

**TTM1 - A FORTRAN IMPLEMENTATION OF
THE TELLEGEN THEOREM METHOD TO
POWER SYSTEM SIMULATION AND DESIGN**

J.W. Bandler, M.A. El-Kady and J. Wojciechowski

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Abstract

This report contains a listing of the computer package TTM1 described in [1] for reduced gradient evaluation and load flow solution of power networks. The package has 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. The listing contains a total of 1916 lines (including 683 comments) constituting twenty-five subroutines. The listing does not include the Harwell package MA28 [2] for solving sparse linear equations.

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The authors are with the Simulation Optimization Systems Research Laboratory and the Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada L8S 4L7.

M.A. El-Kady is also with Ontario Hydro, Toronto, Canada.

J. Wojciechowski is on leave from the Institute of Electronics Fundamentals, Technical University of Warsaw, Warsaw, Poland.

1 INTRODUCTION

This document contains a Fortran listing of all alphabetically ordered subroutines of the TTM1 package. Essentially, the TTM1 package is for reduced gradients evaluation and load flow solution of power networks, though it also contains data handling routines. The user's manual of the TTM1 package together with illustrative examples is found in [1].

The TTM1 package has 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. The package is available at McMaster University in the form of a library of binary relocatable subroutines. The library is in the group indirect file LIBTTM1 accessible under the charge RJWBAND. The package calls subroutines MA28A, MA28B and MA28C of the Harwell Subroutine Library (Harwell package MA28) for solving sparse linear equations; the MA28 package must thus also be available when TTM1 is used. This document does not include the MA28 package: information concerning this package is found in [2].

The TTM1 package contains 1916 lines of which 683 are comments. It has been modularized into 25 subroutines. The list of all subroutines with short statistics is given in Table 1.

TABLE 1
LIST OF SUBROUTINES OF THE TTM1 PACKAGE

	Subroutine	Number of lines (source text)	Number of words (compiled code)	Description (page of [1])	Listing (page)
1	CURR	20	50	90	5
2	DCVARF	36	64	92	6
3	DERIV	91	604	94	7
4	EXCT	78	273	101	9
5	FORMDTF	39	422	103	11
6	FORMPR	59	441	106	12
7	FORMTA	87	512	110	13
8	FORMTAD	80	413	113	15
9	FORMTD	89	472	115	17
10	FORMTE	99	624	117	19
11	FORMTM	100	606	120	21
12	FORMU	45	203	123	23
13	FORMYT	63	315	126	24
14	LFLFD1M	93	274	130	25
15	LFLFDAM	192	1473	134	27
16	LFLFDBM	42	203	141	30
17	LFLFDCM	46	213	144	31
18	LFTTM	157	721	147	32
19	MISM	47	253	152	35
20	PQ	31	210	154	36
21	PTELT	19	34	156	37
22	RDAT	84	720	158	38
23	READDT	76	564	162	40
24	SENSIT	77	635	167	42
25	STEP	166	1270	173	44

2 REFERENCES

- [1] 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.
- [2] I.S. Duff, "MA28 - A set of Fortran subroutines for sparse unsymmetric linear equations", Computer Science and Systems Division, AERE Harwell, Oxfordshire, England, Report R.8730, 1980.

3 LISTING OF THE TTM PACKAGE

C		A	1
C		A	2
C		A	3
	COMPLEX FUNCTIONCURR(X, YT, JRYT, ICYT, MB)	A	4
	12.05.1982.	A	5
	FUNCTION SUBPROGRAM CURR CALCULATES THE VALUE OF THE CURRENT	A	6
	INJECTED INTO THE MBTH BUS FOR THE GIVEN VECTOR X OF BUS VOLTAGES	A	7
		A	8
		A	9
	INTEGER JRYT(1), ICYT(1)	A	10
	COMPLEX X(1), YT(1)	A	11
	K1=JRYT(MB)	A	12
	K2=JRYT(MB+1)-1	A	13
	CURR=(0.,0.)	A	14
	DO 10 I=K1,K2	A	15
	CURR=CURR+YT(I)*X(ICYT(I))	A	16
10	CONTINUE	A	17
	RETURN	A	18
	END	A	19
		A	20

C		B	1
C		B	2
C		B	3
	SUBROUTINE DCVARF (CCVF,ICVF,BTYP,N)	B	4
C		B	5
C	19.05.1982.	B	6
C		B	7
C	SUBROUTINE DCVARF DECLARES CONTROL VARIABLES FOR THE LOAD	B	8
C	FLOW PROBLEM	B	9
C		B	10
	INTEGER BTYP(1),CCVF(1),ICVF(1)	B	11
	DO 20 I=1,N	B	12
	J=2*I-1	B	13
	IF (BTYP(I).EQ.1) GO TO 10	B	14
C		B	15
C	SETTING UP VALUES OF ELEMENTS OF CCVF, ICVF CORRESPONDING	B	16
C	TO A LOAD BUS	B	17
C		B	18
	CCVF(J)=7	B	19
	ICVF(J)=1	B	20
	J=J+1	B	21
	CCVF(J)=8	B	22
	ICVF(J)=1	B	23
	GO TO 20	B	24
C		B	25
C	SETTING UP VALUES OF ELEMENTS OF CCVF, ICVF CORRESPONDING	B	26
C	TO A GENERATOR BUS	B	27
C		B	28
	10 CCVF(J)=7	B	29
	ICVF(J)=1	B	30
	J=J+1	B	31
	CCVF(J)=9	B	32
	ICVF(J)=1	B	33
	20 CONTINUE	B	34
	RETURN	B	35
	END	B	36

C		C	1
C		C	2
C		C	3
	SUBROUTINE DERIV (LBINP, LBOUT, YT, JRYT, ICYT, V, VT, CCV, ICV, PDR, SENS, N	C	4
	ICV, IWRITE)	C	5
		C	6
C	19.05.1982.	C	7
C		C	8
C	SUBROUTINE DERIV CALCULATES VECTOR SENS OF SENSITIVITIES	C	9
C	OF A REAL FUNCTION OF THE POWER SYSTEM STATE AND CONTROL	C	10
C	VARIABLES W.R.T. CONTROL VARIABLES SPECIFIED BY VECTORS CCV,	C	11
C	ICV WHEN VECTOR VT OF THE SOLUTION OF ADJOINT SYSTEM IS GIVEN	C	12
C		C	13
	INTEGER LBINP(1), LBOUT(1), JRYT(1), ICYT(1), CCV(1), ICV(1)	C	14
	REAL SENS(1), RLB(11)	C	15
	COMPLEX V(1), VT(1), YT(1), PDR(1), CS, VA, VAT, CURR	C	16
	DATA RLB/'LINPG(", "LINPB(", " LG(", " LB(", "LOUTG(", "LOUTB(", "	C	17
	1 P(", " Q(", "MOD V(", "ARG V(", "BSTL("/	C	18
	I=0	C	19
	DO 100 J=1, NCV	C	20
	L=CCV(J)	C	21
	M=ICV(J)	C	22
		C	23
C		C	24
C	LINPG LINPB LG LB LOUTG LOUTB P Q MODV ARGV BSTL	C	25
	GO TO (10, 10, 20, 20, 30, 30, 60, 70, 80, 90, 50), L	C	26
C		C	27
C	SENSITIVITY W.R.T. INPUT SHUNT ADMITTANCE	C	28
		C	29
10	K1=LBINP(M)	C	30
	VA=V(K1)	C	31
	I=I+1	C	32
	VAT=VT(K1)+PDR(I)	C	33
	GO TO 40	C	34
C		C	35
C	SENSITIVITY W.R.T. TRANSMISSION LINE ADMITTANCE	C	36
		C	37
20	K1=LBINP(M)	C	38
	K2=LBOUT(M)	C	39
	VA=V(K1)-V(K2)	C	40
	I=I+1	C	41
	VAT=VT(K1)-VT(K2)+PDR(I)	C	42
	GO TO 40	C	43
C		C	44
C	SENSITIVITY W.R.T. OUTPUT SHUNT ADMITTANCE	C	45
		C	46
30	K1=LBOUT(M)	C	47
	VA=V(K1)	C	48
	I=I+1	C	49
	VAT=VT(K1)+PDR(I)	C	50
40	CS=VA*VAT	C	51
	L1=MOD(L, 2)	C	52
	IF (L1.EQ.1) SENS(J)=-REAL(CS)	C	53
	IF (L1.EQ.0) SENS(J)=AIMAG(CS)	C	54
	GO TO 100	C	55
C		C	56
C	SENSITIVITY W.R.T. BUS STATIC LOAD	C	57
		C	58
50	I=I+1	C	59
	SENS(J)=AIMAG(V(M)*(VT(M)+PDR(I)))	C	60
	GO TO 100	C	61
C		C	62
C	SENSITIVITY W.R.T. BUS ACTIVE POWER	C	63
		C	64
60	SENS(J)=REAL(VT(M)/CONJG(V(M)))	C	65
	GO TO 100	C	65

C		C	66
C	SENSITIVITY W.R.T. BUS REACTIVE POWER	C	67
C		C	68
	70 SENS(J)=AIMAG(VT(M)/CONJG(V(M)))	C	69
	GO TO 100	C	70
C		C	71
C	SENSITIVITY W.R.T. MODULUS OF BUS VOLTAGE	C	72
C		C	73
	80 SENS(J)=-REAL(VT(M)*CURR(V, YT, JRYT, ICYT, M)+V(M)*CURR(VT, YT, JRYT, IC	C	74
	1YT, M)/CABS(V(M))	C	75
	GO TO 100	C	76
		C	77
C		C	78
C	SENSITIVITY W.R.T. ARGUMENT OF BUS VOLTAGE	C	79
		C	80
	90 SENS(J)=AIMAG(-VT(M)*CURR(V, YT, JRYT, ICYT, M)+V(M)*CURR(VT, YT, JRYT, I	C	81
	1CYT, M)	C	82
	100 CONTINUE	C	83
	IF (IWRITE.LT.3) GO TO 110	C	84
	WRITE (6,120)	C	85
	WRITE (6,130) (RLB(CCV(J)), ICV(J), SENS(J), J=1, NCV)	C	86
	110 RETURN	C	87
	120 FORMAT (// " VECTOR SENS OF SENSITIVITIES WITH RESPECT TO CONTROL VA	C	88
	1RIABLES "/" VALUE OF SENSITIVITY IS PRECEDED BY THE CONTROL VARIABL	C	89
	2E IDENTIFIER"/)	C	90
	130 FORMAT ((1X, 4(3X, A6, I3, "): ", 1X, E13.7)))	C	91
	END		

