALL XLF1 (V,CV,AI,S,DS,AK,BGK,KA,IG,IZ,IZB,NB,N,NGB,ITMAX,TOLV,
     1ICHTL,IAC,JAC,ZC,SHTLC,CC,IWRITE)
      DO 20 I=1,N
      VO(I)=V(I)
20    CONTINUE
C
C     DETERMINATION OF THE SOLUTION OF THE LOAD FLOW PROBLEM AFTER
C     DECREASING ONE OF THE BUS CONTROL VARIABLES BY A SMALL AMOUNT H
C
      H=0.001
      H1=0.5/H
      NS=4
      READ (2,*) (INDEX(I),I=1,NS)
      DO 110 K=1,2
      IF (K.EQ.2) GO TO 30
      WRITE (6,160)
      GO TO 40
30    WRITE (6,190)
40    WRITE (6,170)
```

```
      DO 100 I=1,NS
      L=INDEX(I)
      IF (K.EQ.2) GO TO 50
      CPX=S(L)+H
      S(L)=S(L)-H
      GO TO 60
50    CPX=S(L)+CMPLX(0.0,H)
      S(L)=S(L)-CMPLX(0.0,H)
60    CALL XLF1 (V,CV,AI,S,DS,AK,BGK,KA,IG,IZ,IZB,NB,N,NGB,ITMAX,TOLV,
     1ICHTL,IAC,JAC,ZC,SHTLC,CC,IWRITE)
      V6=CABS(V(6))
      A1=AIMAG(V(4))
      A2=REAL(V(4))
      DLT4=ATAN2(A1,A2)
      Q20=-AIMAG(CV(20)*AI(20))
      A1=AIMAG(V(20))
      A2=REAL(V(20))
      DLT20=ATAN2(A1,A2)
C
C     DETERMINATION OF THE SOLUTION OF THE LOAD FLOW PROBLEM AFTER
C     INCREASING ONE OF THE BUS CONTROL VARIABLES BY A SMALL AMOUNT H
C
      S(L)=CPX
      DO 70 J=1,N
      V(J)=VO(J)
70    CONTINUE
      CALL XLF1 (V,CV,AI,S,DS,AK,BGK,KA,IG,IZ,IZB,NB,N,NGB,ITMAX,TOLV,
     1ICHTL,IAC,JAC,ZC,SHTLC,CC,IWRITE)
C
C     DETERMINATION OF SENSITIVITIES
C
      DV6=CABS(V(6))-V6
      A1=AIMAG(V(4))
      A2=REAL(V(4))
      DDLT4=ATAN2(A1,A2)-DLT4
      DQ20=-AIMAG(CV(20)*AI(20))-Q20
      A1=AIMAG(V(20))
      A2=REAL(V(20))
      DDLT20=ATAN2(A1,A2)-DLT20
      DV6=DV6*H1
      DDLT4=DDLT4*H1
      DQ20=DQ20*H1
      DDLT20=DDLT20*H1
      DO 80 J=1,N
      V(J)=VO(J)
80    CONTINUE
      WRITE (6,180) L,DV6,DDLT4,DQ20,DDLT20
      IF (K.EQ.2) GO TO 90
      S(L)=S(L)-H
      GO TO 100
90    S(L)=S(L)-CMPLX(0.0,H)
100   CONTINUE
      WRITE (6,200)
110   CONTINUE
      STOP
C
120   FORMAT (10I5)
130   FORMAT (E15.5)
140   FORMAT (4F10.5,I5)
150   FORMAT (2F10.5)
160   FORMAT (1H1,/,2X,*SENSITIVITIES OF  V(6)  ,DELTA(4),Q(20),DELTA(20)
     1 W.R.T.*,//,15X,*ACTIVE POWERS OF THE LOAD BUSES*,/,1X)
170   FORMAT (1X,59(*-*),//,21X,*TOTAL DERIVATIVES*,//,4X,* BUS*,4X,48(*
     1-*),//,11X,*     V(6)        DELTA(4)        Q(20)        DELTA(20)*,//,1X
     2,59(*-*))
```

```
180   FORMAT (/,5X,I2,5X,F9.6,3X,F9.6,3X,F9.6,3X,F9.6)                MN 1310
190   FORMAT (1H1,/,2X,*SENSITIVITIES OF  V(6) ,DELTA(4),Q(20),DELTA(20)MN 1320
     1 W.R.T.*,//,14X,*REACTIVE POWERS OF THE LOAD BUSES*,/,1X)        MN 1330
200   FORMAT (/,1X,59(*-*))                                             MN 1340
      END                                                               MN 1350-
```

Input

```
1,2,3,4
```

SENSITIVITIES OF V(6) ,DELTA(4),Q(20),DELTA(20) W.R.T.

ACTIVE POWERS OF THE LOAD BUSES

BUS	TOTAL DERIVATIVES			
	V(6)	DELTA(4)	Q(20)	DELTA(20)
1	.000416	.272876	-.125585	.267582
2	-.000019	.007825	.001636	.008245
3	.000560	.272596	-.147778	.267275
4	-.000053	.404850	-.047999	.290383

SENSITIVITIES OF V(6) ,DELTA(4),Q(20),DELTA(20) W.R.T.
REACTIVE POWERS OF THE LOAD BUSES

BUS	TOTAL DERIVATIVES			
	V(6)	DELTA(4)	Q(20)	DELTA(20)
1	.003612	-.007064	-.559026	-.007722
2	-.000003	.001294	.000271	.001363
3	.002894	-.005661	-.447971	-.006188
4	.001956	-.025155	-.303855	-.002045

Example 6

In this last example, we calculate the sensitivities of $|V_6|$, δ_4, Q_{20} and δ_{20} in the 26-bus power system with respect to the active power and modulus of voltage of the generator buses 18, 19, 20 and 21.

The main program is listed on pages 54-56. The data files TL26 and BUS26 are used as the input data. Other input data consists of the generator bus indices, namely, 18, 19, 20 and 21, with respect to whose control variables the sensitivities are to be determined.

The results are reported on pages 57-58. The formula (1) is used for determining sensitivities. The value of Δt is taken as 0.002. The sensitivities obtained by this program are comparable with those obtained by the exact method [3].

