CNTL - A FORTRAN PACKAGE FOR PROCESSING CONTINGENCY SOLUTIONS OF POWER SYSTEMS

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Abstract

This document contains the user's manual of the Fortran package CNTL. CNTL is a package of three subroutines designed for comparing pre-contingency and post- contingency states of a power system, i.e., power flow in lines, bus voltages at the solution and losses in the lines. The subroutines for reading and preprocessing data containing the load flow solutions of a power system under a contingency, i.e., when a single transmission line is removed from the system, are also included in the package. The package and documentation have been developed for the CDC 170/730 system with NOS 1.4 level 552 operating system and the Fortran Extended (FTN) version 4.8 compiler. A numerical example illustrates the use of CNTL package.

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I. INTRODUCTION

Contingency analysis is a valuable tool for reliable planning and secure operation of a power system. It is a study of the system under contingencies, i.e., a line outage, a generator outage, etc. The main purpose of this analysis is to determine which contingencies cause component limit violations and also the severity of any such violations, i.e., branch flow limits, bus voltage limits and generator VAR limits. This report describes a computer program package called CNTL for processing contingency solutions of power systems. The main goal of the package is to determine power flow in lines of a power system for pre-contingency and post-contingency states, the changes of the power flow in the lines and the changes of the bus voltages in the system due to the line outage.

The whole package is written in Fortran IV for the CDC 170/730 system. At McMaster University, it is available in the form of a library of binary relocatable subroutines which are linked with a user's program by the appropriate call to the subroutines in the package. The name of the library is LIBCNTL. 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, LIBCNTL/GR. - fetch the library,

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

To use the package the user has to prepare the main program which declares all arguments appearing in the subroutine calls, assigns the necessary dimension of storage and prepares the data to the form desired by the subroutines of the package.

This document contains the user's manual of the package CNTL. A Fortran listing of the package is found in [1].

II. GENERAL DESCRIPTION

The package CNTL is a set of subroutines that calculate:

- the power flow in the lines of the power system for pre-contingency and post-contingency states,
- the deviation and the relative deviation of the power flow in the lines after a contingency,
- the power losses in the lines of the power system for pre-contingency and post-contingency states,
- the deviation of the bus voltage moduli after a contingency,
- the deviation of the bus voltage arguments after a contingency.

It is assumed that on entry to the package data describing the transmission lines and the load flow solutions for pre-contingency and post-contingency states are given.

The data describing the transmission lines of the power system may be prepared directly from typical data describing the power system that is studied. For the test power systems, i.e., the 26-bus system [2,3] and the IEEE 118-bus power system [2,4], this data can be supplied by the appropriate call in the main program to the subroutine RDAT of the package TTM1 [5]. The load flow solutions of test power systems under contingencies, i.e., when single lines are removed from the system, can be obtained by the user from the formatted group data files [6] using subroutine CORDAT of this package. Subroutine CORDAT reads the data from these files and selects the appropriate load flow solution.

The user can fetch (and rename) these data files using the following NOS commands:

for the 26-bus system,

/GET, lfn = CL026/GR.

for the IEEE 118-bus system,

/GET, lfn = CL118/GR.

where lfn is a local file name given the file while in use.

III. STRUCTURE OF THE PACKAGE

A block diagram of the package is shown in Fig. 1. The subroutine CONTI is the main subroutine of the package. It calculates the power flow in the lines of the power system for the pre-contingency and post-contingency states, the changes of the power flow in the lines and the changes of the bus voltages at the solution in the power system under the contingency.

The subroutine CORDAT is an auxiliary subroutine. It reads the data from the formatted data files [6] and selects the desired load flow solution. The subroutine COFDAT is also an auxiliary subroutine. It creates the formatted subfile containing the load flow solution of the power system under a contingency.