C		D	1
C		D	2
C		D	3
	SUBROUTINE EXCT (V, ITYP, I, RHST, NR, IP, IWRITE)	D	4
C		D	5
C	11.05.1982.	D	6
C		D	7
C	SUBROUTINE EXCT FORMS THE RIGHT HAND SIDE VECTOR RHST OF	D	8
C	THE ADJOINT EQUATIONS FOR THE ITH STATE VARIABLE OF THE	D	9
C	POWER FLOW PROBLEM GIVEN IN RECTANGULAR OR POLAR FORMULATION	D	10
C		D	11
	REAL RHST(1)	D	12
	COMPLEX V(1), VA	D	13
	L=MOD(I, 2)	D	14
	K=(I+L)/2	D	15
C		D	16
C	K IS THE INDEX OF THE BUS DESCRIBED BY THE ITH CONTROL VARIABLE	D	17
C		D	18
	DO 10 J=1, NR	D	19
	RHST(J)=0.	D	20
10	CONTINUE	D	21
	J2=2*K	D	22
	J1=J2-1	D	23
C		D	24
C	J1, J2 ARE INDICES OF ELEMENTS OF THE RHST VECTOR WHICH HAVE TO	D	25
C	BE MODIFIED	D	26
C		D	27
	IF (IP.EQ.1) GO TO 30	D	28
C		D	29
C	RECTANGULAR FORMULATION OF RHST VECTOR	D	30
C		D	31
	IF (ITYP.EQ.0) GO TO 20	D	32
C		D	33
C	SETTING UP VALUES OF ELEMENTS OF THE RHST VECTOR CORRESPONDING	D	34
C	TO A GENERATOR	D	35
C		D	36
	IF (L.EQ.0) RHST(J1)=REAL(V(K))	D	37
	IF (L.EQ.1) RHST(J1)=-AIMAG(V(K))	D	38
	GO TO 60	D	39
C		D	40
C	SETTING UP VALUES OF ELEMENTS OF THE RHST VECTOR CORRESPONDING	D	41
C	TO A LOAD BUS	D	42
C		D	43
20	IF (L.EQ.0) RHST(J2)=1.	D	44
	IF (L.EQ.1) RHST(J1)=-1.	D	45
	GO TO 60	D	46
C		D	47
C	POLAR FORMULATION OF RHST VECTOR	D	48
C		D	49
30	IF (ITYP.EQ.0) GO TO 40	D	50
C		D	51
C	SETTING UP VALUES OF ELEMENTS OF THE RHST VECTOR CORRESPONDING	D	52
C	TO A GENERATOR BUS	D	53
C		D	54
	IF (L.EQ.0) RHST(J1)=1.	D	55
	GO TO 60	D	56
C		D	57
C	SETTING UP VALUES OF ELEMENTS OF THE RHST VECTOR CORRESPONDING	D	58
C	TO A LOAD BUS	D	59
C		D	60
40	IF (L.EQ.1) GO TO 50	D	61
	VA=(0., 1.)/V(K)	D	62
	RHST(J1)=REAL(VA)	D	63
	RHST(J2)=AIMAG(VA)	D	64
	GO TO 60	D	65

50	VA=V(K)	D	66
	VA=-CABS(VA)/VA	D	67
	RHST(J1)=REAL(VA)	D	68
	RHST(J2)=AIMAG(VA)	D	69
60	IF (IWRITE.LT.4) GO TO 70	D	70
	WRITE (6,80) K,L,IP	D	71
	WRITE (6,90) (M,RHST(M),M=1,NR)	D	72
70	RETURN	D	73
80	FORMAT (// " RHS VECTOR RHST OF ADJOINT EQUATIONS. BUS NO. ", I3, "	D	74
	1L= ", I2, " IP= ", I2/ " VALUE OF AN ELEMENT IS PRECEDED BY THE EQUATI	D	75
	20N INDEX"/)	D	76
90	FORMAT (5(2X, I4, ":", E13.7))	D	77
	END	D	78

C		E	1
C		E	2
C		E	3
	SUBROUTINE FORMDTF (LBINP, LBOUT, LINPG, LINPB, LR, LX, LOUTC, LOUTB, LTAP	E	4
	1, BNR, BTYP, BVMOD, BVARG, BGP, BLP, BLQ, BSTL, HDLN, NB, NTL, OTPT)	E	5
		E	6
C	27.04.1982.	E	7
C		E	8
C	SUBROUTINE FORMDTF CREATES A FORMATTED DATA FILE DESCRIBING	E	9
C	THE POWER SYSTEM	E	10
C		E	11
	INTEGER LBINP(1), LBOUT(1), BNR(1), BTYP(1), OTPT	E	12
	REAL LINPG(1), LINPB(1), LR(1), LX(1), LOUTC(1), LOUTB(1), LTAP(1), BVMOD	E	13
	1(1), BVARG(1), BGP(1), BLP(1), BLQ(1), BSTL(1), RL(9), RB(8), HDLN(8)	E	14
		E	15
C	MATRIX HDLN KEEPS AN IDENTIFIER OF THE CREATED DATA FILE	E	16
C		E	17
	DATA RL/"LBINP", "LBOUT", "LINPG", "LINPB", "LR", "LX", "LOUTC", "LOUTB",	E	18
	1"LTAP"/, RB/" BNR", "BTYP", "BVMOD", "BVARG", "BGP", "BLP", "BLQ", "BSTL	E	19
	2"/	E	20
	WRITE (OTPT, 10) NB, (HDLN(I), I=1, 8)	E	21
	WRITE (OTPT, 70) NB, NTL	E	22
	WRITE (OTPT, 20)	E	23
	WRITE (OTPT, 30) (RL(I), I=1, 9)	E	24
	WRITE (OTPT, 50) (LBINP(I), LBOUT(I), LINPG(I), LINPB(I), LR(I), LX(I), L	E	25
	1OUTG(I), LOUTB(I), LTAP(I), I=1, NTL)	E	26
	WRITE (OTPT, 40)	E	27
	WRITE (OTPT, 30) (RB(I), I=1, 8)	E	28
	WRITE (OTPT, 60) (BNR(1), BTYP(1), BVMOD(1), BVARG(1), BGP(1), BLP(1), BL	E	29
	1Q(1), BSTL(1), I=1, NB)	E	30
	RETURN	E	31
10	FORMAT (//1X, "B", I3.3, 8A10/)	E	32
20	FORMAT (//1X, "LINE DATA"/)	E	33
30	FORMAT (2(1X, A5), 7(6X, A5, 4X))	E	34
40	FORMAT (//1X, "BUS DATA"/)	E	35
50	FORMAT ((2(1X, I5), 2X, 7(2X, E13.7)))	E	36
60	FORMAT ((2(1X, I5), 2X, 6(2X, E13.7)))	E	37
70	FORMAT (1X, "NB = ", I3.3, " ", " ", "NTL = ", I4.3)	E	38
	END	E	39

C
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SUBROUTINE FORMPR (LBINP, LBOUT, BTYP, YT, JRYT, ICYT, BCV, V, WS, LWS, NB, N
1TL, NLB, IP, INPT, OTPT, IFLAG, IWRITE)

14.08.1982.

SUBROUTINE FORMPR FORMULATES THE LOAD FLOW PROBLEM, I.E.,
THE SPARSE BUS ADMITTANCE MATRIX (VECTORS YT, JRYT, ICYT),
THE RIGHT HAND SIDE VECTOR BCV OF POWER FLOW EQUATIONS AND
VECTOR V OF THE INITIAL BUS VOLTAGES

INTEGER LBINP(1), LBOUT(1), JRYT(1), ICYT(1), BTYP(1), OTPT
REAL BCV(1), WS(1)
COMPLEX YT(1), V(1)
COMMON /MDFRMPR/ JINPG, JINPB, JLG, JLB, JOUTG, JOUTB, JTAP, JNR, JVM, JVA,
1JGP, JLP, JLQ, JSTL, JMX
IFLAG=0
JINPG=1
JINPB=JINPG+NTL
JLG=JINPB+NTL
JLB=JLG+NTL
JOUTG=JLB+NTL
JOUTB=JOUTG+NTL
JTAP=JOUTB+NTL
JNR=JTAP+NTL
JVM=JNR+NB
JVA=JVM+NB
JGP=JVA+NB
JLP=JGP+NB
JLQ=JLP+NB
JSTL=JLQ+NB
JMX=JSTL+NB
IF (JMX.GE.LWS) GO TO 50
CALL RDAT (LBINP, LBOUT, WS(JINPG), WS(JINPB), WS(JLG), WS(JLB), WS(JOUT
1G), WS(JOUTB), WS(JTAP), WS(JNR), BTYP, WS(JVM), WS(JVA), WS(JGP), WS(JLP)
2, WS(JLQ), WS(JSTL), JRYT, NB, NTL, NLB, INPT, IWRITE)
CALL FORMYT (LBINP, LBOUT, WS(JINPG), WS(JINPB), WS(JLG), WS(JLB), WS(JO
1UTG), WS(JOUTB), WS(JTAP), WS(JSTL), JRYT, ICYT, YT, NB, NTL, NYT, OTPT, IWRI
2TE)
CALL FORMU (BTYP, WS(JVM), WS(JVA), WS(JGP), WS(JLP), WS(JLQ), BCV, NB, OT
1PT, IWRITE)
K1=JVM-1
K2=JVA-1
IF (IP.EQ.1) GO TO 20
DO 10 I=1, NB
R1=WS(K1+I)
R2=WS(K2+I)
V(I)=CMPLX(R1*COS(R2), R1*SIN(R2))
10 CONTINUE
GO TO 40
20 DO 30 I=1, NB
V(I)=CMPLX(WS(K1+I), WS(K2+I))
30 CONTINUE
40 RETURN
50 IFLAG=-1
RETURN
END

