CTTM1 - A FORTRAN PACKAGE FOR POWER SYSTEM CONTINGENCY ANALYSIS

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Abstract

CTTM1 is a package of Fortran subroutines for power system contingency analysis. Outages of transmission lines are simulated one at a time. The package employs the fast decoupled method and sparse matrix techniques for solving the load flow problem by appropriate calls to the package TTM1. The user may control some parameters of the solution, i.e., demanded accuracy, upper bound on the number of iterations and upper bound on the iteration time. There are two entries to the package, namely the interactive and non-interactive entries. Using the interactive entry the user may select in an interactive way some options and also perform a series of contingency analyses. The package and documentation have been developed for the CDC 170/730 system with the NOS 1.4 level 552 operating system and the Fortran Extended (FTN) version 4.8 compiler.

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I. INTRODUCTION

Simulation of transmission line outages constitutes an important part of the power system security assessment problem. Recently, security requirements have also been incorporated into the optimal power flow problem [1,2].

This report describes a computer package, called CTTM1, for power system simulation under certain emergency conditions, i.e., when one transmission line at a time is out. To ensure computational efficiency after the simulation of a line outage, the load flow problem [3] is solved with the use of the fast decoupled method [4].

The package CTTM1 is written in Fortran IV for use on the CDC 170/730 system with the NOS 1.4 level 552 operating system. The package is available at McMaster University in the form of a library of binary relocatable subroutines which is linked with the user's program by an appropriate call statement. The name of the library is LIBCTM1. The library is available as a group indirect file under the charge RJWBAND. The general sequence of NOS commands to use the package can be as follows:

/GET,LIBCTM1/GR. - fetch the library,

/LIBRARY, LIBCTM1. - indicate the library to the loader.

The package calls subroutines FORMYT and LFLFD1M of the package TTM1 [5]. Therefore, the package TTM1 and subsequently the package MA28 for solving sparse linear equations [6] must be available when CTTM1 is used.

The user's program should contain at least the main segment which prepares arguments and calls either subroutine CONTA or subroutine CONTB of the package CTTM1.

This document contains the user's manual of the package CTTM1 presented together with illustrative examples. A Fortran listing of the package is found in [7].

II. GENERAL DESCRIPTION

The package CTTM1 simulates removal of one transmission line selected by the user, formulates and solves the load flow equations for the system under contingency and, after obtaining the solution, it reconstructs the original data. This process is either terminated after one contingency analysis or repeated for other line outages.

It is assumed that, on entry to the package, data describing transmission lines of the original system and also the vector of bus control variables constituting the right-hand side of the load flow equations are given. This data can be supplied through appropriate calls in the main segment to subroutines RDAT and FORMU of the package TTM1. Data describing transmission lines is updated in the package CTTM1 to simulate removal of a line selected by the user. The bus admittance matrix is formulated using updated data (call to subroutine FORMYT of the package TTM1) and the load flow problem is solved using the fast decoupled method (call to subroutine LFLFD1M of the package TTM1).

Subroutine LFLFD1M implements the fast decoupled iterative method for solving the power system load flow problem [4,5] using a sparse representation of the bus admittance matrix. The user, in his program, may control some parameters of the iterative procedure for solving load flow equations of the system under contingency, i.e., demanded accuracy of the solution, upper bound on the number of iterations and upper bound on the iteration time. When the contingency analysis is completed the package CTTM1 reconstructs the original transmission line data.

There are two possible entries to the package, i.e., a call to subroutine CONTA or to subroutine CONTB. The main difference is that by calling CONTA, the user selects some options in an interactive way, while calling CONTB all input arguments must be initialized in the main segment. Also using subroutine CONTA it is possible to perform a series of contingency analyses in one call.

The user is supposed to choose in an interactive way the following options while using subroutine CONTA:

- to continue contingency analysis with an alternative line or to terminate execution,
- print out level (0, 1, 2, 3 or 4),
- the starting point for contingency analysis,
- the index of the line which is to be removed.

Using subroutine CONTB the last three options are chosen by appropriate initialization of the call statement arguments. Only a single contingency analysis in one call is allowed while using subroutine CONTB.

There are possible two different starting points for the iterative procedure for solving load flow equations: the first with bus voltages initialized by the user on entry to the package and another one with bus voltages at the solution point of the last performed contingency analysis. The last option is applicable only when the interactive entry to the package is used and a series of contingency analyses is performed.