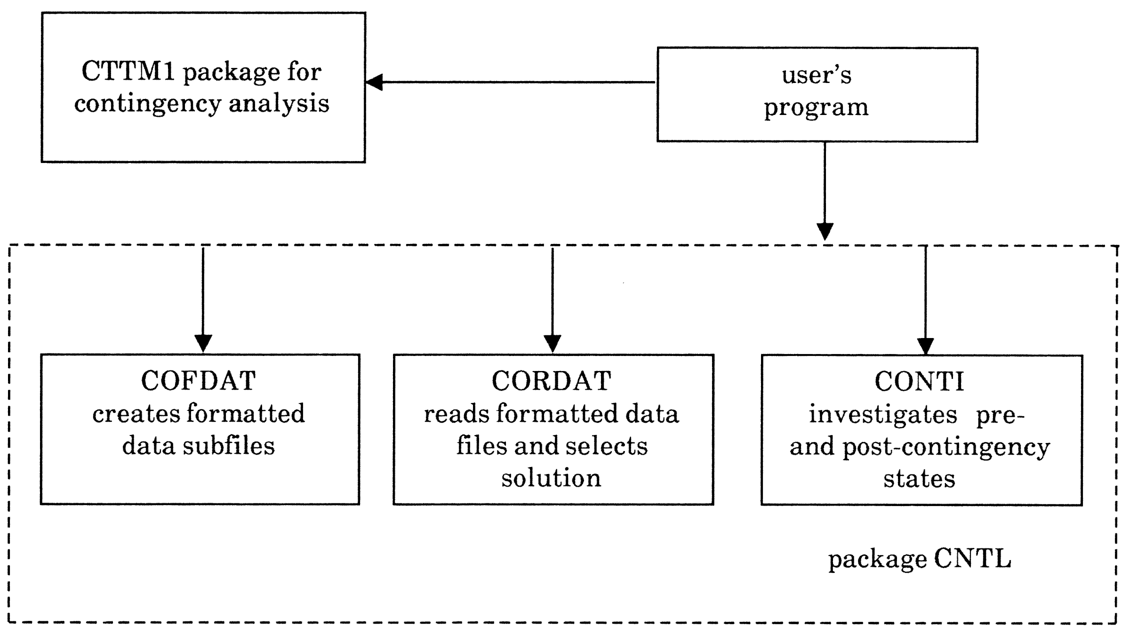

Fig. 1 Overall organization of the CNTL package.

IV. LIST OF ARGUMENTS

Standard entry - subroutine CONTI

The subroutine call is

CALL CONTI (LBINP, LBOUT, LINPG, LINPB, LG, LB, LOUTG, LOUTB, LTAP, V, VCB,

NB, NTL, NLIN, OTPT)

The arguments are as follows.

LBINP, LBOUT — are INTEGER vectors of dimension NTL. On entry to the subroutine, LBINP(k), LBOUT(k) must contain the indices of buses incident with the kth line (k=1,2,...,NTL). The vectors are not altered by the subroutine.

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

LG, LB — are REAL vectors of dimension NTL. On entry to the subroutine, LG(k) and LB(k) must contain the line conductance and susceptance of the kth transmission line (k=1,2,...,NTL). These vectors are not altered by the subroutine.

LOUTG, LOUTB — are REAL vectors of dimension NTL. On entry to the subroutine, LOUTG(k), LOUTB(k) must contain the output conductance and susceptance of the kth transmission line (k=1,2,...,NTL). The vectors are not altered by subroutine.

LTAP — is a REAL vector of dimension NTL. On entry to the subroutine, LTAP(k) must contain the value of the kth line transformer ratio. The vector LTAP is not altered by the subroutine.

V — is a COMPLEX vector of dimension NB. On entry to the subroutine, it must contain the values of bus voltages (in rectangular coordinates) at the solution of the power system under a contingency. This vector is not altered by the subroutine.

VCB — is a COMPLEX vector of dimension NB. On entry to the subroutine, it must contain the values of the bus voltages (in rectangular coordinates) at the solution of the power system. This vector is not altered by the subroutine.

NB — is an INTEGER argument. On entry, it must be equal to the number of buses of the power system. Not altered by the subroutine.

NTL — is an INTEGER argument. On entry, it must be equal to the number of transmission lines of the power system. Not altered by the subroutine.

NLIN — is an INTEGER argument. On entry NLIN must be set to the index of a line removed from the original power system. Not altered by the subroutine.

OTPT — is an INTEGER argument which must be set to the index of the output unit.

Auxiliary subroutines

Subroutine CORDAT

The subroutine call is

CALL CORDAT (NB, NLIN, V, INPT, NS, IFLAG)

The arguments are as follows.

NB — is an INTEGER argument. On entry, NB must be set to the number of buses of the power system. Not altered by the subroutine.