```
      PROGRAM MAIN(INPUT,OUTPUT,TL26,BUS26,TAPE5=BUS26,TAPE6=OUTPUT,
     1TAPE3=TL26,TAPE2=INPUT)
C
      COMPLEX V(26),CV(26),AI(26),S(25),DS(25),AK(25,25),BGK(8,25),ZC,
     1VO(25),CPX
      DIMENSION KA(25), IG(8), IZ(25), IZB(6), INDEX(4)
C
C     THIS IS THE MAIN PROGRAM FOR DETERMINING THE SENSITIVITIES OF
C
C     THE MODULUS OF V(6),DELTA(4),Q(20),DELTA(20).W.R.T. THE ACTIVE
C
C     POWER AND MODULUS OF VOLTAGES OF THE GENERATOR BUSES 18, 19, 20
C
C     AND 21 USING THE PACKAGE XLF1 ALONG WITH PARAMETER PERTURBATION
C
C     A DESCRIPTION OF ALL THE NEW VARIABLES USED IN THE MAIN
C
C     PROGRAM NOW FOLLOWS
C
C     ************************** INTEGER VARIABLES ************************
C
C     INDEX,NS  NS DIMENSIONAL ARRAY. THE SENSITIVITIES ARE TO BE
C               DETERMINED W.R.T. THE CONTROL VARIABLES OF THESE
C               GENERATOR BUSES. NS IS THE NUMBER OF THESE BUSES
C
C     *************************** REAL VARIABLES ***************************
C
C     VO        N DIMENSIONAL ARRAY. IT IS THE BUS VOLTAGE VECTOR
C               AT THE OPERATING POINT
C
C     **********************************************************************
C
C     READING OF BUS DATA FROM TAPE 5
C
      READ (5,120) NB,NGB,ITMAX,ICHTL,IWRITE
      READ (5,130) TOLV
      N=NB-1
      DO 10 I=1,N
      READ (5,140) S(I),V(I),KA(I)
   10 CONTINUE
      READ (5,150) V(NB)
      IWRITE=2
C
C     DETERMINATION OF THE SOLUTION OF THE LOAD FLOW PROBLEM WITH THE
C     GIVEN CONTROL VARIABLES
C
      CALL XLF1 (V,CV,AI,S,DS,AK,BGK,KA,IG,IZ,IZB,NB,N,NGB,ITMAX,TOLV,
     1ICHTL,IAC,JAC,ZC,SHTLC,CC,IWRITE)
      DO 20 I=1,N
      VO(I)=V(I)
   20 CONTINUE
C
C     DETERMINATION OF THE SOLUTION OF THE LOAD FLOW PROBLEM AFTER
C     DECREASING ONE OF THE BUS CONTROL VARIABLES BY A SMALL AMOUNT H
C
      H=0.001
      H1=0.5/H
      NS=4
      READ (2,*) (INDEX(I),I=1,NS)
      DO 110 K=1,2
      IF (K.EQ.2) GO TO 30
      WRITE (6,160)
      GO TO 40
   30 WRITE (6,190)
   40 WRITE (6,170)
```

```
      DO 100 I=1,NS
      L=INDEX(I)
      IF (K.EQ.2) GO TO 50
      CPX=S(L)+H
      S(L)=S(L)-H
      GO TO 60
50    CPX=S(L)+CMPLX(0.0,H)
      S(L)=S(L)-CMPLX(0.0,H)
60    CALL XLF1 (V,CV,AI,S,DS,AK,BGK,KA,IG,IZ,IZB,NB,N,NGB,ITMAX,TOLV,
     1ICHTL,IAC,JAC,ZC,SHTLC,CC,IWRITE)
      V6=CABS(V(6))
      A1=AIMAG(V(4))
      A2=REAL(V(4))
      DLT4=ATAN2(A1,A2)
      Q20=-AIMAG(CV(20)*AI(20))
      A1=AIMAG(V(20))
      A2=REAL(V(20))
      DLT20=ATAN2(A1,A2)
C
C     DETERMINATION OF THE SOLUTION OF THE LOAD FLOW PROBLEM AFTER
C     INCREASING ONE OF THE BUS CONTROL VARIABLES BY A SMALL AMOUNT H
C
      S(L)=CPX
      DO 70 J=1,N
      V(J)=VO(J)
70    CONTINUE
      CALL XLF1 (V,CV,AI,S,DS,AK,BGK,KA,IG,IZ,IZB,NB,N,NGB,ITMAX,TOLV,
     1ICHTL,IAC,JAC,ZC,SHTLC,CC,IWRITE)
C
C     DETERMINATION OF SENSITIVITIES
C
      DV6=CABS(V(6))-V6
      A1=AIMAG(V(4))
      A2=REAL(V(4))
      DDLT4=ATAN2(A1,A2)-DLT4
      DQ20=-AIMAG(CV(20)*AI(20))-Q20
      A1=AIMAG(V(20))
      A2=REAL(V(20))
      DDLT20=ATAN2(A1,A2)-DLT20
      DV6=DV6*H1
      DDLT4=DDLT4*H1
      DQ20=DQ20*H1
      DDLT20=DDLT20*H1
      DO 80 J=1,N
      V(J)=VO(J)
80    CONTINUE
      WRITE (6,180) L,DV6,DDLT4,DQ20,DDLT20
      IF (K.EQ.2) GO TO 90
      S(L)=S(L)-H
      GO TO 100
90    S(L)=S(L)-CMPLX(0.0,H)
100   CONTINUE
      WRITE (6,200)
110   CONTINUE
      STOP
C
120   FORMAT (10I5)
130   FORMAT (E15.5)
140   FORMAT (4F10.5,I5)
150   FORMAT (2F10.5)
160   FORMAT (1H1,/,2X,*SENSITIVITIES OF  V(6) ,DELTA(4),Q(20),DELTA(20)
     1 W.R.T.*,//,12X,*ACTIVE POWERS OF THE GENERATOR BUSES*,/,1X)
170   FORMAT (1X,59(*-*),//,21X,*TOTAL DERIVATIVES*,//,4X,* BUS*,4X,48(*
     1-*),//,11X,*      V(6)        DELTA(4)        Q(20)        DELTA(20)*,//,1X
     2,59(*-*))
```

```
180    FORMAT (/,5X,I2,5X,F9.6,3X,F9.6,2X,F10.6,3X,F9.6)
190    FORMAT (1H1,/,2X,*SENSITIVITIES OF   V(6)  ,DELTA(4),Q(20),DELTA(20)
      1 W.R.T.*,//,10X,*MODULUS OF VOLTAGES OF THE GENERATOR BUSES*,/,1X)
200    FORMAT (/,1X,59(*-*))
       END
```

Input

```
18,19,20,21
```

SENSITIVITIES OF V(6) ,DELTA(4),Q(20),DELTA(20) W.R.T.

ACTIVE POWERS OF THE GENERATOR BUSES

BUS	TOTAL DERIVATIVES			
	V(6)	DELTA(4)	Q(20)	DELTA(20)
18	-.000018	.007196	.001505	.007583
19	-.001371	.081957	-.004018	.080415
20	-.000697	.276179	.075446	.307281
21	-.000689	.281369	.058835	.296480

SENSITIVITIES OF V(6) ,DELTA(4),Q(20),DELTA(20) W.R.T:

MODULUS OF VOLTAGES OF THE GENERATOR BUSES

BUS	TOTAL DERIVATIVES			
	V(6)	DELTA(4)	Q(20)	DELTA(20)
18	-.000060	.024308	.005083	.025614
19	.760458	-.037700	-1.987850	-.039805
20	.047441	-.186725	41.067219	-.354038
21	.008785	-.092272	-35.149911	-.219185

V. REFERENCES

[1] J.W. Bandler, M.A. El-Kady and H. Gupta, "Practical complex solution of power flow equations", Faculty of Engineering, McMaster University, Hamilton, Canada, Report SOC-270, 1981.

[2] J.W. Bandler and M.A. El-Kady, "Newton's load flow in complex mode", Proc. European Conf. Circuit Theory and Design (Hague, Netherlands, 1981), pp. 500-505.

[3] J.W. Bandler and M.A. El-Kady, "Exact power network sensitivities via generalized complex branch modelling", Faculty of Engineering, McMaster University, Hamilton, Canada, Report SOC-258, 1980 (Revised 1981).

APPENDIX

LISTING OF THE XLF1 PACKAGE

Subroutine	Number of lines (source text)	Number of words (complied code)	Listing from page
XLF1	179	520	61
STMEQ	246	2434	63
GEN	152	1561	67
ELIM	107	1204	69
RESULT	155	1473	71
Total	839	7192	