III. STRUCTURE OF THE PACKAGE

Block diagram of the package CTTM1 is shown in Figure 1.

Subroutine CONTA is an entry subroutine to the package when an interactive mode is used. It organizes the interactive mode of work, reads the data which is required to be entered in an interactive way and also checks correctness of some parameters.

Subroutine CONTB either is called by subroutine CONTA or it is an entry subroutine to the package for the non-interactive mode of work. Subroutine

CONTB distributes the workspace provided by the user into a set of vectors used by the called subroutines and initiates the contingency analysis.

Subroutine CONTC simulates the line removal by updating appropriate data, formulates the bus admittance matrix of the system under emergency conditions (call to subroutine FORMYT of the package TTM1) and initiates the load flow solution (call to subroutine LFLFD1M of the package TTM1). The original data describing power system is reconstructed in subroutine CONTC after completing the contingency analysis.

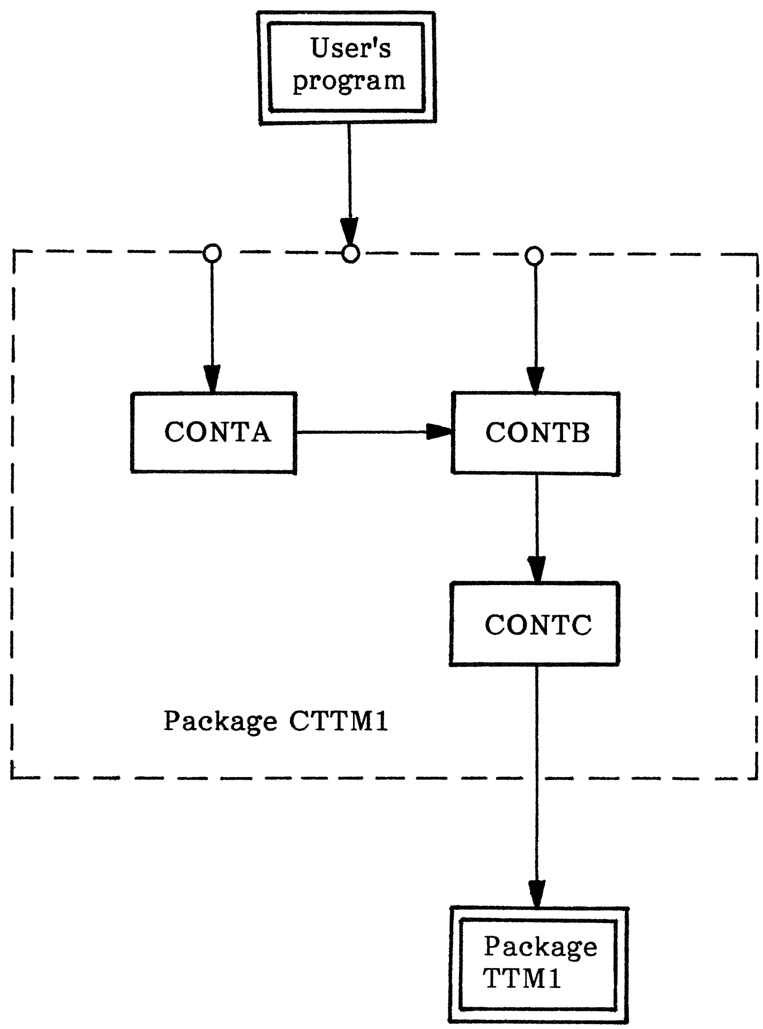

Fig. 1 Structure of the package CTTM1.

IV. LIST OF ARGUMENTS

Interactive Entry (Subroutine CONTA)

The subroutine call is

CALL CONTA(LBINP, LBOUT, LINPG, LINPB, LG, LB, LOUTG, LOUTB, LTAP, BTYP, BSTL, BCV, V, W, LW, NB, NTL, NLB, ITER, TOLV, TIME, INPT, OTPT).

The arguments are as follows.

LBINP, LBOUT are INTEGER vectors of dimension NTL. On entry to the package, LBINP(k) and LBOUT(k) must store the indices of buses incident with the kth transmission line (k = 1, 2, ..., NTL) [5]. Neither vector is altered by the package.

LINPG, LINPB are REAL vectors of dimension NTL. On entry, LINPG(k) and LINPB(k) must store the input shunt conductance and susceptance of the kth transmission line (k = 1, 2, ..., NTL) [5]. These vectors are not altered by the package.