NLIN — is an INTEGER argument. On entry, NLIN must be set to the index of a transmission line removed from the original power system. Not altered by the subroutine.

V is a COMPLEX vector of dimension NB. On exit from the subroutine V stores the values of bus voltages (in rectangular coordinates) at the solution of the power system with the NLINth line removed.

INPT is an INTEGER argument that must be set to the index of the input unit. Not altered by the subroutine.

NS is an INTEGER argument. On entry to the subroutine it must be set to the number of the load flow solutions of the power system under contingencies stored on the input file.

IFLAG is an INTEGER parameter. Return flag from the subroutine.

Subroutine COFDAT

The subroutine call is

CALL COFDAT (NB, NLIN, V, OTPT)

The arguments are as follows.

NB is an INTEGER argument. On entry, it must be set to the number of buses of the power system. Not altered by the subroutine.

NLIN is an INTEGER argument. On entry, it must be set to the index of the line removed from the power system. Not altered by the subroutine.

V is a COMPLEX vector of dimension NB. On entry, vector V must contain the values of the bus voltages (in rectangular coordinates) at the solution of the power system with the NLINth line removed. Not altered by the subroutine.

OTPT is an INTEGER parameter. It must be set to the unit index of the output file.

V. EXAMPLE

In this example the pre-contingency and post-contingency states of the 26- bus test power system are studied. The listing of the program PCSTATE is on pages 10,11.

Permanent group file CL026 [6] contains the set of the load flow solutions of the power system under investigation with the different single lines removed. The permanent group file B026SVA [2] contains the data describing the 26-bus system with bus voltages at the operating point under normal conditions.

The program PCSTATE calls the subroutine RDAT of the package TTM1 [5] to read data describing the power system and to prepare it as required by the subroutine CONTI. The user has to supply the index of the removed line from the power system under study. The appropriate load flow solution is selected by the subroutine CORDAT.

The results of processing the contingency solution of the 26-bus system with the line (15,1) removed are shown on pages 12,13. More results of processing the contingency solutions of the 26-bus system are presented in [7].

VI. REFERENCES

[1] J.W. Bandler, M.A. El-Kady and G. Centkowski, "CNTL - A Fortran package for processing contingency solutions of power systems", Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada, Report SOS-83-26-L, 1983.

[2] J.W. Bandler, M.A. El-Kady and J. Wojciechowski, "Formatted data files for test power systems", Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada, Report SOS-83-9-D, 1983.

[3] M.S. Sadchev and S.A. Ibrahim, "A fast approximate technique for outage studies in power system planning and operation", <u>IEEE Trans. Power Apparatus and Systems,</u> vol. PAS-93, 1974, pp. 1133-1142.

[4] "American Electric Power 118-Bus Test System", American Electric Power Service Corporation, New York, NY, December 1962.

[5] J.W. Bandler, M.A. El-Kady and J. Wojciechowski, "TTM1 - A Fortran implementation of the Tellegen theorem method to power system simulation and design", Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada, Report SOS-82-12-U2, 1983.

[6] J.W. Bandler, M.A. El-Kady and G. Centkowski, "Load flow solutions of test power systems under contingency: formatted data files", Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada, Report SOS-83-25-D, 1983.

[7] J.W. Bandler, M.A. El-Kady and G. Centkowski, "Contingency analysis of the 26-bus test power system: data, results and illustration", Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada, Report SOS-83-27-R, 1983.

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      PROGRAM PCSTATE(B118,CLXXX,INPUT,OUTPUT,TAPE3=B118,TAPE6=OUTPUT,IR
     1ES,TAPE7=IRES,TAPE2=CLXXX,TAPE4=INPUT)

        THIS IS THE MAIN PROGRAM FOR PROCESSING OF THE RESULTS OF THE
        ANALYSIS OF A POWER SYSTEM UNDER A CONTINGENCY

        THE DATA DESCRIBING THE POWER SYSTEM IS READ FROM THE FILE B118

        THE LOAD FLOW SOLUTIONS OF THE SYSTEM UNDER A CONTINGENCY ARE
        READ FROM THE FILE CLXXX

        THE RESULTS OF PROCESSING ARE PRINTED OUT ON THE FILE IRES

      INTEGER BTYP(118),LBINP(180),LBOUT(180),OTPT,CLXXX
      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),VV,VCB(118)