```
      SUBROUTINE XLF1 (V,CV,AI,S,DS,AK,BGK,KA,IG,IZ,IZB,NB,N,NGB,ITMAX,
     1TOLV,ICHTL,IAC,JAC,ZC,SHTLC,CC,IWRITE)
C
      COMPLEX V(1),CV(1),AI(1),S(1),DS(1),AK(N,1),BGK(NGB,1),ZC
      DIMENSION KA(1), IG(1), IZ(1), IZB(1)
C
C     THIS IS THE MAIN SUBROUTINE OF THE PACKAGE XLF1. IT GIVES THE
C
C     SOLUTION OF THE POWER SYSTEM LOAD FLOW PROBLEM USING THE
C
C     METHOD PUBLISHED IN REPORT SOC-270 OF THE FACULTY OF
C
C     ENGINEERING ,MCMASTER UNIVERSITY ,HAMILTON ,CANADA
C
C     A DESCRIPTION OF ALL THE SUBROUTINES AND VARIABLES USED IN
C
C     THIS SUBROUTINE NOW FOLLOWS
C
C     **************************** SUBROUTINES ***************************
C
C     ELIM       THIS SUBROUTINE SOLVES EQUATIONS OBTAINED BY STMEQ
C                USING CONJUGATE REDUCTION COMBINED WITH FORWARD
C                GAUSSIAN ELIMINATION PRESENTED BY BANDLER AND
C                EL-KADY(2)
C
C     RESULT     THIS WRITES FINAL RESULTS
C
C     STMEQ      THIS SUBROUTINE PREPARES THE SYSTEM EQUATIONS TO
C                THE FORM OF EQUATION (38) OF SOC-270. IT DOES THIS BY
C                CALLING SUBROUTINE GEN WHICH USES SECTION III OF SOC-270
C
C     ************************* INTEGER VARIABLES ***********************
C
C     IAC,JAC    (IAC,JAC) IS THE TRANSMISSION LINE WHOSE PARAMETERS
C                HAVE BEEN ALTERED BY THE USER
C
C     ICHTL      = 0 IF THERE IS NO ALTERATION IN THE LINE DATA
C                    FILE REQUIRED BY THE USER
C                = 1 IF PARAMETERS OF ONE LINE HAVE BEEN ALTERED
C                = 2 IF ONE LINE IS TO BE REMOVED FOR CONTINGENCY
C                    ANALYSIS
C
C     IG         NGB DIMENSIONAL ARRAY. IG(I) IS THE BUS NUMBER
C                OF THE ITH GENERATOR BUS
C
C     IT         CURRENT ITERATION NUMBER
C
C     ITMAX      MAXIMUM NUMBER OF ITERATIONS AFTER WHICH THE PROGRAM
C                WILL STOP
C
C     IWRITE     = 0 PRINTS THE FINAL LOAD FLOW SOLUTION ONLY
C                = 1 ALSO PRINTS INTERMEDIATE RESULTS
C                = 2 SUPRESSES ALL PRINTOUTS
C
C     IZ         N DIMENSIONAL ARRAY
C                IZ(I)= 0 IF /AI(I)/ GREATER THAN 1.0E-6
C                     = I IF /AI(I)/ LESS THAN 1.0E-6
C
C     IZB        AN ARRAY TO IDENTIFY THE ZERO CURRENT BUSES DURING
C                THE ITERATION. THE DIMENSION OF IZB IS THE NUMBER
C                OF EXPECTED ZERO CURRENT BUSES DURING THE SOLUTION
C                PROCESS. THIS DIMENSION CAN BE EQUAL TO OR SLIGHTLY
C                LARGER THAN THE NUMBER OF DUMMY BUSES
C
C     KA         N DIMENSIONAL ARRAY IDENTIFYING THE TYPE OF BUS
```

```
C                KA(I)= 0 IF THE ITH BUS IS A LOAD BUS
C                     = 1 IF THE ITH BUS IS A GENERATOR BUS
C
C     N          =NB-1
C
C     NB         TOTAL NUMBER OF BUSES
C
C     NGB        NUMBER OF GENERATOR BUSES
C
C     NIZ        NUMBER OF ZERO CURRENT BUSES
C
C     *************************** REAL VARIABLES **************************
C
C     CC         ALTERED TRANSFORMER TAP IN TRANSMISSION LINE (IAC,JAC)
C
C     SHTLC      ALTERED VALUE OF HALF SHUNT SUSCEPTANCE OF THE
C                TRANSMISSION LINE (IAC,JAC)
C
C     TOLV       TOLERANCE OVER BUS VOLTAGES TO THE ACCURACY THE
C                FINAL SOLUTION IS REQUIRED
C
C     ************************* COMPLEX VARIABLES *************************
C
C     AI         NB DIMENSIONAL ARRAY OF BUS CURRENTS
C
C     AK         N*N MATRIX WHICH IS DENOTED BY K    IN EQUATION (20) OF
C                                                SM
C                SOC-270
C
C                                                  -    -    -
C     BGK        NGB*N MATRIX WHICH IS DENOTED BY ( K    K    K    )
C                                                    GL   GD   GG
C                IN EQUATION (32) OF SOC-270. THESE ARE COEFFICIENTS
C                OF THE CONJUGATE OF THE VOLTAGES IN THE GENERATOR
C                BUS EQUATIONS
C
C     CPX,CPY,CPZ  COMPLEX DUMMY VARIABLES IN ALL SUBROUTINES
C
C     CV         NB DIMENSIONAL ARRAY OF THE CONJUGATE OF V
C
C     DS         N DIMENSIONAL ARRAY WHICH REPRESENTS MISMATCHES
C                AS WELL AS CORRECTION VOLTAGES
C
C     S          N DIMENSIONAL ARRAY OF LOAD BUS POWERS, AND GENERATOR
C                BUS ACTIVE POWER AND MODULUS OF VOLTAGE, WHICH IS
C                REPRESENTED AS P +J/V /
C                                G    G
C
C     V          NB DIMENSIONAL ARRAY OF BUS VOLTAGES
C
C     ZC         ALTERED IMPEDANCE OF TRANSMISSION LINE (IAC,JAC)
C
C     ********************************************************************
C
      CALL SECOND (T1)
      IT=0
C
C     CALCULATION OF THE VECTOR CV AND IDENTIFICATION OF GENERATOR
C     BUSES
C
      N=NB-1
      K=0
      DO 10 I=1,N
      CV(I)=CONJG(V(I))
      IF (KA(I).NE.1) GO TO 10
```