LG, LB are REAL vectors of dimension NTL. On entry, LG(k) and LB(k) must store the conductance and susceptance of the kth transmission line (k = 1, 2, ..., NTL) [5]. These vectors are not altered by the package.

LOUTG, LOUTB are REAL vectors of dimension NTL. On entry, LOUTG(k) and LOUTB(k) must store the output conductance and susceptance of the kth transmission line (k = 1, 2, ..., NTL) [5]. Neither vector is altered by the package.

LTAP is a REAL vector of dimension NTL. On entry to the subroutine, it must contain the line transformer ratios [5]. LTAP is not altered by the package.

BTYP is an INTEGER vector of length NB-1 of bus types (0 for load bus, 1 for generator bus).

BSTL is a REAL vector of dimension NB. On entry, it must contain bus static loads [5]. Not altered by the package.

BCV is a REAL vector of dimension 2*(NB-1). On entry, it stores the scheduled values of bus control variables [3,5]. BCV is not altered by the package.

V is a COMPLEX vector of dimension NB. On entry to the package, it must store initial values of bus voltages in rectangular coordinates. On return, V stores values of bus voltages at the solution.

W is a REAL vector of dimension LW. W is used as workspace by the package.

LW is the length of the workspace W. It must be at least

LW = max (14*NB+5*NLB+9*NYT+6*NZ2,10*NB+16*NLB+9*NYT+7*NZ2, 21*NB+10*NYT),

where NYT = NB+2*NTL and NZ2 is the integral part of (NYT*(NLB**2))/((NB-1)**2).

When the declared length of the workspace is less than LW, the program execution is terminated and an appropriate message is printed.

NB is an INTEGER parameter. On entry, NB must be equal to the total number of buses and is not altered by the package.

NTL is an INTEGER parameter. On entry, NTL must be equal to the number of transmission lines of the original system and is not altered by the package.

NLB is an INTEGER parameter. On entry, NLB must be equal to the number of load buses and is not altered by the package.

ITER — is an INTEGER parameter that controls the iterative procedure for solving load flow equations. On entry, ITER is the upper bound on the number of iterations; if ITER $<$ 0 the number of iterations is unbounded. On return, ITER is equal to the number of iterations performed [5].

TOLV — is a REAL parameter that controls the iterative procedure for solving load flow equations. On entry, TOLV is the required accuracy of the solution of load flow equations. The iterative procedure terminates when the maximal value of the modulus of corrections of bus voltages is not greater than TOLV. On return, TOLV is the attained accuracy of the solution [5].

TIME — is a REAL parameter that controls the iterative procedure for solving load flow equations. On entry, TIME is the upper bound on total iteration time (in seconds); if TIME $\leq$ 0, the iteration time is unbounded. On return, TIME is equal to the value of the total iteration time [5].

INPT — is an INTEGER argument which must be set to the unit number that is used to input data in an interactive way. The value of INPT is not changed by the package.

OTPT — is an INTEGER argument which must be set to the unit number that is used for the printed output generated by the package. Usually it is the unit number of the file OUTPUT. The value of OTPT is not changed by the package.

Non-interactive Entry (Subroutine CONTB)

The subroutine call is

CALL CONTB(LBINP, LBOUT, LINPG, LINPB, LG, LB, LOUTG, LOUTB, LTAP,

BTYP, BSTL, BCV, V, W, LW, NB, NTL, NLB, ITER, TOLV, TIME, LN, ISTART, ICALL, OTPT, IWRITE).

List of arguments of subroutine CONTB contains all arguments appearing on the list of arguments of subroutine CONTA except parameter INPT. The meaning of these arguments is the same in both subroutines. It should be noted, however, that the non-interactive entry requires also 4 arguments which do not exist when the interactive entry is used.

LN — is an INTEGER argument. On entry, LN must be equal to the index of a transmission line which is to be removed. When the interactive entry is used this argument is supplied interactively.

ISTART — is an INTEGER argument to select a starting point for the contingency analysis. For the non-interactive entry this parameter must be set to zero. When the interactive entry is used the value of ISTART is entered interactively.

ICALL — is an INTEGER argument. On the first call to subroutine CONTB this parameter must be set to one. It is advised to set ICALL to the value greater than one in subsequent calls. On return from the package, ICALL is increased by one.