        SET THE INDICES OF THE INPUT AND OUTPUT UNITS

      INP1=3
      CLXXX=2
      OTPT=6
      IRES=7

      NB=120
      NTL=179
      IWRITE=0

      I1=1
      I2=I1+NB
      I3=I2+NB
      I4=I3+NB
      I5=I4+NB
      I6=I5+NB

        SUBROUTINE RDAT OF THE TTM1 LIBRARY PREPROCESSES INPUT DATA
        DESCRIBING THE POWER SYSTEM

      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)
      NS=25
      IF (NB.EQ.118) NS=4
      IS1=I2-1
      IS2=I3-1
      DO 10 I=1,NB
      VMOD=W(IS1+I)
      VARG=W(IS2+I)
      VCB(I)=CMPLX(VMOD*COS(VARG),VMOD*SIN(VARG))
   10 CONTINUE

   20 CONTINUE
      WRITE (6,60)
      READ (4,*) ISTER
      IF (ISTER.EQ."YES") GO TO 30
      IF (ISTER.NE."STOP") GO TO 20
      STOP
   30 CONTINUE
      WRITE (6,70)

        THE INDEX OF A LINE REMOVED FROM THE POWER SYSTEM IS READ FROM
        THE FILE INPUT
```

```
      READ (4,*) NLIN

      IF (NLIN.LE.0) STOP
      REWIND CLXXX

        SUBROUTINE CORDAT SELECTS FROM THE FILE CLXXX THE LOAD FLOW
        SOLUTION OF THE POWER SYSTEM WITH THE NLINTH LINE REMOVED

      CALL CORDAT (NB,NLIN,V,CLXXX,NS,IFLAG)
      IF (IFLAG.LT.0) GO TO 40

        SUBROUTINE CONTI OF THE CNTL LIBRARY CALCULATES POWER FLOW IN
        LINES OF THE POWER SYSTEM BEFORE AND AFTER A CONTINGENCY

      CALL CONTI (LBINP,LBOUT,LINPG,LINPB,LG,LB,LOUTG,LOUTB,LTAP,V,VCB,N
     1B,NTL,NLIN,IRES)