```
      K=K+1
      IG(K)=I
10    CONTINUE
      CV(NB)=CONJG(V(NB))
20    IT=IT+1
      IF (IWRITE.NE.1) GO TO 30
      WRITE (6,90) IT
30    CALL STMEQ (V,CV,KA,AI,IG,S,DS,AK,BGK,NGB,NB,N,IZ,NIZ,IZB,ICHTL,
     1IAC,JAC,ZC,SHTLC,CC,IWRITE)
      CALL ELIM (AK,AI,DS,N,IZ,NIZ,IZB,IWRITE)
C
C     UPDATING OF VECTORS V AND CV
C
      DO 40 I=1,N
      V(I)=V(I)+DS(I)
      CV(I)=CONJG(V(I))
40    CONTINUE
      IF (IWRITE.NE.1) GO TO 60
      WRITE (6,110)
      WRITE (6,120)
      DO 50 I=1,N
      WRITE (6,130) I,V(I),DS(I)
50    CONTINUE
60    IF (IT.EQ.ITMAX) GO TO 80
C
C     CHECKING THE ACCURACY OF THE SOLUTION
C
      DO 70 I=1,N
      IF (CABS(DS(I)).GT.TOLV) GO TO 20
70    CONTINUE
80    CALL RESULT (V,CV,S,DS,AI,KA,IG,NGB,NB,N,ICHTL,IAC,JAC,ZC,SHTLC,
     1CC,IWRITE)
      IF (IWRITE.EQ.2) RETURN
      WRITE (6,100) IT
      CALL SECOND (T2)
      TIME=T2-T1
      WRITE (6,140) TIME
      RETURN
C
90    FORMAT (1H1,* ITERATION NO.  *,I2,* OF XLF1 *,/)
100   FORMAT (1H0,* TOTAL NUMBER OF ITERATIONS TAKEN BY XLF1 = *,I2,/)
110   FORMAT (/,* BUS NO.            VOLTAGE                    VOLTAGE CORR
     1ECTION VECTOR    *,/)
120   FORMAT (*                  REAL            IMAGINARY            REAL
     1  IMAGINARY  *,/)
130   FORMAT (1X,I5,2X,2E14.5,4X,2E14.5)
140   FORMAT (1X,* TOTAL EXECUTION TIME TAKEN BY XLF1 =*,F7.3,* SECONDS
     1*)
      END


      SUBROUTINE STMEQ (V,CV,KA,AI,IG,S,DS,AK,BGK,NGB,NB,N,IZ,NIZ,IZB,
     1ICHTL,IAC,JAC,ZC,SHTLC,CC,IWRITE)
C
      COMPLEX V(1),CV(1),AI(1),S(1),DS(1),AK(N,1),BGK(NGB,1),Y,YL,CPX,
     1CPY,CPZ,ZC
      DIMENSION KA(1), IG(1), IZ(1), IZB(1)
C
C     THIS SUBROUTINE READS LINE DATA FROM TAPE 3 AND PREPARES THE
C
C     SYSTEM EQUATIONS USING SUBROUTINE GEN TO THE FORM OF EQUATION
C
C     (33) OF SOC-270
C
C     A DESCRIPTION OF ALL THE NEW VARIABLES USED IN THIS SUBROUTINE
```

```
C
C     NOW FOLLOWS
C
C     ************************** INTEGER VARIABLES *************************
C
C     IA,JA     (IA,JA) REPRESENTS A TRANSMISSION LINE CONNECTING
C               BUSES IA AND JA
C
C     ICODE     CODE TO IDENTIFY DATA CARD
C               = 4 FOR THE TRANSMISSION LINE WITHOUT TRANSFORMER
C               = 7 FOR THE TRANSMISSION LINE HAVING TRANSFORMER
C
C     IKM       DUMMY VARIABLE
C
C     ************************** REAL VARIABLES ****************************
C
C     A1        IDENTIFIES THE CIRCUIT NUMBER IF ICODE = 4
C               IDENTIFIES THE TYPE OF TRANSFORMATION RATIO IF
C               ICODE = 7
C               = 0 FOR FIX TAP
C               = 1 FOR REAL TRANSFORMATION RATIO
C               = 2 FOR COMPLEX TRANSFORMATION RATIO
C
C     A2        DENOTES BRANCH TYPE IF ICODE = 4
C               SERIES RESISTANCE OF THE LINE IF ICODE = 7
C
C     A3        SERIES RESISTANCE OF THE LINE IF ICODE = 4
C               SERIES REACTANCE OF THE LINE IF ICODE = 7
C
C     A4        SERIES REACTANCE OF THE LINE IF ICODE = 4
C               REAL PART OF THE TRANSFORMATION RATIO IF ICODE = 7
C
C     A5        HALF SHUNT SUSCEPTANCE OF THE LINE IF ICODE = 4
C               IMAGINARY PART OF THE TRANSFORMATION RATIO IF ICODE = 7
C
C     ABSV      DUMMY VARIABLE
C
C     C         TRANSFORMER TAP BETWEEN BUSES IA AND JA
C
C     ************************** COMPLEX VARIABLES *************************
C
C     Y         LINE ADMITTANCE
C
C     YL        HALF LEAKAGE ADMITTANCE OF THE LINE
C
C     **********************************************************************
C
C     INITIALIZATION OF MATRICES AND VECTORS
C
      DO 20 I=1,N
      AI(I)=(0.0,0.0)
      DO 10 J=1,N
      AK(I,J)=(0.0,0.0)
10    CONTINUE
      DO 20 J=1,NGB
20    BGK(J,I)=(0.0,0.0)
C
C     DETERMINATION OF MATRIX AK, AND CURRENT VECTOR AI FROM LINE DATA
C
      REWIND 3
30    READ (3,*) ICODE,IA,JA,A1,A2,A3,A4,A5
      IF (EOF(3).NE.0) GO TO 280
C
C     CHECK WHETHER DATA IS TEMPORARILY ALTERED
C
```