F 1
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C		G	1
C		G	2
C		G	3
	SUBROUTINE FORMTA (YT, JRYT, ICYT, BTYP, T, IRT, ICT, N, NT, OTPT, IWRITE)	G	4
C		G	5
C	07.05.1982.	G	6
C		G	7
C	SUBROUTINE FORMTA FORMS A REAL, APPROXIMATE ADJOINT MATRIX	G	8
C	OF THE POWER SYSTEM AND STORES IT IN A SPARSE FORM	G	9
C		G	10
	INTEGER JRYT(1), ICYT(1), BTYP(1), ICT(1), IRT(1), OTPT	G	11
	REAL T(1)	G	12
	COMPLEX YT(1), Y	G	13
	NT=0	G	14
	IF (IWRITE.GE.4) WRITE (OTPT,60)	G	15
	DO 50 I=1,N	G	16
C		G	17
C	MATRIX YT IS ANALYSED ROW BY ROW IN THIS LOOP. K1 (OR K2)	G	18
C	INDICATES THE LOCATION OF THE FIRST (OR THE LAST) ELEMENT OF	G	19
C	THE ITH ROW OF NODAL ADMITTANCE MATRIX OF THE POWER SYSTEM	G	20
C		G	21
	K1=JRYT(1)	G	22
	K2=JRYT(I+1)-1	G	23
	JE=NT+1	G	24
	IR=2*I-1	G	25
	IR1=IR+1	G	26
C		G	27
C	IR, IR1 ARE INDICES OF ROWS OF THE ADJOINT MATRIX CORRESPONDING	G	28
C	TO THE REAL AND IMAGINARY PARTS OF CURRENT OF THE ITH ADJOINT BUS	G	29
C		G	30
	ITYP=BTYP(1)	G	31
	IF (ITYP.EQ.1) GO TO 20	G	32
	DO 10 J=K1,K2	G	33
C		G	34
C	IN THIS LOOP TWO ROWS OF THE ADJOINT MATRIX CORRESPONDING TO AN	G	35
C	ADJOINT LOAD BUS ARE FORMED	G	36
C		G	37
	ITYP1=BTYP(ICYT(J))	G	38
	IF (ITYP1.EQ.2) GO TO 10	G	39
	IC=2*ICYT(J)-1	G	40
	IC1=IC+1	G	41
C		G	42
C	IC, IC1 ARE INDICES OF COLUMNS OF THE ADJOINT MATRIX ASSOCIATED	G	43
C	WITH THE REAL AND IMAGINARY PARTS OF VOLTAGE OF AN ADJOINT BUS	G	44
C	ADJACENT TO THE ITH ADJOINT BUS	G	45
C		G	46
	R2=AIMAG(YT(J))	G	47
	R1=REAL(YT(J))	G	48
	CALL PTELT (T,NT,R1,IRT,ICT,IR,IC)	G	49
	CALL PTELT (T,NT,R2,IRT,ICT,IR1,IC)	G	50
	IF (ITYP1.EQ.1) GO TO 10	G	51
	CALL PTELT (T,NT,-R2,IRT,ICT,IR,IC1)	G	52
	CALL PTELT (T,NT,R1,IRT,ICT,IR1,IC1)	G	53
	10 CONTINUE	G	54
	GO TO 40	G	55
	20 DO 30 J=K1,K2	G	56
C		G	57
C	IN THIS LOOP A ROW OF THE ADJOINT MATRIX CORRESPONDING TO THE	G	58
C	REAL PART OF CURRENT OF AN ADJOINT GENERATOR BUS IS DETERMINED	G	59
C		G	60
	ITYP1=BTYP(ICYT(J))	G	61
	IF (ITYP1.EQ.2) GO TO 30	G	62
	IC=2*ICYT(J)-1	G	63
	IC1=IC+1	G	64
C		G	65

C	IC, IC1 ARE INDICES OF COLUMNS OF THE ADJOINT MATRIX ASSOCIATED	G	66
C	WITH THE REAL AND IMAGINARY PARTS OF VOLTAGE OF AN ADJOINT BUS	G	67
C		G	68
	Y=YT(J)	G	69
	CALL PTELT (T,NT,AIMAG(Y),IRT,ICT,IR,IC)	G	70
	IF (ITYP1.EQ.0) CALL PTELT (T,NT,REAL(Y),IRT,ICT,IR,IC1)	G	71
	30 CONTINUE	G	72
C		G	73
C	A ROW OF THE ADJOINT MATRIX CORRESPONDING TO THE IMAGINARY	G	74
C	PART OF CURRENT OF AN ADJOINT GENERATOR BUS IS NOW DETERMINED	G	75
C		G	76
	CALL PTELT (T,NT,1.,IRT,ICT,IR1,IR1)	G	77
	40 IF (IWRITE.LT.4) GO TO 50	G	78
	WRITE (OTPT,70) I	G	79
	WRITE (OTPT,80) (IRT(J),ICT(J),T(J),J=JE,NT)	G	80
	50 CONTINUE	G	81
	RETURN	G	82
	60 FORMAT (// " MATRIX T OF ADJOINT EQUATIONS (APPROXIMATE VERSION) "/"	G	83
	1 VALUE OF AN ELEMENT IS PRECEDED BY THE ROW AND COLUMN INDICES")	G	84
	70 FORMAT ("/" BUS NO.",I3)	G	85
	80 FORMAT (5(3X,I3," ",I3," ": ",E13.7))	G	86
	END	G	87

C		H	1
C		H	2
C		H	3
	SUBROUTINE FORMTAD (YT,JRYT,ICYT,BTYP,T,IRT,ICT,N,NT,OTPT,IWRITE)	H	4
C		H	5
C	10.05.1982.	H	6
C		H	7
C	SUBROUTINE FORMTAD FORMS A REAL, APPROXIMATE, DECOUPLED ADJOINT	H	8
C	MATRIX OF THE POWER SYSTEM AND STORES IT IN A SPARSE FORM	H	9
C		H	10
	INTEGER JRYT(1),ICYT(1),BTYP(1),ICT(1),IRT(1),OTPT	H	11
	REAL T(1)	H	12
	COMPLEX YT(1)	H	13
	NT=0	H	14
	IF (IWRITE.GE.4) WRITE (OTPT,60)	H	15
	DO 50 I=1,N	H	16
C		H	17
C	MATRIX YT IS ANALYSED ROW BY ROW IN THIS LOOP. K1 (OR K2)	H	18
C	INDICATES THE LOCATION OF THE FIRST (OR THE LAST) ELEMENT OF	H	19
C	THE ITH ROW OF NODAL ADMITTANCE MATRIX OF THE POWER SYSTEM	H	20
C		H	21
	K1=JRYT(I)	H	22
	K2=JRYT(I+1)-1	H	23
	JE=NT+1	H	24
	IR=2*I-1	H	25
	IR1=IR+1	H	26
C		H	27
C	IR, IR1 ARE INDICES OF ROWS OF THE ADJOINT MATRIX CORRESPONDING	H	28
C	TO THE REAL AND IMAGINARY PARTS OF CURRENT OF THE ITH ADJOINT BUS	H	29
C		H	30
	ITYP=BTYP(I)	H	31
	IF (ITYP.EQ.1) GO TO 20	H	32
	DO 10 J=K1,K2	H	33
C		H	34
C	IN THIS LOOP TWO ROWS OF THE ADJOINT MATRIX CORRESPONDING TO AN	H	35
C	ADJOINT LOAD BUS ARE FORMED	H	36
C		H	37
	ITYP1=BTYP(ICYT(J))	H	38
	IF (ITYP1.EQ.2) GO TO 10	H	39
	IC=2*ICYT(J)-1	H	40
	IC1=IC+1	H	41
C		H	42
C	IC, IC1 ARE INDICES OF COLUMNS OF THE ADJOINT MATRIX ASSOCIATED	H	43
C	WITH THE REAL AND IMAGINARY PARTS OF VOLTAGE OF AN ADJOINT BUS	H	44
C	ADJACENT TO THE ITH ADJOINT BUS	H	45
C		H	46
	R2=AIMAG(YT(J))	H	47
	CALL PTELT (T,NT,R2,IRT,ICT,IR1,IC)	H	48
	CALL PTELT (T,NT,-R2,IRT,ICT,IR,IC1)	H	49
10	CONTINUE	H	50
	GO TO 40	H	51
20	DO 30 J=K1,K2	H	52
C		H	53
C	IN THIS LOOP A ROW OF THE ADJOINT MATRIX CORRESPONDING TO THE	H	54
C	REAL PART OF CURRENT OF AN ADJOINT GENERATOR BUS IS DETERMINED	H	55
C		H	56
	IF (BTYP(ICYT(J)).EQ.2) GO TO 30	H	57
	IC=2*ICYT(J)-1	H	58
C		H	59
C	IC IS THE INDEX OF COLUMN OF THE ADJOINT MATRIX ASSOCIATED	H	60
C	WITH THE REAL PART OF VOLTAGE OF AN ADJOINT BUS	H	61
C		H	62
	CALL PTELT (T,NT,AIMAG(YT(J)),IRT,ICT,IR,IC)	H	63
30	CONTINUE	H	64
C		H	65

C	A ROW OF THE ADJOINT MATRIX CORRESPONDING TO THE IMAGINARY	H	66
C	PART OF CURRENT OF AN ADJOINT GENERATOR BUS IS NOW DETERMINED	H	67
C	CALL PTELT (T,NT,1.,IRT,ICT,IR1,IR1)	H	68
	40 IF (IWRITE.LT.4) GO TO 50	H	69
	WRITE (OTPT,70) I	H	70
	WRITE (OTPT,80) (IRT(J),ICT(J),T(J),J=JE,NT)	H	71
	50 CONTINUE	H	72
	RETURN	H	73
	60 FORMAT (// " MATRIX T OF ADJOINT EQUATIONS (APPROXIMATE, DECOUPLED	H	74
	1VERSION) "/" VALUE OF AN ELEMENT IS PRECEDED BY THE ROW AND COLUMN	H	75
	2INDICES")	H	76
	70 FORMAT (/ " BUS NO. ", I3)	H	77
	80 FORMAT (5(3X, I3, " ", " ", I3, " : ", E13.7))	H	78
	END	H	79
		H	80