IWRITE — is an INTEGER argument that controls printed output. When the interactive entry is used the value of this parameter is entered interactively. In normal conditions the non-interactive entry may generate printed output only due to call to subroutines FORMYT and LFLFD1M of the package TTM1. Possible values of IWRITE for both interactive and non-interactive entires are

≤ 0 all prints are suppressed,

$= 1$ total number of iterations ITER, return flag from subroutine LFLFD1M, attained accuracy of the solution TOLV and the total iteration time TIME are printed out,

= 2 as above and additionally

- vector of bus voltages at the solution in rectangular and polar coordinates,
- short information about each iteration performed, i.e., iteration number, iteration type, accuracy obtained are printed out,

= 3 as above and additionally

- bus admittance matrix of the system under contingency in a sparse form,
- vector of bus voltages for each iteration in rectangular coordinates are printed out,

$\geq$ 4 as above and additionally

- matrices of the power flow decoupled equations are printed out in a sparse form.

V. GENERAL INFORMATION

Common Blocks

COMMON /C1/JIRYT, JICYT, JYT, JVI, JWS, LWS, JMAX

where

JIRYT, JICYT, JYT, JVI, JWS

indicate locations in the workspace vector W of the first elements of vectors JRYT, ICYT, YT, VI, WS. These vectors are used by the called subroutines FORMYT and LFLFD1M of the package TTM1 [5].

LWS is the length of the workspace vector WS used by subroutine LFLFD1M.

JMAX is the length of the workspace vector W used by the package.

COMMON/C2/IFLAG

where

IFLAG is the return flag from subroutine LFLFD1M [5].

Workspace

Provided by the user; see arguments W and LW.

Error Diagnostics

When the length LW of the workspace W declared by the user is too small or when the return flag IFLAG from subroutine LFLFD1M is less than zero, the program execution is terminated and an appropriate message is printed out.

More error diagnostics may appear due to subsequent calls to subroutines MA28A and MA28C of the package MA28 [6].

Input/Output

Input (for the interactive entry only) as defined by the user; see argument INPT. Output as defined by the user; see argument OTPT. Printed output is controlled by the parameter IWRITE.

Related Software

Package CTTM1 calls subroutines FORMYT and LFLFD1M of the package TTM1 [5]. Due to subsequent calls subroutines MA28A and MA28C of the package MA28 [6] are also used.

VI. EXAMPLES

Example 1

In this example contingency analysis of the American Electric Power 118-bus test power system [8] is considered. The listing of the main program CNT118 is on page 13.

Permanent group file B118SVA [9] contains data describing the system considered with bus voltages at the operating point under normal conditions. These voltages (in rectangular coordinates) constitutes the vector of initial bus voltages for the contingency analysis.

Program CNT118 calls subroutines RDAT and FORMU of the package TTM1 to read data and to formulate the vector of bus control variables as is required by the package CTTM1. The demanded accuracy of the solution of the load flow equations of the system under contingency is 10^{-4}. The number of iterations is limited to 25 and the execution time is limited to 2.0 seconds. Subroutine CONTA of the package CTTM1 is called, i.e., the interactive entry is used.