```
      IF (ICHTL.EQ.0) GO TO 40
      IF (IA.NE.IAC) GO TO 40
      IF (JA.NE.JAC) GO TO 40
      IF (ICHTL.EQ.2) GO TO 30
      Y=1.0/ZC
      YL=CMPLX(0.0,SHTLC)
      C=CC
      IF (C.GT.0.0) GO TO 140
      GO TO 50
40    IF (ICODE.EQ.7) GO TO 130
      Y=1.0/CMPLX(A3,A4)
      YL=CMPLX(0.0,A5)
      C=0.0
50    IF (IA.EQ.NB) GO TO 220
      IF (JA.EQ.NB) GO TO 220
C
C     CONTRIBUTION TO THE CURRENTS AI(IA) AND AI(JA) DUE TO THE
C     LINE (IA,JA) WHEN C=0.0
C
      CPX=YL+Y
      AI(IA)=AI(IA)+CPX*V(IA)-Y*V(JA)
      AI(JA)=AI(JA)+CPX*V(JA)-Y*V(IA)
      IF (KA(IA).EQ.1) GO TO 70
C
C     DETERMINATION OF AK(IA,JA), AK(JA,IA) AND CONTRIBUTION TO
C     AK(IA,IA) AND AK(JA,JA) DUE TO THE LINE (IA,JA) WHEN IA
C     AND JA ARE THE LOAD BUSES, AND C=0.0
C
      CPY=Y*CV(IA)
      AK(IA,JA)=-CPY
      AK(IA,IA)=AK(IA,IA)+CPX*CV(IA)
      IF (KA(JA).EQ.1) GO TO 100
60    CPY=Y*CV(JA)
      AK(JA,IA)=-CPY
      AK(JA,JA)=AK(JA,JA)+CPY+YL*CV(JA)
      GO TO 30
C
C     DETERMINATION OF AK(IA,JA), AK(JA,IA) AND CONTRIBUTION TO
C     AK(IA,IA) AND AK(JA,JA) DUE TO THE LINE (IA,JA) WHEN IA
C     AND JA ARE THE GENERATOR BUSES, AND C=0.0
C
70    AK(IA,JA)=-0.5*CV(IA)*Y
      DO 80 K=1,NGB
      IF (IA.NE.IG(K)) GO TO 80
      BGK(K,JA)=-0.5*V(IA)*CONJG(Y)
      GO TO 90
80    CONTINUE
90    AK(IA,IA)=AK(IA,IA)+CPX
      IF (KA(JA).NE.1) GO TO 60
100   AK(JA,IA)=-0.5*CV(JA)*Y
      DO 110 K=1,NGB
      IF (JA.NE.IG(K)) GO TO 110
      BGK(K,IA)=-0.5*V(JA)*CONJG(Y)
      GO TO 120
110   CONTINUE
120   AK(JA,JA)=AK(JA,JA)+CPX
      GO TO 30
C
C     CONTRIBUTION TO THE CURRENTS AI(IA) AND AI(JA) DUE TO THE
C     LINE (IA,JA) WHEN C IS POSITIVE REAL
C
130   Y=1.0/CMPLX(A2,A3)
      C=A4
140   IF (IA.EQ.NB) GO TO 220
      IF (JA.EQ.NB) GO TO 220
```

```
      CPZ=Y/C
      CPY=CPZ/C
      AI(IA)=AI(IA)+CPY*V(IA)-CPZ*V(JA)
      AI(JA)=AI(JA)+Y*V(JA)-CPZ*V(IA)
      IF (KA(IA).EQ.1) GO TO 160
C
C     DETERMINATION OF AK(IA,JA), AK(JA,IA) AND CONTRIBUTION TO
C     AK(IA,IA) AND AK(JA,JA) DUE TO THE LINE (IA,JA) WHEN IA
C     AND JA ARE THE LOAD BUSES, AND C IS POSITIVE REAL
C
      AK(IA,JA)=-CPZ*CV(IA)
      AK(IA,IA)=AK(IA,IA)+CPY*CV(IA)
      IF (KA(JA).EQ.1) GO TO 190
150   AK(JA,IA)=-CPZ*CV(JA)
      AK(JA,JA)=AK(JA,JA)+Y*CV(JA)
      GO TO 30
C
C     DETERMINATION OF AK(IA,JA), AK(JA,IA) AND CONTRIBUTION TO
C     AK(IA,IA) AND AK(JA,JA) DUE TO THE LINE (IA,JA) WHEN IA
C     AND JA ARE THE GENERATOR BUSES, AND C IS POSITIVE REAL
C
160   AK(IA,JA)=-0.5*CPZ*CV(IA)
      DO 170 K=1,NGB
      IF (IA.NE.IG(K)) GO TO 170
      BGK(K,JA)=-0.5*V(IA)*CONJG(CPZ)
      GO TO 180
170   CONTINUE
180   AK(IA,IA)=AK(IA,IA)+CPY
      IF (KA(JA).NE.1) GO TO 150
190   AK(JA,IA)=-0.5*CPZ*CV(JA)
      DO 200 K=1,NGB
      IF (JA.NE.IG(K)) GO TO 200
      BGK(K,IA)=-0.5*V(JA)*CONJG(CPZ)
      GO TO 210
200   CONTINUE
210   AK(JA,JA)=AK(JA,JA)+Y
      GO TO 30
C
C     CONTRIBUTION IN CURRENTS AND AK DUE TO THE SLACK BUS
C
220   IF (C.NE.0.0) GO TO 240
      IKM=IA
      IF (IA.GT.JA) IKM=JA
      AI(IKM)=AI(IKM)+(Y+YL)*V(IKM)-Y*V(NB)
      IF (KA(IKM).EQ.1) GO TO 230
      AK(IKM,IKM)=AK(IKM,IKM)+(Y+YL)*CV(IKM)
      GO TO 30
230   AK(IKM,IKM)=AK(IKM,IKM)+Y+YL
      GO TO 30
240   CPY=Y/C
      IF (IA.GT.JA) GO TO 260
      CPZ=CPY/C
      AI(IA)=AI(IA)+CPZ*V(IA)-CPY*V(NB)
      IF (KA(IA).EQ.1) GO TO 250
      AK(IA,IA)=AK(IA,IA)+CPZ*CV(IA)
      GO TO 30
250   AK(IA,IA)=AK(IA,IA)+CPZ
      GO TO 30
260   AI(JA)=AI(JA)+Y*V(JA)-CPY*V(NB)
      IF (KA(JA).EQ.1) GO TO 270
      AK(JA,JA)=AK(JA,JA)+Y*CV(JA)
      GO TO 30
270   AK(JA,JA)=AK(JA,JA)+Y
      GO TO 30
C
```

```
C     CALCULATION OF AK(I,I),BGK(I,J) AND DS(I) FOR GENERATOR BUSES
C
280   DO 290 I=1,NGB
      ABSV=CABS(V(IG(I)))
      CPX=V(IG(I))*0.5/ABSV
      CPY=.5*(V(IG(I))*CONJG(AK(IG(I),IG(I)))+AI(IG(I)))
      BGK(I,IG(I))=CMPLX(0.0,1.0)*CPX+CPY
      AK(IG(I),IG(I))=CMPLX(0.0,1.0)*CONJG(CPX)+CONJG(CPY)
      DS(IG(I))=S(IG(I))-CMPLX(REAL(CV(IG(I))*AI(IG(I))),ABSV)
290   CONTINUE
C
C     CALCULATION OF DELTA SM FOR LOAD BUSES
C
      DO 300 I=1,N
      IF (KA(I).EQ.1) GO TO 300
      DS(I)=CONJG(S(I))-CV(I)*AI(I)
300   CONTINUE
C
C     WRITING OF VECTOR AI AND DS
C
      IF (IWRITE.NE.1) GO TO 320
      WRITE (6,360)
      WRITE (6,330)
      WRITE (6,350)
      DO 310 I=1,N
      WRITE (6,340) I,AI(I),DS(I)
310   CONTINUE
320   CALL GEN (V,CV,AI,DS,AK,BGK,IG,KA,NB,NGB,N,IZ,NIZ,IZB)
      RETURN
C
330   FORMAT (*  BUS NO.        BUS CURRENT(AI)                  MISMATCHES
     1S(DS)         */)
340   FORMAT (I6,2X,2E14.5,4X,2E14.5)
350   FORMAT (*                 REAL           IMAGINARY            REAL
     1  IMAGINARY  *,/)
360   FORMAT (/,1X,68(*-*),/)
      END