C		I	1
C		I	2
C		I	3
	SUBROUTINE FORMTD (YT, JRYT, ICYT, BCS, V, BTYP, T, IRT, ICT, N, NT, OTPT, IWR	I	4
	1 IITE)	I	5
		I	6
C	07.05.1982.	I	7
C		I	8
C	SUBROUTINE FORMTD FORMS A REAL, DECOUPLED ADJOINT MATRIX	I	9
C	OF THE POWER SYSTEM AND STORES IT IN A SPARSE FORM	I	10
C		I	11
	INTEGER JRYT(1), ICYT(1), BTYP(1), ICT(1), IRT(1), OTPT	I	12
	REAL T(1)	I	13
	COMPLEX YT(1), BCS(1), V(1), VA, Y	I	14
	NT=0	I	15
	IF (IWRITE.GE.4) WRITE (OTPT,70)	I	16
	DO 60 I=1,N	I	17
C		I	18
C	MATRIX YT IS ANALYSED ROW BY ROW IN THIS LOOP. K1 (OR K2)	I	19
C	INDICATES THE LOCATION OF THE FIRST (OR THE LAST) ELEMENT OF	I	20
C	THE ITH ROW OF NODAL ADMITTANCE MATRIX OF THE POWER SYSTEM	I	21
C		I	22
	K1=JRYT(I)	I	23
	K2=JRYT(I+1)-1	I	24
	JE=NT+1	I	25
	IR=2*I-1	I	26
	IR1=IR+1	I	27
C		I	28
C	IR, IR1 ARE INDICES OF ROWS OF THE ADJOINT MATRIX CORRESPONDING	I	29
C	TO THE REAL AND IMAGINARY PARTS OF CURRENT OF THE ITH ADJOINT BUS	I	30
C		I	31
	ITYP=BTYP(I)	I	32
	IF (ITYP.EQ.1) GO TO 20	I	33
	DO 10 J=K1,K2	I	34
C		I	35
C	IN THIS LOOP TWO ROWS OF THE ADJOINT MATRIX CORRESPONDING TO AN	I	36
C	ADJOINT LOAD BUS ARE FORMED	I	37
C		I	38
	ITYP1=BTYP(ICYT(J))	I	39
	IF (ITYP1.EQ.2) GO TO 10	I	40
	IC=2*ICYT(J)-1	I	41
	IC1=IC+1	I	42
C		I	43
C	IC, IC1 ARE INDICES OF COLUMNS OF THE ADJOINT MATRIX ASSOCIATED	I	44
C	WITH THE REAL AND IMAGINARY PARTS OF VOLTAGE OF AN ADJOINT BUS	I	45
C	ADJACENT TO THE ITH ADJOINT BUS	I	46
C		I	47
	R2=AIMAG(YT(J))	I	48
	CALL PTELT (T,NT,R2,IRT,ICT,IR1,IC)	I	49
	CALL PTELT (T,NT,-R2,IRT,ICT,IR,IC1)	I	50
10	CONTINUE	I	51
	PSI=AIMAG(BCS(I)/V(I)**2)	I	52
	GO TO 40	I	53
20	VA=V(I)	I	54
	DO 30 J=K1,K2	I	55
C		I	56
C	IN THIS LOOP A ROW OF THE ADJOINT MATRIX CORRESPONDING TO THE	I	57
C	REAL PART OF CURRENT OF AN ADJOINT GENERATOR BUS IS DETERMINED	I	58
C		I	59
	IF (BTYP(ICYT(J)).EQ.2) GO TO 30	I	60
	IC=2*ICYT(J)-1	I	61
C		I	62
C	IC IS THE INDEX OF COLUMN OF THE ADJOINT MATRIX ASSOCIATED	I	63
C	WITH THE REAL PART OF VOLTAGE OF AN ADJOINT BUS	I	64
C		I	65

	Y=VA*YT(J)	I	66
	CALL PTELT (T,NT,AIMAG(Y),IRT,ICT,IR,IC)	I	67
	30 CONTINUE	I	68
C		I	69
C	A ROW OF THE ADJOINT MATRIX CORRESPONDING TO THE IMAGINARY	I	70
C	PART OF CURRENT OF AN ADJOINT GENERATOR BUS IS NOW DETERMINED	I	71
C		I	72
	CALL PTELT (T,NT,REAL(VA),IRT,ICT,IR1,IR1)	I	73
	PSI=AIMAG(BCS(I)/VA)	I	74
	40 T(JE)=T(JE)+PSI	I	75
	IF (ITYP.EQ.1) GO TO 50	I	76
	JE=JE+1	I	77
	T(JE)=T(JE)+PSI	I	78
	50 IF (IWRITE.LT.4) GO TO 60	I	79
	IF (ITYP.EQ.0) JE=JE-1	I	80
	WRITE (OTPT,80) I	I	81
	WRITE (OTPT,90) (IRT(J),ICT(J),T(J),J=JE,NT)	I	82
	60 CONTINUE	I	83
	RETURN	I	84
	70 FORMAT (// " MATRIX T OF ADJOINT EQUATIONS (DECOUPLED VERSION) " / " V	I	85
	1ALUE OF AN ELEMENT IS PRECEDED BY THE ROW AND COLUMN INDICES")	I	86
	80 FORMAT (/ " BUS NO. ", I3)	I	87
	90 FORMAT (5(3X, I3, " ", " ", I3, " : ", " ,E13.7))	I	88
	END	I	89

C		J	1
C		J	2
C		J	3
	SUBROUTINE FORMTE (YT,JRYT,ICYT,BCS,V,BTYP,T,IRT,ICT,N,NT,OTPT,IWR	J	4
	ITE)	J	5
C		J	6
C	06.05.1982.	J	7
C		J	8
C	SUBROUTINE FORMTE FORMS A REAL, EXACT ADJOINT MATRIX	J	9
C	OF THE POWER SYSTEM AND STORES IT IN A SPARSE FORM	J	10
C		J	11
	INTEGER JRYT(1),ICYT(1),BTYP(1),ICT(1),IRT(1),OTPT	J	12
	REAL T(1)	J	13
	COMPLEX YT(1),BCS(1),V(1),PSI,VA,Y	J	14
	NT=0	J	15
	IF (IWRITE.GE.4) WRITE (OTPT,70)	J	16
	DO 60 I=1,N	J	17
C		J	18
C	MATRIX YT IS ANALYSED ROW BY ROW IN THIS LOOP. K1 (OR K2)	J	19
C	INDICATES THE LOCATION OF THE FIRST (OR THE LAST) ELEMENT OF	J	20
C	THE ITH ROW OF NODAL ADMITTANCE MATRIX OF THE POWER SYSTEM	J	21
C		J	22
	K1=JRYT(1)	J	23
	K2=JRYT(I+1)-1	J	24
	JE=NT+1	J	25
	IR=2*I-1	J	26
	IR1=IR+1	J	27
C		J	28
C	IR, IR1 ARE INDICES OF ROWS OF THE ADJOINT MATRIX CORRESPONDING	J	29
C	TO THE REAL AND IMAGINARY PARTS OF CURRENT OF THE ITH ADJOINT BUS	J	30
C		J	31
	ITYP=BTYP(1)	J	32
	IF (ITYP.EQ.1) GO TO 20	J	33
	DO 10 J=K1,K2	J	34
C		J	35
C	IN THIS LOOP TWO ROWS OF THE ADJOINT MATRIX CORRESPONDING TO AN	J	36
C	ADJOINT LOAD BUS ARE FORMED	J	37
C		J	38
	IF (BTYP(ICYT(J)).EQ.2) GO TO 10	J	39
	IC=2*ICYT(J)-1	J	40
	IC1=IC+1	J	41
C		J	42
C	IC, IC1 ARE INDICES OF COLUMNS OF THE ADJOINT MATRIX ASSOCIATED	J	43
C	WITH THE REAL AND IMAGINARY PARTS OF VOLTAGE OF AN ADJOINT BUS	J	44
C	ADJACENT TO THE ITH ADJOINT BUS	J	45
C		J	46
	R2=AIMAG(YT(J))	J	47
	R1=REAL(YT(J))	J	48
	CALL PTELT (T,NT,R1,IRT,ICT,IR,IC)	J	49
	CALL PTELT (T,NT,R2,IRT,ICT,IR1,IC)	J	50
	CALL PTELT (T,NT,-R2,IRT,ICT,IR,IC1)	J	51
	CALL PTELT (T,NT,R1,IRT,ICT,IR1,IC1)	J	52
10	CONTINUE	J	53
	PSI=BCS(1)/V(1)**2	J	54
	GO TO 40	J	55
20	VA=V(1)	J	56
	DO 30 J=K1,K2	J	57
C		J	58
C	IN THIS LOOP A ROW OF THE ADJOINT MATRIX CORRESPONDING TO THE	J	59
C	REAL PART OF CURRENT OF AN ADJOINT GENERATOR BUS IS DETERMINED	J	60
C		J	61
	IF (BTYP(ICYT(J)).EQ.2) GO TO 30	J	62
	IC=2*ICYT(J)-1	J	63
	IC1=IC+1	J	64
C		J	65

C	IC, IC1 ARE INDICES OF COLUMNS OF THE ADJOINT MATRIX ASSOCIATED	J	66
C	WITH THE REAL AND IMAGINARY PARTS OF VOLTAGE OF AN ADJOINT BUS	J	67
C		J	68
	Y=VA*YT(J)	J	69
	CALL PTELT (T,NT,AIMAG(Y),IRT,ICT,IR,IC)	J	70
	CALL PTELT (T,NT,REAL(Y),IRT,ICT,IR,IC1)	J	71
30	CONTINUE	J	72
		J	73
C	A ROW OF THE ADJOINT MATRIX CORRESPONDING TO THE IMAGINARY	J	74
C	PART OF CURRENT OF AN ADJOINT GENERATOR BUS IS NOW DETERMINED	J	75
C		J	76
	CALL PTELT (T,NT,AIMAG(VA),IRT,ICT,IR1,IR)	J	77
	CALL PTELT (T,NT,REAL(VA),IRT,ICT,IR1,IR1)	J	78
	PSI=(BCS(I)/VA)*(0.,-1.)	J	79
40	T(JE)=T(JE)+REAL(PSI)	J	80
	JE=JE+1	J	81
	T(JE)=T(JE)+AIMAG(PSI)	J	82
	IF (ITYP.EQ.1) GO TO 50	J	83
	JE=JE+1	J	84
	T(JE)=T(JE)+AIMAG(PSI)	J	85
	JE=JE+1	J	86
	T(JE)=T(JE)-REAL(PSI)	J	87
50	IF (IWRITE.LT.4) GO TO 60	J	88
	JE=JE-1	J	89
	IF (ITYP.EQ.0) JE=JE-2	J	90
	WRITE (OTPT,80) I	J	91
	WRITE (OTPT,90) (IRT(J),ICT(J),T(J),J=JE,NT)	J	92
60	CONTINUE	J	93
	RETURN	J	94
70	FORMAT (// " MATRIX T OF ADJOINT EQUATIONS (EXACT VERSION) "/" VALUE	J	95
	1 OF AN ELEMENT IS PRECEDED BY THE ROW AND COLUMN INDICES")	J	96
80	FORMAT (/" BUS NO. ",I3)	J	97
90	FORMAT (5(3X,I3," ",I3," ": ",E13.7))	J	98
	END	J	99