Contingency analysis of the system considered was performed with different transmission lines, different starting points and different printing levels. The results of the analysis are shown on pages 14-18. It can be noted that by proper choice of the starting point we may reduce the number of iterations needed to get the solution. In the example discussed outage of the 30th transmission line was simulated twice with different starting points. In the first analysis initial bus voltages were taken as a starting point (i.e., bus voltages initialized on entry to the package). In the subsequent analysis bus voltages at the solution point for the last performed contingency analysis (line 109) were taken as a starting point. The number of iterations needed to get the solution was less in the second case due to

```
C
C
C
      PROGRAM CNT118(B118,INPUT,OUTPUT,TAPE3=B118,TAPE4=INPUT,TAPE6=OUTP
     1UT)
C
C     THIS IS THE MAIN PROGRAM FOR THE CONTINGENCY ANALYSIS OF 118 BUS
C     POWER SYSTEM
C
      INTEGER BTYP(118),LBINP(180),LBOUT(180),OTPT
      REAL W(9000),LINPG(180),LINPB(180),LG(180),LB(180),LOUTG(180),LOUT
     1B(180),LTAP(180),BSTL(118)
      COMPLEX BCV(118),V(118)
C
      IWRITE=0
      INP1=3
      INP2=4
      OTPT=6
      WRITE (OTPT,20)
      LW=9000
      TIME=2.0
      ITER=25
      TOLV=1.E-4
      NB=120
      I1=1
      I2=I1+NB
      I3=I2+NB
      I4=I3+NB
      I5=I4+NB
      I6=I5+NB
      CALL RDAT (LBINP,LBOUT,LINPG,LINPB,LG,LB,LOUTG,LOUTB,LTAP,W(I1),BT
     1YP,W(I2),W(I3),W(I4),W(I5),W(I6),BSTL,W(I1),NB,NTL,NLB,INP1,IWRITE
     2)
      CALL FORMU (BTYP,W(I2),W(I3),W(I4),W(I5),W(I6),BCV,NB,OTPT,IWRITE)
      IS1=I2-1
      IS2=I3-1
      DO 10 I=1,NB
      VMOD=W(IS1+I)
      VARG=W(IS2+I)
      V(I)=CMPLX(VMOD*COS(VARG),VMOD*SIN(VARG))
   10 CONTINUE
      CALL CONTA (LBINP,LBOUT,LINPG,LINPB,LG,LB,LOUTG,LOUTB,LTAP,BTYP,BS
     1TL,BCV,V,W,LW,NB,NTL,NLB,ITER,TOLV,TIME,INP2,OTPT)
      STOP
   20 FORMAT (//" CONTINGENCY ANALYSIS OF 118-BUS POWER SYSTEM")
      END
```

```
CONTINGENCY ANALYSIS OF 118-BUS POWER SYSTEM

-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
TYPE "YES" FOR CONTINGENCY ANALYSIS OR "STOP" TO STOP
*INPUT*  "YES"

SELECT PRINTOUT LEVEL (0,1,2,3 OR 4)
*INPUT*  1

SELECT STARTING POINT (0-INITIAL POINT,1-LAST SOLUTION)
*INPUT*  0

ENTER LINE INDEX
*INPUT*  30

LINE REMOVED. TERMINAL BUSES:  23,  24


LOAD FLOW SOLUTION OF 118-BUS SYSTEM USING THE FAST DECOUPLED METHOD


RESULTS OF ANALYSIS

NUMBER OF ITERATIONS:          9
RETURN FLAG:                   0
ACCURACY OBTAINED:     .5402E-04
ANALYSIS TIME:             .708 SECONDS