      SUBROUTINE GEN (V,CV,AI,DS,AK,BGK,IG,KA,NB,NGB,N,IZ,NIZ,IZB)
C
      COMPLEX V(1),CV(1),AI(1),DS(1),AK(N,1),BGK(NGB,1),CPX,CPY,CPZ
      DIMENSION KA(1), IG(1), IZ(1), IM(10), II(10), IKM(5), IZB(1)
C
C     THIS SUBROUTINE USES SECTION III OF SOC-270 TO CONVERT THE
C
C     EQUATIONS TO THE FORM OF EQUATION (38) OF SOC-270
C
C     A DESCRIPTION OF ALL THE NEW VARIABLES USED IN THIS SUBROUTINE
C
C     NOW FOLLOWS
C
C     ************************ INTEGER VARIABLES ***********************
C
C     IK,IKM    IK IS THE TOTAL NUMBER OF THOSE LOAD BUSES WHOSE
C               CURRENT IS ZERO AND ARE CONNECTED TO ONE OF THE
C               GENERATOR BUSES. IKM STORES THE BUS INDECES OF
C               SUCH BUSES
C
C     IM(K),II(K)- IM(K) STORES THE INDEX OF THE GENERATOR BUS
C               EQUATION IN WHICH THE CONJUGATE OF THE VOLTAGE OF
C               ZERO CURRENT LOAD BUS II(K) IS TO BE ELIMINATED.
C               CASES OF ZERO CURRENT LOAD BUSES ARE FEW MOSTLY DUE
C               TO DUMMY BUSES. K1 IS THE NUMBER OF SUCH CASES
C
```

```
C       KL        DUMMY VARIABLE
C
C       ****************************************************************************
C
C       ELIMINATION OF THE CONJUGATE OF THE ZERO CURRENT LOAD BUS
C       VOLTAGES FROM GENERATOR BUS EQUATIONS. SEE EQUATION (32) OF
C       SOC-270. SIMULTANEOUSLY WE ARE NORMALIZING NON ZERO CURRENT
C       LOAD BUS EQUATIONS W.R.T. THE CONJUGATE OF THE LOAD BUS VOLTAGES
C
C       INITIALIZATION OF INTEGER VARIABLES
C
        NIZ=0
        IK=0
        KL=0
        K1=0
C
C       DETERMINATION OF ZERO CURRENT BUSES
C
        DO 40 I=1,N
        IZ(I)=0
        IF (KA(I).EQ.1) GO TO 40
        IF (CABS(AI(I)).LT.1.E-6) GO TO 20
        CPX=1.0/AI(I)
        DO 10 J=1,N
        IF (AK(I,J).EQ.(0.0,0.0)) GO TO 10
        AK(I,J)=AK(I,J)*CPX
10      CONTINUE
        DS(I)=DS(I)*CPX
        GO TO 40
20      IZ(I)=I
        NIZ=NIZ+1
        IZB(NIZ)=I
        DO 30 M=1,NGB
        IF (BGK(M,I).EQ.(0.0,0.0)) GO TO 30
        K1=K1+1
        IM(K1)=M
        II(K1)=I
30      CONTINUE
        IF (K1.EQ.KL) GO TO 40
        KL=K1
        IK=IK+1
        IKM(IK)=I
40      CONTINUE
        IF (IK.EQ.0) GO TO 120
C
C       ELIMINATION OF THE CONJUGATE OF THE ZERO CURRENT LOAD BUS
C       VOLTAGES FROM GENERATOR BUS EQUATIONS
C
        DO 50 I=1,IK
        DS(IKM(I))=CONJG(DS(IKM(I)))
        DO 50 J=1,N
50      AK(IKM(I),J)=CONJG(AK(IKM(I),J))
        DO 80 M=1,IK
        DO 70 I=1,IK
        IF (I.EQ.M) GO TO 70
        IF (AK(IKM(I),IKM(M)).EQ.(0.0,0.0)) GO TO 70
        CPX=-AK(IKM(I),IKM(M))/AK(IKM(M),IKM(M))
        DO 60 J=1,N
        IF (AK(IKM(M),J).EQ.(0.0,0.0)) GO TO 60
        AK(IKM(I),J)=AK(IKM(I),J)+CPX*AK(IKM(M),J)
60      CONTINUE
        DS(IKM(I))=DS(IKM(I))+CPX*DS(IKM(M))
70      CONTINUE
80      CONTINUE
        DO 100 I=1,K1
```

```
      CPX=-BGK(IM(I),II(I))/AK(II(I),II(I))
      DO 90 J=1,N
      IF (AK(II(I),J).EQ.(0.0,0.0)) GO TO 90
      BGK(IM(I),J)=BGK(IM(I),J)+CPX*AK(II(I),J)
   90 CONTINUE
      KL=IM(I)
      DS(IG(KL))=DS(IG(KL))+CPX*DS(II(I))
  100 CONTINUE
      DO 110 I=1,IK
      DS(IKM(I))=CONJG(DS(IKM(I)))
      DO 110 J=1,N
  110 AK(IKM(I),J)=CONJG(AK(IKM(I),J))
C
C     CONVERT EQUATIONS TO THE FORM OF EQUATION (37) OF SOC-270
C
  120 DO 150 I=1,N
      IF (KA(I).EQ.1) GO TO 150
      IF (I.EQ.IZ(I)) GO TO 150
      DO 140 M=1,NGB
      IF (BGK(M,I).EQ.(0.0,0.0)) GO TO 140
      DO 130 J=1,N
      IF (AK(I,J).EQ.(0.0,0.0)) GO TO 130
      AK(IG(M),J)=AK(IG(M),J)-BGK(M,I)*AK(I,J)
  130 CONTINUE
      DS(IG(M))=DS(IG(M))-BGK(M,I)*DS(I)
  140 CONTINUE
  150 CONTINUE
C
C     CONVERT EQUATIONS TO THE FORM OF EQUATION (38) OF SOC-270
C
      DO 220 M=1,NGB
      CPX=1.0/BGK(M,IG(M))
      DS(IG(M))=DS(IG(M))*CPX
      DO 160 J=1,N
      IF (AK(IG(M),J).EQ.(0.0,0.0)) GO TO 160
      AK(IG(M),J)=AK(IG(M),J)*CPX
  160 CONTINUE
      MM=M+1
      IF (MM.GT.NGB) GO TO 180
      DO 170 J=MM,NGB
      IF (BGK(M,IG(J)).EQ.(0.0,0.0)) GO TO 170
      BGK(M,IG(J))=BGK(M,IG(J))*CPX
  170 CONTINUE
  180 DO 210 I=1,NGB
      IF (I.EQ.M) GO TO 210
      IF (BGK(I,IG(M)).EQ.(0.0,0.0)) GO TO 210
      CPX=-BGK(I,IG(M))
      DO 190 J=1,N
      IF (AK(IG(M),J).EQ.(0.0,0.0)) GO TO 190
      AK(IG(I),J)=AK(IG(I),J)+CPX*AK(IG(M),J)
  190 CONTINUE
      DS(IG(I))=DS(IG(I))+CPX*DS(IG(M))
      IF (MM.GT.NGB) GO TO 210
      DO 200 J=MM,NGB
      IF (BGK(M,IG(J)).EQ.(0.0,0.0)) GO TO 200
      BGK(I,IG(J))=BGK(I,IG(J))+CPX*BGK(M,IG(J))
  200 CONTINUE
  210 CONTINUE
  220 CONTINUE
      RETURN
      END