C		K	1
C		K	2
C		K	3
	SUBROUTINE FORMTM (YT, JRYT, ICYT, BCS, V, BTYP, T, IRT, ICT, N, NT, OTPT, IWR	K	4
	1 IITE)	K	5
		K	6
C	10.05.1982.	K	7
C		K	8
C	SUBROUTINE FORMTM FORMS A REAL, MIXED ADJOINT MATRIX	K	9
C	OF THE POWER SYSTEM AND STORES IT IN A SPARSE FORM	K	10
C		K	11
	INTEGER JRYT(1), ICYT(1), BTYP(1), ICT(1), IRT(1), OTPT	K	12
	REAL T(1)	K	13
	COMPLEX YT(1), BCS(1), V(1), PSI, VA, Y	K	14
	NT=0	K	15
	IF (IWRITE.GE.4) WRITE (OTPT,70)	K	16
	DO 60 I=1,N	K	17
C		K	18
C	MATRIX YT IS ANALYSED ROW BY ROW IN THIS LOOP. K1 (OR K2)	K	19
C	INDICATES THE LOCATION OF THE FIRST (OR THE LAST) ELEMENT OF	K	20
C	THE ITH ROW OF NODAL ADMITTANCE MATRIX OF THE POWER SYSTEM	K	21
C		K	22
	K1=JRYT(1)	K	23
	K2=JRYT(I+1)-1	K	24
	JE=NT+1	K	25
	IR=2*I-1	K	26
	IR1=IR+1	K	27
C		K	28
C	IR, IR1 ARE INDICES OF ROWS OF THE ADJOINT MATRIX CORRESPONDING	K	29
C	TO THE REAL AND IMAGINARY PARTS OF CURRENT OF THE ITH ADJOINT BUS	K	30
C		K	31
	ITYP=BTYP(1)	K	32
	IF (ITYP.EQ.1) GO TO 20	K	33
	DO 10 J=K1,K2	K	34
C		K	35
C	IN THIS LOOP TWO ROWS OF THE ADJOINT MATRIX CORRESPONDING TO AN	K	36
C	ADJOINT LOAD BUS ARE FORMED	K	37
C		K	38
	ITYP1=BTYP(ICYT(J))	K	39
	IF (ITYP1.EQ.2) GO TO 10	K	40
	IC=2*ICYT(J)-1	K	41
	IC1=IC+1	K	42
C		K	43
C	IC, IC1 ARE INDICES OF COLUMNS OF THE ADJOINT MATRIX ASSOCIATED	K	44
C	WITH THE REAL AND IMAGINARY PARTS OF VOLTAGE OF AN ADJOINT BUS	K	45
C	ADJACENT TO THE ITH ADJOINT BUS	K	46
C		K	47
	R2=AIMAG(YT(J))	K	48
	R1=REAL(YT(J))	K	49
	CALL PTELT (T, NT, R1, IRT, ICT, IR, IC)	K	50
	CALL PTELT (T, NT, R2, IRT, ICT, IR1, IC)	K	51
	IF (ITYP1.EQ.1) GO TO 10	K	52
	CALL PTELT (T, NT, -R2, IRT, ICT, IR, IC1)	K	53
	CALL PTELT (T, NT, R1, IRT, ICT, IR1, IC1)	K	54
10	CONTINUE	K	55
	PSI=BCS(1)/V(1)**2	K	56
	GO TO 40	K	57
20	VA=V(1)	K	58
	DO 30 J=K1,K2	K	59
C		K	60
C	IN THIS LOOP A ROW OF THE ADJOINT MATRIX CORRESPONDING TO THE	K	61
C	REAL PART OF CURRENT OF AN ADJOINT GENERATOR BUS IS DETERMINED	K	62
C		K	63
	ITYP1=BTYP(ICYT(J))	K	64
	IF (ITYP1.EQ.2) GO TO 30	K	65

	IC=2*ICYT(J)-1	K 66
	IC1=IC+1	K 67
C		K 68
C	IC, IC1 ARE INDICES OF COLUMNS OF THE ADJOINT MATRIX ASSOCIATED	K 69
C	WITH THE REAL AND IMAGINARY PARTS OF VOLTAGE OF AN ADJOINT BUS	K 70
		K 71
	Y=VA*YT(J)	K 72
	CALL PTELT (T,NT,AIMAG(Y),IRT,ICT,IR,IC)	K 73
	IF (ITYP.EQ.0) CALL PTELT (T,NT,REAL(Y),IRT,ICT,IR,IC1)	K 74
30	CONTINUE	K 75
		K 76
C	A ROW OF THE ADJOINT MATRIX CORRESPONDING TO THE IMAGINARY	K 77
C	PART OF CURRENT OF AN ADJOINT GENERATOR BUS IS NOW DETERMINED	K 78
C		K 79
	CALL PTELT (T,NT,REAL(VA),IRT,ICT,IR1,IR1)	K 80
	PSI=(BCS(I)/VA)*(0.,-1.)	K 81
40	T(JE)=T(JE)+REAL(PSI)	K 82
	IF (ITYP.EQ.1) GO TO 50	K 83
	JE=JE+1	K 84
	T(JE)=T(JE)+AIMAG(PSI)	K 85
	JE=JE+1	K 86
	T(JE)=T(JE)+AIMAG(PSI)	K 87
	JE=JE+1	K 88
	T(JE)=T(JE)-REAL(PSI)	K 89
50	IF (IWRITE.LT.4) GO TO 60	K 90
	IF (ITYP.EQ.0) JE=JE-3	K 91
	WRITE (OTPT,80) I	K 92
	WRITE (OTPT,90) (IRT(J),ICT(J),T(J),J=JE,NT)	K 93
60	CONTINUE	K 94
	RETURN	K 95
70	FORMAT (// " MATRIX T OF ADJOINT EQUATIONS (MIXED VERSION) " / " VALUE	K 96
	1 OF AN ELEMENT IS PRECEDED BY THE ROW AND COLUMN INDICES "	K 97
80	FORMAT (/" BUS NO. ",I3)	K 98
90	FORMAT (5(3X,I3," ",I3," ": ",E13.7))	K 99
	END	K 100

C		L	1
C		L	2
C		L	3
	SUBROUTINE FORMU (BTYP, BVMOD, BVARG, BGP, BLP, BLQ, BCV, NB, OTPT, IWRITE)	L	4
C		L	5
C	05.05.1982.	L	6
C		L	7
C	SUBROUTINE FORMU FORMS VECTOR BCV OF BUS CONTROL VARIABLES	L	8
C	OF THE POWER SYSTEM.	L	9
C		L	10
	INTEGER BTYP(1), OTPT	L	11
	REAL BVMOD(1), BVARG(1), BGP(1), BLP(1), BLQ(1), BCV(1)	L	12
	DO 40 I=1, NB	L	13
	J=2*I-1	L	14
	IF (BTYP(I)-1) 10, 20, 30	L	15
C		L	16
C	SETTING UP VALUES OF ELEMENTS OF BCV CORRESPONDING TO A LOAD BUS	L	17
C		L	18
	10 BCV(J)=BGP(I)-BLP(I)	L	19
	J=J+1	L	20
	BCV(J)=-BLQ(I)	L	21
	GO TO 40	L	22
C		L	23
C	SETTING UP VALUES OF ELEMENTS OF BCV CORRESPONDING TO A GENERATOR	L	24
C	BUS	L	25
C		L	26
	20 BCV(J)=BGP(I)-BLP(I)	L	27
	J=J+1	L	28
	BCV(J)=BVMOD(I)	L	29
	GO TO 40	L	30
C		L	31
C	SETTING UP VALUES OF ELEMENTS OF BCV CORRESPONDING TO SLACK BUS	L	32
C		L	33
	30 BCV(J)=BVMOD(I)	L	34
	J=J+1	L	35
	BCV(J)=BVARG(I)	L	36
	40 CONTINUE	L	37
	IF (IWRITE.LT.3) GO TO 50	L	38
	WRITE (OTPT, 60)	L	39
	WRITE (OTPT, 70) (I, BCV(2*I-1), BCV(2*I), I=1, NB)	L	40
	50 RETURN	L	41
	60 FORMAT (// " VECTOR BCV OF BUS CONTROL VARIABLES " / " VALUE OF AN ELE	L	42
	1MENT IS PRECEDED BY THE NUMBER OF BUS " /)	L	43
	70 FORMAT (3(3X, 13, " : ", 2(1X, E13.7)))	L	44
	END	L	45

C		M	1
C		M	2
C		M	3
	SUBROUTINE FORMYT (LBINP, LBOUT, LINPG, LINPB, LG, LB, LOUTG, LOUTB, LTAP,	M	4
	IBSTL, JRYT, ICYT, YT, NB, NTL, NYT, OTPT, IWRITE)	M	5
C		M	6
C	05.05.1982.	M	7
C		M	8
C	SUBROUTINE FORMYT FORMS THE NODAL ADMITTANCE MATRIX OF POWER	M	9
C	SYSTEM AND STORES IT IN A SPARSE FORM (VECTORS YT, JRYT, ICYT)	M	10
C		M	11
	INTEGER LBINP(1), LBOUT(1), JRYT(1), ICYT(1), OTPT	M	12
	REAL LINPG(1), LINPB(1), LG(1), LB(1), LOUTG(1), LOUTB(1), LTAP(1), BSTL(M	13
	11)	M	14
	COMPLEX YT(1), Y	M	15
	NYT=NB+2*NTL	M	16
C		M	17
C	BUS STATIC LOADS ARE PLACED INTO THE NODAL ADMITTANCE MATRIX	M	18
C		M	19
	DO 10 I=1, NB	M	20
	J=JRYT(I)	M	21
	YT(J)=CMPLX(0., BSTL(I))	M	22
	ICYT(NYT+I)=J	M	23
10	CONTINUE	M	24
C		M	25
C	LINE PARAMETERS ARE ADDED TO THE NODAL ADMITTANCE MATRIX	M	26
C		M	27
	DO 20 I=1, NTL	M	28
	IB1=LBINP(I)	M	29
	IB2=LBOUT(I)	M	30
	Y=CMPLX(LG(I), LB(I))	M	31
	L1=JRYT(IB1)	M	32
	L2=JRYT(IB2)	M	33
	YT(L1)=YT(L1)+CMPLX(LINPG(I), LINPB(I))+Y/(LTAP(I)**2)	M	34
	YT(L2)=YT(L2)+CMPLX(LOUTG(I), LOUTB(I))+Y	M	35
	ICYT(L1)=IB1	M	36
	ICYT(L2)=IB2	M	37
	K1=NYT+IB1	M	38
	K2=NYT+IB2	M	39
	ICYT(K1)=ICYT(K1)+1	M	40
	ICYT(K2)=ICYT(K2)+1	M	41
	L1=ICYT(K1)	M	42
	L2=ICYT(K2)	M	43
	Y=-Y/LTAP(I)	M	44
	YT(L1)=Y	M	45
	YT(L2)=Y	M	46
	ICYT(L1)=IB2	M	47
	ICYT(L2)=IB1	M	48
20	CONTINUE	M	49
	IF (IWRITE.LT.3) GO TO 40	M	50
	WRITE (OTPT, 50)	M	51
	DO 30 I=1, NB	M	52
	K1=JRYT(I)	M	53
	K2=JRYT(I+1)-1	M	54
	WRITE (OTPT, 60) ICYT(K1)	M	55
	WRITE (OTPT, 70) (ICYT(J), YT(J), J=K1, K2)	M	56
30	CONTINUE	M	57
40	RETURN	M	58
50	FORMAT (// " BUS ADMITTANCE MATRIX YT" / " IN EACH ROW DATA IS IN SEQ	M	59
	UENCE: COLUMN INDEX, REAL(YT), IMAG(YT) ")	M	60
60	FORMAT (/ " BUS NO. ", I3)	M	61
70	FORMAT (3(3X, I3, ":", 2(1X, E13.7)))	M	62
	END	M	63