-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
TYPE "YES" FOR CONTINGENCY ANALYSIS OR "STOP" TO STOP
*INPUT*  "YES"

SELECT PRINTOUT LEVEL (0,1,2,3 OR 4)
*INPUT*  2

SELECT STARTING POINT (0-INITIAL POINT,1-LAST SOLUTION)
*INPUT*  1

ENTER LINE INDEX
*INPUT*  109

LINE REMOVED. TERMINAL BUSES:  24,  70


LOAD FLOW SOLUTION OF 118-BUS SYSTEM USING THE FAST DECOUPLED METHOD

RESULTS OF ITERATION NO.       1
ITERATION TYPE:          P-DELTA
ACCURACY OBTAINED:     .6111E-01
ITERATION TIME:            .430 SECONDS

RESULTS OF ITERATION NO.       2
ITERATION TYPE:              Q-V
ACCURACY OBTAINED:     .6025E-01
ITERATION TIME:            .028 SECONDS
```

```
RESULTS OF ITERATION NO.      3
ITERATION TYPE:          P-DELTA
ACCURACY OBTAINED:     .3838E-01
ITERATION TIME:             .062 SECONDS

RESULTS OF ITERATION NO.      4
ITERATION TYPE:              Q-V
ACCURACY OBTAINED:     .3795E-02
ITERATION TIME:             .029 SECONDS

RESULTS OF ITERATION NO.      5
ITERATION TYPE:          P-DELTA
ACCURACY OBTAINED:     .2340E-02
ITERATION TIME:             .062 SECONDS

RESULTS OF ITERATION NO.      6
ITERATION TYPE:              Q-V
ACCURACY OBTAINED:     .1448E-03
ITERATION TIME:             .029 SECONDS

RESULTS OF ITERATION NO.      7
ITERATION TYPE:          P-DELTA
ACCURACY OBTAINED:     .1347E-03
ITERATION TIME:             .059 SECONDS

RESULTS OF ITERATION NO.      8
ITERATION TYPE:              Q-V
ACCURACY OBTAINED:     .6649E-05
ITERATION TIME:             .029 SECONDS

RESULTS OF ITERATION NO.      9
ITERATION TYPE:          P-DELTA
ACCURACY OBTAINED:     .8317E-05
ITERATION TIME:             .062 SECONDS


RESULTS OF ANALYSIS

NUMBER OF ITERATIONS:         9
RETURN FLAG:                  0
ACCURACY OBTAINED:     .8317E-05
ANALYSIS TIME:              .799 SECONDS

VECTOR OF BUS VOLTAGES
   BUS        RECTANGULAR COORDINATES             POLAR COORDINATES

     1     .1007392E+01 -.5546718E+00      .1150000E+01 -.5033049E+00
     2     .8952771E+00 -.4360066E+00      .9958027E+00 -.4531996E+00
     3     .9642941E+00 -.4835924E+00      .1073761E+01 -.4648460E+00
     4     .9935885E+00 -.4719977E+00      .1100000E+01 -.4434838E+00
     5     .9631014E+00 -.3653077E+00      .1030055E+01 -.3625383E+00
     6     .8339291E+00 -.3384706E+00      .9000000E+00 -.3855604E+00
     7     .8336005E+00 -.3471971E+00      .9030147E+00 -.3946516E+00
     8     .1050460E+01 -.2909200E+00      .1090000E+01 -.2701739E+00
     9     .1005369E+01 -.1444624E+00      .1015695E+01 -.1427141E+00
    10     .9198044E+00  .1897022E-01      .9200000E+00  .2062126E-01
```