      SUBROUTINE ELIM (AK,AI,BS,N,IZ,NIZ,IZB,IWRITE)
C
```

```
      COMPLEX AK(N,1),AI(1),DS(1),CPX,CPY,CPZ
      DIMENSION IZ(1), IZB(1)
C
C     THIS SUBROUTINE SOLVES THE EQUATIONS OF THE FORM OF EQUATION
C
C     (38) OF SOC-270 USING CONJUGATE REDUCTION COMBINED WITH
C
C     FORWARD GAUSSIAN ELIMINATION PRESENTED BY BANDLER AND EL-KADY(2)
C
C     ************************************************************************
C
C     THIS STEP IS EXECUTED FOR ALL BUSES WHOSE BUS CURRENTS ARE ZERO
C
      IF (NIZ.EQ.0) GO TO 60
      IF (IWRITE.NE.1) GO TO 10
      WRITE (6,180)
      WRITE (6,190) (IZB(I),I=1,NIZ)
10    DO 50 L=1,NIZ
      I=IZB(L)
      CPX=1./AK(I,I)
      DO 20 J=1,N
      IF (AK(I,J).EQ.(0.0,0.0)) GO TO 20
      AK(I,J)=AK(I,J)*CPX
20    CONTINUE
      DS(I)=DS(I)*CPX
      DO 40 J=1,N
      IF (J.EQ.I) GO TO 40
      IF (AK(J,I).EQ.(0.0,0.0)) GO TO 40
      CPY=AK(J,I)
      DO 30 K=1,N
      IF (AK(I,K).EQ.(0.0,0.0)) GO TO 30
      AK(J,K)=AK(J,K)-AK(I,K)*CPY
30    CONTINUE
      DS(J)=DS(J)-DS(I)*CPY
40    CONTINUE
50    CONTINUE
C
C     CONJUGATE REDUCTION
C
60    DO 150 M=1,N
      MM=M+1
      IF (M.EQ.IZ(M)) GO TO 150
      CPX=(0.0,0.0)
      CPY=(0.0,0.0)
      DO 90 I=M,N
      IF (IZ(I).EQ.I) GO TO 80
      IF (AK(M,I).EQ.(0.0,0.0)) GO TO 80
      AI(I)=-CONJG(AK(M,I))
      IF (AK(I,M).EQ.(0.0,0.0)) GO TO 70
      CPX=CPX+AI(I)*AK(I,M)
70    CPY=CPY+AI(I)*DS(I)
      GO TO 90
80    AI(I)=(0.0,0.0)
90    CONTINUE
      AK(M,M)=CPX+1.0
      DS(M)=CPY+CONJG(DS(M))
      IF (MM.GT.N) GO TO 150
      DO 110 J=MM,N
      CPX=(0.0,0.0)
      DO 100 I=M,N
      IF (AI(I).EQ.(0.0,0.0)) GO TO 100
      IF (AK(I,J).EQ.(0.0,0.0)) GO TO 100
      CPX=CPX+AI(I)*AK(I,J)
100   CONTINUE
      AK(M,J)=CPX
```

```
110   CONTINUE
C
C     GAUSSIAN FORWARD ELIMINATION
C
      CPX=1.0/AK(M,M)
      DO 120 I=MM,N
      IF (AK(M,I).EQ.(0.0,0.0)) GO TO 120
      AK(M,I)=AK(M,I)*CPX
120   CONTINUE
      DS(M)=DS(M)*CPX
      DO 140 I=MM,N
      IF (AK(I,M).EQ.(0.0,0.0)) GO TO 140
      DS(I)=DS(I)-DS(M)*AK(I,M)
      CPX=AK(I,M)
      DO 130 J=MM,N
      IF (AK(M,J).EQ.(0.0,0.0)) GO TO 130
      AK(I,J)=AK(I,J)-AK(M,J)*CPX
130   CONTINUE
140   CONTINUE
150   CONTINUE
C
C     BACKWARD SUBSTITUTION
C
      DS(N)=DS(N)/AK(N,N)
      N1=N-1
      DO 170 I=1,N1
      NI=N-I
      CPX=(0.0,0.0)
      DO 160 J=1,I
      NJ=N-J+1
      IF (AK(NI,NJ).EQ.CMPLX(0.0,0.0)) GO TO 160
      CPX=DS(NJ)*AK(NI,NJ)+CPX
160   CONTINUE
      DS(NI)=DS(NI)-CPX
170   CONTINUE
      RETURN
C
180   FORMAT (/,*   THE BUS CURRENT IS ZERO FOR THE FOLLOWING BUSES *,/)
190   FORMAT (10I10)
      END

      SUBROUTINE RESULT (V,CV,S,DS,AI,KA,IG,NGB,NB,N,ICHTL,IAC,JAC,ZC,
     1SHTLC,CC,IWRITE)
C
      COMPLEX V(1),CV(1),AI(1),S(1),DS(1),Y,YL,CPX,CPY,CPZ,ZC
      DIMENSION IG(1), KA(1)
C
C     THIS SUBROUTINE WRITES FINAL RESULTS
C
C     ************************************************************************
C
C     CALCULATION OF BUS CURRENTS
C
      REWIND 3
      DO 10 I=1,NB
      AI(I)=(0.0,0.0)
10    CONTINUE
20    READ (3,*) ICODE,IA,JA,A1,A2,A3,A4,A5
      IF (EOF(3).NE.0) GO TO 70
      IF (ICHTL.NE.1) GO TO 30
      IF (IA.NE.IAC) GO TO 30
      IF (JA.NE.JAC) GO TO 30
      IF (ICHTL.EQ.2) GO TO 20
      Y=1.0/ZC
```