C		N	1
C		N	2
C		N	3
	SUBROUTINE LFLFD1M (NB,NLB, NYT, JRYT, ICYT, BTYP, YT, V, BCV, W, LW, ITEL, V	N	4
	IEPS, TIMEL, MODE, IFLAG, OTPT, IWRITE)	N	5
		N	6
C	04.08.1982.	N	7
C		N	8
C	SUBROUTINE LFLFD1M IS THE HIGHEST LEVEL SUBROUTINE FOR SOLVING	N	9
C	THE LOAD FLOW PROBLEM USING A SPARSE MATRIX TECHNIQUE (HARWELL	N	10
C	PACKAGE MA28) AND THE FAST DECOUPLED METHOD	N	11
C		N	12
C	LIBRARY : LIBRHSM (HARWELL PACKAGE MA28)	N	13
C		N	14
C	NB NUMBER OF BUSES	N	15
C	NLB NUMBER OF LOAD BUSES	N	16
C	NYT NUMBER OF NONZEROS IN THE BUS ADMITTANCE MATRIX	N	17
C	JRYT VECTOR OF LENGTH (NB+1). IT HOLDS ROW INDICES OF THE	N	18
C	SPARSE BUS ADMITTANCE MATRIX	N	19
C	ICYT VECTOR OF LENGTH NYT. IT HOLDS COLUMN INDICES OF THE	N	20
C	SPARSE BUS ADMITTANCE MATRIX	N	21
C	BTYP VECTOR OF BUS TYPES (0 LOAD BUS, 1 GENERATOR BUS)	N	22
C	YT SPARSE BUS ADMITTANCE MATRIX	N	23
C	V COMPLEX BUS VOLTAGES (RECTANGULAR COORDINATES)	N	24
C	BCV REAL VECTOR OF THE LENGTH 2*(NB-1). IT HOLDS NOMINAL	N	25
C	VALUES OF BUS CONTROL VARIABLES	N	26
C	W REAL WORKSPACE	N	27
C	LW LENGTH OF THE WORKSPACE W	N	28
C	ITEL LIMIT OF ITERATIONS	N	29
C	VEPS REQUIRED ACCURACY OF SOLUTION	N	30
C	TIMEL LIMIT OF ITERATION TIME	N	31
C	MODE MODE OF OPERATION :	N	32
C	0 - EVALUATE AND FACTORIZE APPROXIMATE JACOBIAN MATRICES	N	33
C	1 - PERFORM P-DELTA ITERATION (FOR FACTORIZED MATRICES)	N	34
C	2 - PERFORM Q-MOD.V ITERATION (FOR FACTORIZED MATRICES)	N	35
C	3 - PERFORM BOTH ITERATIONS (FOR FACTORIZED MATRICES)	N	36
C	IFLAG RETURN FLAG :	N	37
C	-2 - INCORRECT USAGE (SINGULAR P-DELTA OR Q-V MATRIX)	N	38
C	-1 - INCORRECT PARAMETERS	N	39
C	0 - NORMAL RETURN (REQUIRED ACCURACY OBTAINED)	N	40
C	1 - LIMIT OF ITERATIONS REACHED	N	41
C	2 - LIMIT OF ITERATION TIME REACHED	N	42
C	OTPT NUMBER OF OUTPUT UNIT	N	43
C		N	44
C	INTEGER JRYT(1), ICYT(1), BTYP(1)	N	45
C	REAL W(1), BCV(1)	N	46
C	COMPLEX YT(1), V(1)	N	47
C	COMMON /MDLFLF/ JA1, JICN1, JIKP1, JA2, JICN2, JIKP2, JVM, JVA, NZ, NZR	N	48
C	IF (MODE.LT.0.OR.MODE.GT.3) GO TO 20	N	49
C	IF (MODE.NE.0) GO TO 10	N	50
C	N=NB-1	N	51
C	NZ1=NYT	N	52
C	NZ2=(NYT*(NLB**2))/(N**2)	N	53
C	LICN1=3*NZ1	N	54
C	LICN2=3*NZ2	N	55
C	LIRN1=NZ1+N+N	N	56
C	LIRN2=NZ2+NLB+NLB	N	57
C	JNRB=1	N	58
C	JA1=JNRB+NB	N	59
C	JICN1=JA1+LICN1	N	60
C	JIKP1=JICN1+LICN1	N	61
C	JA2=JIKP1+5*N	N	62
C	JICN2=JA2+LICN2	N	63
C	JIKP2=JICN2+LICN2	N	64
C	JRHS=JIKP2+5*NLB	N	65

	JW=JRHS+NB	N	66
	JVM=JW+NB	N	67
	JVA=JVM+NB	N	68
	MXJ=JVA+NB	N	69
	JIRN2=JRHS	N	70
	JIW2=JIRN2+LIRN2	N	71
	JW2=JIW2+8*NLB	N	72
	JIRN1=JA2	N	73
	JIW1=JIRN1+LIRN1	N	74
	JW1=JIW1+8*N	N	75
	MXJ=MAX0(MXJ, JW1+N, JW2+NLB)	N	76
	J=LW-MXJ	N	77
	IF (J.LT.0) GO TO 20	N	78
	10 CALL LFLFDAM (NB, NLB, NZ, NZR, JRYT, ICYT, BTYP, YT, V, BCV, LICN1, LIRN1, LI	N	79
	1CN2, LIRN2, W(JA1), W(JICN1), W(JIKP1), W(JA2), W(JICN2), W(JIKP2), W(JRHS	N	80
	2), W(JW), W(JVMD), W(JVA), W(JNRB), W(JIRN1), W(JIW1), W(JW1), W(JIRN2), W(J	N	81
	3IW2), W(JW2), MODE, ITEL, VEPS, TIMEL, IFLAG, OTPT, IWRITE)	N	82
C		N	83
C	IN THE ABOVE CALL FORMAL PARAMETER ARRAYS: (RHS, W, VM, VA)	N	84
C	AND (IRN2, IW2, W2)	N	85
C	AS WELL AS (A2, ICN2, IKEEP2, IRN2, IW2, W2)	N	86
C	AND (IRN1, IW1, W1)	N	87
C	SHARE THE SAME WORKSPACE	N	88
		N	89
	RETURN	N	90
20	IFLAG=-1	N	91
	RETURN	N	92
	END	N	93

C		0	1
C		0	2
C		0	3
	SUBROUTINE LFLFDAM (NB,NLB,NZ,NZR,JRYT,ICYT,BTYP,YT,V,BCV,LICN1,LI	0	4
	1RN1,LICN2,LIRN2,A1,ICN1,IKEEP1,A2,ICN2,IKEEP2,RHS,W,VM,VA,NRB,IRN1	0	5
	2,IW1,W1,IRN2,IW2,W2,MODE,ITE,VEPS,TIMEX,IERR,OTPT,IWRITE)	0	6
		0	7
C	05.08.1982.	0	8
C		0	9
C	THIS SUBROUTINE IMPLEMENTS THE FAST DECOUPLED ITERATIVE METHOD	0	10
C	USING THE HARWELL PACKAGE MA28 FOR SOLVING THE SPARSE SYSTEMS	0	11
C	OF LINEAR EQUATIONS WITH REAL COEFFICIENTS	0	12
C		0	13
C	LIBRARY : LIBRHSM (HARWELL PACKAGE MA28)	0	14
C		0	15
	INTEGER JRYT(1),ICYT(1),BTYP(1),ICN1(1),ICN2(1),IKEEP1(1),IKEEP2(1	0	16
	1),IW1(1),IW2(1),NRB(1),IRN1(1),IRN2(1),OTPT	0	17
	REAL BCV(1),A1(1),A2(1),RHS(1),W(1),W1(1),W2(1),VM(1),VA(1),R(2)	0	18
	COMPLEX YT(1),V(1),VV	0	19
	LOGICAL SWITCH	0	20
	DATA R/"P-DELTA", " Q-V"/	0	21
	IF (IWRITE.LT.1) GO TO 10	0	22
	WRITE (OTPT,230) NB	0	23
10	CALL SECOND (TTIME1)	0	24
	T1=TTIME1	0	25
	N=NB-1	0	26
	IERR=-2	0	27
	IF (MODE.NE.0) GO TO 100	0	28
		0	29
C	SET ORDERING OF BUSES	0	30
C		0	31
	L=0	0	32
	K=NLB	0	33
	DO 30 I=1,N	0	34
	IF (BTYP(I).NE.0) GO TO 20	0	35
	L=L+1	0	36
	NRB(I)=L	0	37
	GO TO 30	0	38
20	K=K+1	0	39
	NRB(I)=K	0	40
30	CONTINUE	0	41
		0	42
C	SET AND FACTORIZE SPARSE MATRICES OF REAL COEFFICIENTS	0	43
C		0	44
	NZ=0	0	45
	IF (IWRITE.LT.4) GO TO 40	0	46
	WRITE (OTPT,240)	0	47
40	DO 60 I=1,N	0	48
	NZ=NZ+1	0	49
	L=NZ	0	50
	J1=JRYT(I)+1	0	51
	J2=JRYT(I+1)-1	0	52
	X=0.0	0	53
	DO 50 J=J1,J2	0	54
	KK=ICYT(J)	0	55
	IF (YT(J).EQ.(0.,0.)) GO TO 50	0	56
	XX=1.0/AIMAG(1.0/YT(J))	0	57
	X=X+XX	0	58
	IF (BTYP(KK).EQ.2) GO TO 50	0	59
	NZ=NZ+1	0	60
	ICN1(NZ)=KK	0	61
	IRN1(NZ)=I	0	62
	A1(NZ)=XX	0	63
50	CONTINUE	0	64
	ICN1(L)=I	0	65