      GO TO 20
   40 CONTINUE
      WRITE (IRES,50) IFLAG
      STOP
   50 FORMAT (1X,"IFLAG FROM CORDAT=  ",I3)
   60 FORMAT (///,1X,43HTYPE "YES" FOR PROCESSING OR "STOP" TO STOP)
   70 FORMAT (//1X,"ENTER LINE INDEX")
      END
```

CONTINGENCY ANALYSIS OF THE 26-BUS POWER SYSTEM

INDEX OF THE LINE REMOVED: 24 TERMINAL BUSES: 15 1
P - REAL POWER ; Q - REACTIVE POWER

LINE NO.	FROM	TO	LINE FLOWS BASE CASE P	LINE FLOWS BASE CASE Q	LINE FLOWS CONTINGENCY P	LINE FLOWS CONTINGENCY Q	DEVIATION DP	RELATIVE DEVIA. DP/P (IN %)	LINE LOSSES BASE CASE	LINE LOSSES CONTINGENCY
1	13	26	1.1767	.4717	1.3889	.4084	.212	18.03	0.0000	0.0000
2	26	16	1.2646	.4515	1.2646	.4504	-.000	-.00	.0000	.0000
3	16	23	-.0454	.0876	-.0454	.0877	-.000	-.00	.0000	-.0000
4	23	26	-.0854	-.0307	-.0854	-.0307	-.000	-.00	0.0000	0.0000
5	2	10	1.5615	-.1119	1.3452	-.0513	-.216	-13.85	.0000	0.0000
6	9	10	-.5008	-.3222	-.3093	-.4429	-.216	-39.91	.0407	.0161
7	9	12	-.1946	.0575	.0976	-.1044	-.100	-50.64	.0031	.0012
8	12	26	-.6277	-.0353	-.3336	-.1933	-.308	-47.43	.0224	.0082
9	9	14	.0255	.0548	-.4582	.3373	.456	1788.75	.0005	.0230
10	11	14	-.0234	-.1647	.5087	-.2513	.484	1937.94	.0016	.0279
11	19	26	.4077	.0533	-.2876	.2181	-.112	-27.49	.0096	.0081
12	6	26	.2962	.0273	-.5361	.0948	.255	86.21	.0044	.0155
13	6	19	-.8096	-.1088	-.7509	-.7518	-.052	-6.39	.0080	.0144
14	7	19	-.2203	-.0830	-.8444	-.2711	.745	331.54	.0044	.1252
15	6	7	.1134	-.0185	.8841	.5602	.771	679.55	.0012	.1059
16	11	22	-.0240	.0441	-.2988	-.0351	.281	1155.26	.0003	.0061
17	8	11	.3982	.0033	.6906	-.0190	.292	73.46	.0155	.0510
18	17	22	.5966	.1372	.8918	.0583	.295	49.48	.0123	.0269
19	8	21	-.6282	-.0633	-.9207	-.0403	.337	51.01	.0325	.0770
20	17	21	-.6266	-.1472	-.9219	-.0676	.321	49.46	.0214	.0467
21	1	4	-.0500	.1736	-.9202	1.0492	1.111	2110.19	.0026	.2436
22	4	21	-.5327	.0189	-1.6476	-.0649	1.574	285.91	.0178	.4766
23	20	21	.5592	.3739	2.7978	.4831	2.239	400.35	-.0000	.0000
24	15	1	2.1793	.8868					-.0000	
25	2	13	1.1877	-.1125	1.4041	-.1391	.216	18.21	.0110	.0152
26	1	7	.7893	.0724	-.4976	-.2313	-.280	-35.50	.0118	.0115
27	15	20	-2.1793	-.8867	-.0001	-.0001	-2.238	-99.89	.0615	.0023
28	2	18	-2.7493	.2244	-2.7494	.1874	.000	.00	.0507	.0507
29	1	3	.6200	.3566	.6177	-1.0183	-.002	-.37	.0000	-.0000
30	24	3	-.0500	-.1645	-.0499	1.6929	-.000	-.14	-.0000	0.0000
31	5	21	.2000	-.0064	.2000	-.0064	-.000	-.01	-.0000	-.0000
32	5	25	-.6300	-.1036	-.6300	-.1035	.000	.00	0.0000	-.0000

CHANGES OF THE BUS VOLTAGES DUE TO THE LINE OUTAGE

INDEX OF THE LINE REMOVED: 24 TERMINAL BUSES: 15 1
VB-BUS VOLTAGE FOR A PRE-CONTINGENCY STATE
VA-BUS VOLTAGE FOR A POST-CONTINGENCY STATE

BUS	MOD(VA-VB)	MOD(VA)-MOD(VB)	VB ANGLE	VA ANGLE	ANGLE DEVIATION
1	.6068	-.3261	.0748	-.5879	-.6062
2	.0182	-.0021	.0886	.1057	.0169
3	.6159	-.2639	.0527	-.6472	-.6270
4	.4122	-.4010	.0993	.2277	.1249
5	.6861	.0000	.2667	1.4134	.6944
6	.1713	-.0336	.0537	-.1122	-.1654
7	.4941	-.2649	.0178	-.5027	-.4836
8	.5378	-.0456	.0426	.7328	.5898
9	.0995	-.0060	-.1131	-.0096	.1030
10	.0208	-.0030	.0668	.0867	.0198
11	.3897	-.0384	-.1105	.3449	.4421
12	.0436	-.0012	-.0766	-.0315	.0450
13	.0030	-.0009	.0150	.0177	.0027
14	.2393	-.0349	-.1141	.1433	.2560
15	.8515	.0960	.1046	1.5494	.8934
16	.0000	.0000	-.0455	-.0455	.0000
17	.5345	-.0172	.0298	.7088	.5868
18	.0182	.0000	.2432	.2612	.0170
19	.1835	.0000	.0924	-.0831	-.1750
20	.7413	.0000	.2481	1.5663	.7594
21	.6941	.0000	.2309	1.3170	.6944
22	.4514	-.0000	-.0999	.4385	.5128
23	.0000	.0000	-.0266	-.0266	.0000
24	.6190	-.0000	.0459	-.6602	-.6293
25	.6805	-.0000	.3763	1.7610	.6944
26	0.0000	0.0000	0.0000	0.0000	0.0000