11	.8774795E+00	-.3863053E+00	.9587503E+00	-.4147115E+00
12	.8374904E+00	-.3559633E+00	.9100000E+00	-.4019009E+00
13	.8599433E+00	-.3982639E+00	.9476902E+00	-.4337175E+00
14	.8462290E+00	-.3725284E+00	.9245977E+00	-.4146926E+00
15	.8872229E+00	-.3920912E+00	.9700000E+00	-.4161235E+00
16	.8436269E+00	-.3628146E+00	.9183359E+00	-.4061531E+00
17	.9183235E+00	-.3528598E+00	.9837826E+00	-.3668498E+00
18	.8903137E+00	-.3850214E+00	.9700000E+00	-.4081689E+00
19	.8779239E+00	-.3883937E+00	.9600000E+00	-.4165159E+00
20	.8740498E+00	-.3682759E+00	.9484673E+00	-.3987702E+00
21	.8812133E+00	-.3405386E+00	.9447239E+00	-.3687648E+00
22	.9026792E+00	-.2999793E+00	.9512189E+00	-.3208393E+00
23	.9495568E+00	-.2205480E+00	.9748331E+00	-.2282177E+00
24	.8899359E+00	-.1900371E+00	.9100000E+00	-.2103805E+00
25	.1091280E+01	-.1382289E+00	.1100000E+01	-.1259957E+00
26	.1005746E+01	-.9259867E-01	.1010000E+01	-.9181078E-01
27	.9159985E+00	-.3191342E+00	.9700000E+00	-.3352491E+00
28	.7841418E+00	-.2730647E+00	.8303269E+00	-.3351005E+00
29	.8100783E+00	-.3084584E+00	.8668180E+00	-.3638249E+00
30	.1009699E+01	-.2833482E+00	.1048703E+01	-.2735894E+00
31	.8554683E+00	-.3384879E+00	.9200000E+00	-.3767729E+00
32	.9027708E+00	-.3265041E+00	.9600000E+00	-.3470322E+00
33	.8824077E+00	-.3779075E+00	.9599257E+00	-.4046359E+00
34	.8695739E+00	-.3569892E+00	.9400000E+00	-.3895539E+00
35	.9001254E+00	-.3784713E+00	.9764560E+00	-.3980232E+00
36	.9016609E+00	-.3839369E+00	.9800000E+00	-.4025572E+00
37	.9062231E+00	-.3402077E+00	.9679781E+00	-.3591324E+00
38	.9998462E+00	-.2749021E+00	.1036949E+01	-.2683145E+00
39	.8822070E+00	-.3832954E+00	.9618755E+00	-.4098672E+00
40	.8844926E+00	-.3982120E+00	.9700000E+00	-.4230329E+00
41	.9051719E+00	-.4184516E+00	.9972151E+00	-.4330268E+00
42	.1006505E+01	-.4437872E+00	.1100000E+01	-.4152764E+00
43	.8773449E+00	-.3397118E+00	.9408179E+00	-.3694273E+00
44	.9219139E+00	-.2786877E+00	.9631158E+00	-.2935587E+00
45	.9419435E+00	-.2405093E+00	.9721637E+00	-.2499916E+00
46	.9810765E+00	-.1936205E+00	.1000000E+01	-.1948511E+00
47	.1000447E+01	-.1534118E+00	.1012141E+01	-.1521580E+00
48	.1001912E+01	-.1653100E+00	.1015458E+01	-.1635213E+00
49	.1009397E+01	-.1466861E+00	.1020000E+01	-.1443103E+00
50	.9822131E+00	-.1703210E+00	.9968710E+00	-.1716980E+00
51	.9439281E+00	-.1942406E+00	.9637063E+00	-.2029460E+00
52	.9321766E+00	-.2022272E+00	.9538601E+00	-.2136305E+00
53	.9204170E+00	-.2000407E+00	.9419043E+00	-.2140088E+00
54	.9336999E+00	-.1752269E+00	.9500000E+00	-.1855116E+00
55	.9285971E+00	-.2005179E+00	.9500000E+00	-.2126710E+00
56	.9292545E+00	-.1974491E+00	.9500000E+00	-.2093674E+00
57	.9474782E+00	-.1923335E+00	.9668026E+00	-.2002739E+00
58	.9343676E+00	-.2000295E+00	.9555389E+00	-.2108967E+00
59	.9774980E+00	-.1568365E+00	.9900000E+00	-.1590910E+00
60	.9834572E+00	-.1204407E+00	.9908047E+00	-.1218599E+00
61	.9965967E+00	-.8243193E-01	.1000000E+01	-.8252557E-01
62	.9946806E+00	-.1030074E+00	.1000000E+01	-.1031905E+00
63	.1014231E+01	-.1077932E+00	.1019943E+01	-.1058833E+00
64	.1013178E+01	-.8077860E-01	.1016393E+01	-.7955965E-01
65	.9994040E+00	-.3452138E-01	.1000000E+01	-.3452824E-01
66	.1049388E+01	-.3585189E-01	.1050000E+01	-.3415130E-01
67	.1017428E+01	-.8101227E-01	.1020649E+01	-.7945691E-01
68	.1033958E+01	-.5270996E-01	.1035300E+01	-.5093474E-01
69	.9423464E+00	-.1186513E+00	.9497868E+00	-.1252514E+00
70	.9720244E+00	-.1247743E+00	.9800000E+00	-.1276672E+00
71	.9743916E+00	-.1391087E+00	.9842715E+00	-.1418064E+00
72	.9615091E+00	-.1894737E+00	.9800000E+00	-.1945658E+00
73	.9794952E+00	-.1438373E+00	.9900000E+00	-.1458062E+00
74	.9509354E+00	-.1316124E+00	.9600000E+00	-.1375294E+00
75	.9617864E+00	-.1086070E+00	.9678990E+00	-.1124458E+00