	IRN1(L)=I	0	66
	A1(L)=-X	0	67
	IF (IWRITE.LT.4) GO TO 60	0	68
	WRITE (OTPT,250) I	0	69
	WRITE (OTPT,260) (IRN1(J),ICN1(J),A1(J),J=L,NZ)	0	70
60	CONTINUE	0	71
	U=0.1	0	72
	CALL MA28A (N,NZ,A1,LICN1,IRN1,LIRN1,ICN1,U,IKEEP1,IW1,W1,IFLAG)	0	73
	IF (IFLAG.LT.0) RETURN	0	74
	NZR=0	0	75
	IF (IWRITE.LT.4) GO TO 70	0	76
	WRITE (OTPT,270)	0	77
70	DO 90 I=1,N	0	78
	K=BTYP(I)	0	79
	IF (K.NE.0) GO TO 90	0	80
	L=NZR+1	0	81
	LL=NRB(I)	0	82
	J1=JRYT(I)	0	83
	J2=JRYT(I+1)-1	0	84
	DO 80 J=J1,J2	0	85
	KK=ICYT(J)	0	86
	IF (BTYP(KK).NE.0) GO TO 80	0	87
	NZR=NZR+1	0	88
	ICN2(NZR)=NRB(KK)	0	89
	IRN2(NZR)=LL	0	90
	A2(NZR)=-AIMAG(YT(J))	0	91
80	CONTINUE	0	92
	IF (IWRITE.LT.4) GO TO 90	0	93
	WRITE (OTPT,250) I	0	94
	WRITE (OTPT,260) (IRN2(J),ICN2(J),A2(J),J=L,NZR)	0	95
90	CONTINUE	0	96
	CALL MA28A (NLB,NZR,A2,LICN2,IRN2,LIRN2,ICN2,U,IKEEP2,IW2,W2,IFLAG)	0	97
	1) IF (IFLAG.LT.0) RETURN	0	98
		0	99
C		0	100
C	SET INITIAL VALUES AND CHECK LIMIT OF ITERATIONS	0	101
C		0	102
100	IT=0	0	103
	CMX=0.0	0	104
	CALL SECOND (TTIME2)	0	105
	IF (ITE.EQ.0) GO TO 180	0	106
C		0	107
C	CONVERT VOLTAGES TO POLAR COORDINATES	0	108
C		0	109
	DO 110 I=1,NB	0	110
	VV=V(I)	0	111
	VM(I)=CABS(VV)	0	112
	VA(I)=ATAN2(AIMAG(VV),REAL(VV))	0	113
110	CONTINUE	0	114
C		0	115
C	ITERATION LOOP	0	116
C		0	117
	CORRA=0.0	0	118
	CORRM=0.0	0	119
	IF (MODE.EQ.1) GO TO 120	0	120
	IF (MODE.EQ.2) GO TO 140	0	121
120	IT=IT+1	0	122
	CALL LFLFDBM (N,YT,V,VM,VA,BCV,JRYT,ICYT,A1,LICN1,ICN1,IKEEP1,RHS,	0	123
	1W,CORRA)	0	124
	IF (IWRITE.LT.2) GO TO 130	0	125
	CALL SECOND (T2)	0	126
	T=T2-T1	0	127
	WRITE (OTPT,280) IT,R(1),CORRA,T	0	128
	T1=T2	0	129
	IF (IWRITE.LT.3) GO TO 130	0	130

WRITE (OTPT,290)	0 131
WRITE (OTPT,300) (L,V(L),L=1,N)	0 132
130 SWITCH=.TRUE.	0 133
IF (IT.EQ.1.AND.(MODE.EQ.0.OR.MODE.EQ.3)) GO TO 140	0 134
GO TO 150	0 135
140 IT=IT+1	0 136
CALL LFLFDCM (N,NLB,YT,V,VM,VA,BCV,JRYT,ICYT,BTYP,NRB,A2,LICN2,ICN	0 137
12,IKEEP2,RHS,W,CORRM)	0 138
SWITCH=.FALSE.	0 139
IF (IWRITE.LT.2) GO TO 150	0 140
CALL SECOND (T2)	0 141
T=T2-T1	0 142
WRITE (OTPT,280) IT,R(2),CORRM,T	0 143
T1=T2	0 144
IF (IWRITE.LT.3) GO TO 150	0 145
WRITE (OTPT,300) (L,V(L),L=1,N)	0 146
T1=T2	0 147
150 CMX=AMAX1(CORRA,CORRM)	0 148
CALL SECOND (TTIME2)	0 149
IF (CMX.LE.VEPS) GO TO 200	0 150
IF (TIMEX.LE.0.0) GO TO 160	0 151
IF (TTIME2-TTIME1.GE.TIMEX) GO TO 190	0 152
160 IF (ITE.LT.0) GO TO 170	0 153
IF (IT.GE.ITE) GO TO 180	0 154
170 IF (CORRA.GT.2.0*CORRM) GO TO 120	0 155
IF (CORRM.GT.2.0*CORRA) GO TO 140	0 156
IF (SWITCH) GO TO 140	0 157
GO TO 120	0 158
180 IERR=1	0 159
GO TO 210	0 160
190 IERR=2	0 161
GO TO 210	0 162
200 IERR=0	0 163
210 ITE=IT	0 164
TIMEX=TTIME2-TTIME1	0 165
VEPS=CMX	0 166
IF (IWRITE.LT.1) GO TO 220	0 167
WRITE (OTPT,310) ITE,IERR,VEPS,TIMEX	0 168
IF (IWRITE.LT.2) GO TO 220	0 169
WRITE (OTPT,320)	0 170
WRITE (OTPT,330) (L,V(L),VM(L),VA(L),L=1,NB)	0 171
220 RETURN	0 172
230 FORMAT (///" LOAD FLOW SOLUTION OF ",I3,"-BUS SYSTEM USING THE FAS	0 173
IT DECOUPLED METHOD")	0 174
240 FORMAT (///" MATRIX OF P-DELTA EQUATIONS"/" VALUE OF AN ELEMENT IS	0 175
1PRECEDED BY THE ROW AND COLUMN INDICES")	0 176
250 FORMAT (/ " BUS NO. ",I3)	0 177
260 FORMAT (5(3X,I3," ",I3," : ",E13.7))	0 178
270 FORMAT (///" MATRIX OF Q-V EQUATIONS"/" VALUE OF AN ELEMENT IS PREC	0 179
1EDED BY THE ROW AND COLUMN INDICES")	0 180
280 FORMAT (///" RESULTS OF ITERATION NO.",3X,I3/" ITERATION TYPE:",8X,	0 181
1A7/" ACCURACY OBTAINED:",2X,E10.4/" ITERATION TIME:",9X,F6.3," SEC	0 182
2ONDS")	0 183
290 FORMAT (/ " VECTOR OF BUS VOLTAGES")	0 184
300 FORMAT (3(3X,I4," :",2(1X,E13.7)))	0 185
310 FORMAT (///" RESULTS OF ANALYSIS"/" NUMBER OF ITERATIONS:",6X,I3/	0 186
1" RETURN FLAG:",16X,I2/" ACCURACY OBTAINED:",2X,E10.4/" ANALYSIS T	0 187
2IME:",10X,F6.3," SECONDS")	0 188
320 FORMAT (/ " VECTOR OF BUS VOLTAGES"/4X,"BUS",7X,"RECTANGULAR COORDI	0 189
1NATES",10X," POLAR COORDINATES"/)	0 190
330 FORMAT ((3X,I4,2(3X,2(1X,E13.7))))	0 191
END	0 192

C		P	1
C		P	2
C		P	3
	SUBROUTINE LFLFDBM (N, YT, V, VM, VA, BCV, JRYT, ICYT, A1, LICN1, ICN1, IKEEP	P	4
	11, RHS, W, CORRA)	P	5
C		P	6
C	05.08.1982.	P	7
C		P	8
C	SUBROUTINE LFLFDBM DETERMINES THE RIGHT HAND SIDE VECTOR FOR	P	9
C	ARGUMENT CORRECTIONS OF THE FAST DECOUPLED METHOD, SOLVES THE	P	10
C	SPARSE SYSTEM OF LINEAR EQUATIONS AND UPDATES THE VOLTAGES	P	11
C		P	12
C	LIBRARY : LIBRHSM (HARWELL PACKAGE MA28)	P	13
C		P	14
	INTEGER JRYT(1), ICYT(1), ICN1(1), IKEEP1(1)	P	15
	REAL VM(1), VA(1), A1(1), BCV(1), RHS(1), W(1)	P	16
	COMPLEX YT(1), V(1), CURR, PW	P	17
C		P	18
C	SETTING RIGHT HAND SIDE VECTOR	P	19
C		P	20
	DO 10 I=1, N	P	21
	PW=V(I)*CONJG(CURR(V, YT, JRYT, ICYT, I))	P	22
	RHS(I)=(BCV(2*I-1)-REAL(PW))/VM(I)	P	23
	10 CONTINUE	P	24
C		P	25
C	SOLVING LINEAR EQUATIONS	P	26
C		P	27
	CALL MA28C (N, A1, LICN1, ICN1, IKEEP1, RHS, W, 1)	P	28
C		P	29
C	UPDATING VOLTAGES	P	30
C		P	31
	CORRA=0.0	P	32
	DO 20 I=1, N	P	33
	V1=VM(I)	P	34
	DV=ABS(V1*(RHS(I)))	P	35
	V2=VA(I)+RHS(I)	P	36
	VA(I)=V2	P	37
	IF (DV.GT.CORRA) CORRA=DV	P	38
	V(I)=CMPLX(V1*COS(V2), V1*SIN(V2))	P	39
	20 CONTINUE	P	40
	RETURN	P	41
	END	P	42

C		Q	1
C		Q	2
C		Q	3
	SUBROUTINE LFLFDCM (N,NLB,YT,V,VM,VA,BCV,JRYT,ICYT,BTYP,NRB,A2,LIC	Q	4
	1N2,ICN2,IKEEP2,RHS,W,CORRM)	Q	5
		Q	6
C	05.08.1982.	Q	7
C		Q	8
C	SUBROUTINE LFLFDCM DETERMINES THE RIGHT HAND SIDE VECTOR FOR	Q	9
C	MODULUS CORRECTIONS OF THE FAST DECOUPLED METHOD, SOLVES THE	Q	10
C	SPARSE SYSTEM OF LINEAR EQUATIONS AND UPDATES THE VOLTAGES	Q	11
C		Q	12
C	LIBRARY : LIBRHSM (HARWELL PACKAGE MA28)	Q	13
C		Q	14
	INTEGER JRYT(1),ICYT(1),BTYP(1),NRB(1),ICN2(1),IKEEP2(1)	Q	15
	REAL VM(1),VA(1),A2(1),BCV(1),RHS(1),W(1)	Q	16
	COMPLEX YT(1),V(1),CURR,PW	Q	17
C		Q	18
C	SETTING RIGHT HAND SIDE VECTOR	Q	19
C		Q	20
	DO 10 I=1,N	Q	21
	IF (BTYP(I).NE.0) GO TO 10	Q	22
	L=NRB(I)	Q	23
	PW=V(I)*CONJG(CURR(V,YT,JRYT,ICYT,I))	Q	24
	RHS(L)=(BCV(2*I)-AIMAG(PW))/VM(I)	Q	25
	10 CONTINUE	Q	26
C		Q	27
C	SOLVING LINEAR EQUATIONS	Q	28
C		Q	29
	CALL MA28C (NLB,A2,LICN2,ICN2,IKEEP2,RHS,W,1)	Q	30
C		Q	31
C	UPDATE VOLTAGES	Q	32
C		Q	33
	CORRM=0.0	Q	34
	DO 20 I=1,N	Q	35
	IF (BTYP(I).NE.0) GO TO 20	Q	36
	K=NRB(I)	Q	37
	DV=ABS(RHS(K))	Q	38
	IF (DV.GT.CORRM) CORRM=DV	Q	39
	V1=VM(I)	Q	40
	V2=V1+RHS(K)	Q	41
	VM(I)=V2	Q	42
	V(I)=(V2/V1)*V(I)	Q	43
	20 CONTINUE	Q	44
	RETURN	Q	45
	END	Q	46