```
      YL=CMPLX(0.0,SHTLC)
      C=CC
      IF (C.GT.0.0) GO TO 60
      GO TO 40
30    IF (ICODE.EQ.7) GO TO 50
      Y=1.0/CMPLX(A3,A4)
      YL=CMPLX(0.0,A5)
      C=0.0
40    CPX=YL+Y
      AI(IA)=AI(IA)+CPX*V(IA)-Y*V(JA)
      AI(JA)=AI(JA)+CPX*V(JA)-Y*V(IA)
      GO TO 20
50    Y=1.0/CMPLX(A2,A3)
      C=A4
60    CPZ=Y/C
      CPY=CPZ/C
      AI(IA)=AI(IA)+CPY*V(IA)-CPZ*V(JA)
      AI(JA)=AI(JA)+Y*V(JA)-CPZ*V(IA)
      GO TO 20
C
C     WRITING OF FINAL BUS CURRENTS AND MISMATCHES
C
70    IF (IWRITE.NE.1) GO TO 100
      WRITE (6,240)
      WRITE (6,350)
      WRITE (6,360)
      DO 90 I=1,N
      IF (KA(I).EQ.1) GO TO 80
      DS(I)=CONJG(S(I))-CV(I)*AI(I)
      GO TO 90
80    DS(I)=S(I)-CMPLX(REAL(CV(I)*AI(I)),CABS(V(I)))
90    WRITE (6,250) I,AI(I),DS(I)
      WRITE (6,370) NB,AI(NB)
C
C     WRITING OF FINAL LOAD BUS VOLTAGES
C
100   IF (IWRITE.EQ.2) RETURN
      WRITE (6,340)
      WRITE (6,480)
      WRITE (6,260) NB
      WRITE (6,480)
      WRITE (6,270)
      I=1
110   IF (I.GT.N) GO TO 210
      IF (KA(I).EQ.0) GO TO 120
      I=I+1
      GO TO 110
120   J=I+1
130   IF (J.GT.N) GO TO 190
      IF (KA(J).EQ.0) GO TO 140
      J=J+1
      GO TO 130
140   IF (AIMAG(V(I)).LT.0.0) GO TO 150
      IF (AIMAG(V(J)).LT.0.0) GO TO 170
      WRITE (6,280) I,V(I),J,V(J)
      GO TO 180
150   IF (AIMAG(V(J)).LT.0.0) GO TO 160
      P=REAL(V(I))
      Q=-AIMAG(V(I))
      WRITE (6,380) I,P,Q,J,V(J)
      GO TO 180
160   P=REAL(V(I))
      Q=-AIMAG(V(I))
      P2=REAL(V(J))
      Q2=-AIMAG(V(J))
```

```
      WRITE (6,390) I,P,Q,J,P2,Q2
      GO TO 180
170   P2=REAL(V(J))
      Q2=-AIMAG(V(J))
      WRITE (6,400) I,V(I),J,P2,Q2
180   I=J+1
      GO TO 110
190   IF (AIMAG(V(I)).LT.0.0) GO TO 200
      WRITE (6,290) I,V(I)
      GO TO 210
200   P=REAL(V(I))
      Q=-AIMAG(V(I))
      WRITE (6,410) I,P,Q
C
C     WRITING OF GENERATOR BUS REACTIVE POWERS AND VOLTAGES
C
210   WRITE (6,300)
      DO 230 I=1,NGB
      QG=-AIMAG(CV(IG(I))*AI(IG(I)))
      IF (AIMAG(V(IG(I))).LT.0.0) GO TO 220
      WRITE (6,310) IG(I),QG,IG(I),V(IG(I))
      GO TO 230
220   P=REAL(V(IG(I)))
      Q=-AIMAG(V(IG(I)))
      WRITE (6,420) IG(I),QG,IG(I),P,Q
230   CONTINUE
C
C     WRITING OF SLACK BUS POWER
C
      CPX=CV(NB)*AI(NB)
      P=REAL(CPX)
      Q=-AIMAG(CPX)
      WRITE (6,320)
      WRITE (6,330) NB,P,NB,Q
      WRITE (6,430)
      RETURN
C
240   FORMAT (/,* FINAL BUS CURRENTS AND MISMATCHES*,/)
250   FORMAT (I6,2X,2E14.5,4X,2E14.5)
260   FORMAT (*                LOAD FLOW SOLUTION OF*,I3,*-BUS POWER SYSTEM
     1*)
270   FORMAT (* LOAD BUSES*,/)
280   FORMAT (1X,*V(*,I3,*) =*,F8.5,* + J*,F7.5,6X,*V(*,I3,*) =*,F8.5,*
     1+ J*,F7.5,/)
290   FORMAT (1X,*V(*,I3,*) =*,F8.5,* + J*,F7.5,/)
300   FORMAT (* GENERATOR BUSES*,/)
310   FORMAT (1X,*Q(*,I3,*) =*,F8.5,17X,*V(*,I3,*) =*,F8.5,* + J*,F7.5,/
     1)
320   FORMAT (* SLACK BUS*,/)
330   FORMAT (1X,*P(*,I3,*) =*,F8.5,17X,*Q(*,I3,*) =*,F8.5,/)
340   FORMAT (*1*)
350   FORMAT (*  BUS NO.        BUS CURRENT(AI)                    MISMATCHE
     1S(DS)         */)
360   FORMAT (*                REAL          IMAGINARY            REAL
     1  IMAGINARY  *,/)
370   FORMAT (I6,2X,2E14.5)
380   FORMAT (1X,*V(*,I3,*) =*,F8.5,* - J*,F7.5,6X,*V(*,I3,*) =*,F8.5,*
     1+ J*,F7.5,/)
390   FORMAT (1X,*V(*,I3,*) =*,F8.5,* - J*,F7.5,6X,*V(*,I3,*) =*,F8.5,*
     1- J*,F7.5,/)
400   FORMAT (1X,*V(*,I3,*) =*,F8.5,* + J*,F7.5,6X,*V(*,I3,*) =*,F8.5,*
     1- J*,F7.5,/)
410   FORMAT (1X,*V(*,I3,*) =*,F8.5,* - J*,F7.5,/)
420   FORMAT (1X,*Q(*,I3,*) =*,F8.5,17X,*V(*,I3,*) =*,F8.5,* - J*,F7.5,/
     1)
```

```
430    FORMAT (/,1X,61(*-*),/)                                RST1540
       END                                                    RST1550-
```

SOC-283

XLF1 - A PROGRAM FOR COMPLEX LOAD FLOW ANALYSIS BY CONJUGATE ELIMINATION

J.W. Bandler, M.A. El-Kady and H. Gupta

December 1981, No. of Pages: 74

Revised:

Key Words: Load flow analysis, conjugate notation, complex analysis, power systems analysis

Abstract: XLF1 is a package of five compiled library subroutines for solving steady-state power flow equations in the compact complex mode. A user-supplied main program provides the necessary dimensional storage and system data. The program implements the recently developed algorithm for practical complex solution of power flow equations presented by Bandler, El-Kady and Gupta. Sensitivities of system states with respect to system control variables can also be evaluated by the program using a perturbation method. The program is written in Fortran IV, documented and tested on a CYBER 170 computer. The report includes a listing of the program, a user's guide and some illustrative examples.

Description: Contains Fortran program, user's manual. Source deck or magnetic tape available for $150.00. The listing contains 839 lines, of which 338 are comments.

Related Work: SOC-242, SOC-243, SOC-253, SOC-254, SOC-255, SOC-256, SOC-257, SOC-258, SOC-270.

Price: $100.00.