76	.9340689E+00	-.1054293E+00	.9400000E+00	-.1123954E+00
77	.1009895E+01	-.1458290E-01	.1010000E+01	-.1443902E-01
78	.9990554E+00	-.2613451E-01	.9993972E+00	-.2615326E-01
79	.1005899E+01	-.1631888E-01	.1006032E+01	-.1622176E-01
80	.1039324E+01	.3749560E-01	.1040000E+01	.3606127E-01
81	.1005707E+01	.2339776E-01	.1005979E+01	.2326079E-01
82	.9915164E+00	.1139228E-01	.9915818E+00	.1148925E-01
83	.9871489E+00	.3462025E-01	.9877558E+00	.3505658E-01
84	.9806604E+00	.8220113E-01	.9840995E+00	.8362672E-01
85	.9837117E+00	.1114055E+00	.9900000E+00	.1127697E+00
86	.9839962E+00	.8891313E-01	.9880051E+00	.9011450E-01
87	.1005394E+01	.9635190E-01	.1010000E+01	.9554322E-01
88	.9716384E+00	.1692522E+00	.9862695E+00	.1724621E+00
89	.9695733E+00	.2448012E+00	.1000000E+01	.2473146E+00
90	.9812091E+00	.1316388E+00	.9900000E+00	.1333634E+00
91	.9709691E+00	.1327368E+00	.9800000E+00	.1358634E+00
92	.9794289E+00	.1442881E+00	.9900000E+00	.1462665E+00
93	.9819494E+00	.9137830E-01	.9861920E+00	.9279082E-01
94	.9898047E+00	.5403448E-01	.9912785E+00	.5453692E-01
95	.9811874E+00	.3168401E-01	.9816989E+00	.3228028E-01
96	.9933784E+00	.2251272E-01	.9936335E+00	.2265891E-01
97	.1011650E+01	.2354310E-01	.1011924E+01	.2326778E-01
98	.1024345E+01	.2353097E-01	.1024616E+01	.2296768E-01
99	.1009333E+01	.3669765E-01	.1010000E+01	.3634231E-01
100	.1018309E+01	.5870832E-01	.1020000E+01	.5758901E-01
101	.9902988E+00	.7923282E-01	.9934634E+00	.7983893E-01
102	.9825372E+00	.1207375E+00	.9899277E+00	.1222704E+00
103	.1009804E+01	.1988234E-01	.1010000E+01	.1968676E-01
104	.9694046E+00	-.3398010E-01	.9700000E+00	-.3503820E-01
105	.9586730E+00	-.5045857E-01	.9600000E+00	-.5258524E-01
106	.9564782E+00	-.5816381E-01	.9582450E+00	-.6073560E-01
107	.9443886E+00	-.1031025E+00	.9500000E+00	-.1087431E+00
108	.9595405E+00	-.6932498E-01	.9620415E+00	-.7212279E-01
109	.9601422E+00	-.7642716E-01	.9631792E+00	-.7943235E-01
110	.9658442E+00	-.8969381E-01	.9700000E+00	-.9260013E-01
111	.9779499E+00	-.6335569E-01	.9800000E+00	-.6469378E-01
112	.9690186E+00	-.1462972E+00	.9800000E+00	-.1498429E+00
113	.9239961E+00	-.3554311E+00	.9900000E+00	-.3672191E+00
114	.9014421E+00	-.3316383E+00	.9605112E+00	-.3525293E+00
115	.9041395E+00	-.3323782E+00	.9632983E+00	-.3522833E+00
116	.9887977E+00	-.1492618E+00	.1000000E+01	-.1498216E+00
117	.8101883E+00	-.3754890E+00	.8929709E+00	-.4339898E+00
118	.1030000E+01	0.	.1030000E+01	0.

```
-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
TYPE "YES" FOR CONTINGENCY ANALYSIS OR "STOP" TO STOP
*INPUT*  "YES"

SELECT PRINTOUT LEVEL (0,1,2,3 OR 4)
*INPUT*  1

SELECT STARTING POINT (0-INITIAL POINT,1-LAST SOLUTION)
*INPUT*  1

ENTER LINE INDEX
*INPUT*  30

LINE REMOVED. TERMINAL BUSES:  23,  24
```

```
LOAD FLOW SOLUTION OF 118-BUS SYSTEM USING THE FAST DECOUPLED METHOD


RESULTS OF ANALYSIS

NUMBER OF ITERATIONS:          7
RETURN FLAG:                   0
ACCURACY OBTAINED:     .5574E-04
ANALYSIS TIME:              .632 SECONDS


-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
TYPE "YES" FOR CONTINGENCY ANALYSIS OR "STOP" TO STOP
*INPUT*   "YES"

SELECT PRINTOUT LEVEL (0,1,2,3 OR 4)
*INPUT*   1

SELECT STARTING POINT (0-INITIAL POINT,1-LAST SOLUTION)
*INPUT*  0

ENTER LINE INDEX
*INPUT*  34

LINE REMOVED. TERMINAL BUSES:  27,  28


LOAD FLOW SOLUTION OF 118-BUS SYSTEM USING THE FAST DECOUPLED METHOD


RESULTS OF ANALYSIS

NUMBER OF ITERATIONS:         25
RETURN FLAG:                   1
ACCURACY OBTAINED:     .6370E-01
ANALYSIS TIME:             1.058 SECONDS


-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
TYPE "YES" FOR CONTINGENCY ANALYSIS OR "STOP" TO STOP
*INPUT*   "STOP"
```

that both lines 30th and 109th have one common bus. It should also be noted that in the last performed contingency analysis (line 34) the limit of iterations has been reached and the solution has not been found.

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