C		R	1
C		R	2
C		R	3
	SUBROUTINE LFTTM (NB,NTL,JRYT,ICYT,BTYP,YT,V,BCV,W,LW,IVT,IP,ITEL,	R	4
	1VEPS,TIMEL,MODE,IFLAG,OTPT,IWRITE)	R	5
C		R	6
C	28.08.1982.	R	7
C		R	8
C	SUBROUTINE LFTTM IS THE HIGHEST LEVEL SUBROUTINE FOR SOLVING	R	9
C	THE LOAD FLOW PROBLEM USING A SPARSE MATRIX TECHNIQUE	R	10
C	(HARWELL PACKAGE MA28) AND THE TELLEGEN THEOREM METHOD	R	11
C		R	12
C	LIBRARY : LIBRHSM (HARWELL PACKAGE MA28)	R	13
C		R	14
C	NB NUMBER OF BUSES	R	15
C	NTL NUMBER OF TRANSMISSION LINES	R	16
C	JRYT VECTOR OF LENGTH (NB+1). IT HOLDS ROW INDICES OF THE	R	17
C	SPARSE BUS ADMITTANCE MATRIX	R	18
C	ICYT VECTOR OF LENGTH NB+2*NTL. IT HOLDS COLUMN INDICES OF	R	19
C	THE SPARSE BUS ADMITTANCE MATRIX	R	20
C	BTYP VECTOR OF BUS TYPES (0 LOAD BUS, 1 GENERATOR BUS)	R	21
C	YT SPARSE BUS ADMITTANCE MATRIX	R	22
C	V COMPLEX BUS VOLTAGES	R	23
C	BCV REAL VECTOR OF THE LENGTH 2*(NB-1). IT HOLDS NOMINAL	R	24
C	VALUES OF BUS CONTROL VARIABLES	R	25
C	W REAL WORKSPACE	R	26
C	LW LENGTH OF THE WORKSPACE W. IT SHOULD BE DECLARED AT	R	27
C	LEAST 70*NB+56*NTL-35	R	28
C	IVT VERSION OF ADJOINT MATRIX WHICH IS TO BE USED. RANGE	R	29
C	OF VALUES OF IVT IS FROM 1 TO 5	R	30
C	IP VERSION OF THE POWER FLOW EQUATIONS (1 POLAR VERSION,	R	31
C	0 RECTANGULAR VERSION)	R	32
C	ITEL LIMIT OF ITERATIONS	R	33
C	VEPS REQUIRED ACCURACY OF SOLUTION	R	34
C	TIMEL LIMIT OF ITERATION TIME	R	35
C	MODE MODE OF OPERATION :	R	36
C	1-ADJOINT MATRIX IS FORMED AND DECOMPOSED INTO LU FACTORS	R	37
C	IN THE FIRST ITERATION OF THE CURRENT CALL TO THE SUB-	R	38
C	ROUTINE AND IS UPDATED AND FACTORIZED IN THE SUBSEQUENT	R	39
C	ITERATIONS USING THE PIVOTAL STRATEGY DETERMINED EARLIER	R	40
C	2-ADJOINT MATRIX IS UPDATED AND FACTORIZED IN EACH ITERA-	R	41
C	TION USING THE PIVOTAL STRATEGY DETERMINED IN THE PRE-	R	42
C	VIOUS CALL TO THE SUBROUTINE	R	43
C	3-ADJOINT MATRIX IS KEPT CONSTANT FROM THE PREVIOUS CALL	R	44
C	TO THE SUBROUTINE	R	45
C	IFLAG RETURN FLAG :	R	46
C	-3 INCORRECT PARAMETER IVT	R	47
C	-2 INCORRECT PARAMETER MODE	R	48
C	-1 WORKSPACE TOO SMALL	R	49
C	0 NORMAL RETURN	R	50
C	1 LIMIT OF ITERATIONS REACHED	R	51
C	2 LIMIT OF TIME REACHED	R	52
C	OTPT NUMBER OF OUTPUT UNIT	R	53
C		R	54
C	INTEGER JRYT(1), ICYT(1), BTYP(1), OTPT	R	55
C	REAL W(1), BCV(1)	R	56
C	COMPLEX YT(1), V(1), Z	R	57
C	COMMON /MDLFTTM/ JT, JICN, JICT, JIRT, JIKEEP, JIW, JCS, JVD, JRHS, JSENS, J	R	58
C	1DEL, JICV, JCCV, JMAX	R	59
C	IFLAG=0	R	60
C	IT=0	R	61
C	IF (IWRITE.LT.1) GO TO 10	R	62
C	WRITE (OTPT,140) NB	R	63
C	10 CALL SECOND (TS)	R	64
C	TT=TS	R	65

TA=0.	R 66
IF (MODE.LE.3.OR.MODE.GE.1) GO TO 20	R 67
IFLAG=-2	R 68
RETURN	R 69
20 IF (MODE.EQ.3) GO TO 40	R 70
IF (IVT.LE.5.OR.IVT.GE.1) GO TO 30	R 71
IFLAG=-3	R 72
RETURN	R 73
30 IF (MODE.EQ.2) GO TO 40	R 74
NYT=NB+2*NIL	R 75
N1=NB+NB	R 76
NR=N1-2	R 77
NZ=(7*NYT)/2	R 78
LICN=3*NZ	R 79
LIRN=NZ+NR	R 80
JT=1	R 81
JICN=JT+LICN	R 82
JICT=JICN+LICN	R 83
JIRT=JICT+NZ	R 84
JIKEEP=JIRT+LIRN	R 85
JIW=JIKEEP+5*NR	R 86
JCS=JIW+8*NR	R 87
JVD=JCS+N1	R 88
JRHS=JVD+NR	R 89
JSENS=JRHS+N1	R 90
JDEL=JSENS+NR	R 91
JICV=JDEL+NR	R 92
JCCV=JICV+NR	R 93
JMAX=JCCV+NR	R 94
40 IF (JMAX.LE.LW) GO TO 50	R 95
IFLAG=-1	R 96
RETURN	R 97
50 IF (MODE.EQ.2.OR.MODE.EQ.3) GO TO 60	R 98
CALL DCVARF (W(JCCV),W(JICV),BTYP,NB-1)	R 99
60 CALL STEP (YT,JRYT,ICYT,V,W(JVD),BTYP,BCV,W(JCS),W(JDEL),W(JT),W(J	R 100
1IRT),W(JICT),W(JICN),W(JRHS),W(JIKEEP),W(JIW),W(JCCV),W(JICV),W(JS	R 101
2ENS),NB,IVT,MODE,IP,EPS,OTPT,IWRITE)	R 102
IT=IT+1	R 103
IF (MODE.EQ.1) MODE=2	R 104
CALL SECOND (TIME)	R 105
TT=TIME-TS	R 106
TI=TT-TA	R 107
TA=TT	R 108
IF (IWRITE.GE.1) WRITE (OTPT,150) IT,EPS,TI,TT	R 109
IF (EPS.LE.VEPS) GO TO 90	R 110
IF (IT.GE.ITEL) GO TO 70	R 111
IF (TT.GE.TIMEL) GO TO 80	R 112
GO TO 60	R 113
70 IFLAG=1	R 114
GO TO 90	R 115
80 IFLAG=2	R 116
90 VEPS=EPS	R 117
TIMEL=TT	R 118
ITEL=IT	R 119
IF (IWRITE.LT.1) GO TO 130	R 120
WRITE (OTPT,160) ITEL,IFLAG,VEPS,TIMEL	R 121
WRITE (OTPT,170)	R 122
JV1=JCS-1	R 123
JV2=JSENS-1	R 124
IF (IP.EQ.1) GO TO 110	R 125
DO 100 I=1,NB	R 126
Z=V(I)	R 127
R1=CABS(Z)	R 128
R2=ATAN2(AIMAG(Z),REAL(Z))	R 129
W(JV1+I)=R1	R 130

	W(JV2+I)=R2	R 131
	WRITE (OTPT, 180) I, Z, R1, R2	R 132
100	CONTINUE	R 133
	GO TO 130	R 134
110	DO 120 I=1, NB	R 135
	Z=V(I)	R 136
	R1=REAL(Z)	R 137
	R2=AIMAG(Z)	R 138
	R3=R1*COS(R2)	R 139
	R4=R1*SIN(R2)	R 140
	W(JV1+I)=R3	R 141
	W(JV2+I)=R4	R 142
	WRITE (OTPT, 180) I, R3, R4, Z	R 143
120	CONTINUE	R 144
130	RETURN	R 145
C		R 146
140	FORMAT (///" LOAD FLOW SOLUTION OF ", I3, "-BUS SYSTEM USING THE TEL 1LEGEN THEOREM METHOD")	R 147
150	FORMAT (///" IT = ", I2, 3X, "EPS = ", E10.4, 3X, "ITERATION TIME ", F5.3, 3 1X, "TOTAL TIME ", F6.3/)	R 148
160	FORMAT (///" RESULTS OF ANALYSIS"// " NUMBER OF ITERATIONS: ", 6X, I3/ 1" RETURN FLAG: ", 16X, I2/" ACCURACY OBTAINED: ", 2X, E10.4/" ANALYSIS T 2IME: ", 10X, F6.3, " SECONDS")	R 149
170	FORMAT (/ " VECTOR OF BUS VOLTAGES"/4X, "BUS", 7X, "RECTANGULAR COORDI INATES", 10X, "POLAR COORDINATES"/)	R 150
180	FORMAT (3X, I4, 2(3X, 2(1X, E13.7)))	R 151
	END	R 152
		R 153
		R 154
		R 155
		R 156
		R 157

C		S	1
C		S	2
C		S	3
	SUBROUTINE MISM (BCV,BCS,V,BTYP,UDEL,N,IWRITE)	S	4
C		S	5
C	11.05.1982.	S	6
C		S	7
C	SUBROUTINE MISM CALCULATES REAL VECTOR UDEL OF MISMATCHES	S	8
C	OF BUS CONTROL VARIABLES	S	9
C		S	10
	INTEGER BTYP(1)	S	11
	REAL BCV(1),UDEL(1)	S	12
	COMPLEX BCS(1),V(1),Y,VA	S	13
	DO 30 I=1,N	S	14
	J1=2*I-1	S	15
	J2=2*I	S	16
	K=BTYP(1)	S	17
	IF (K.NE.0) GO TO 10	S	18
C		S	19
C	SETTING UP VALUES OF ELEMENTS OF UDEL CORRESPONDING TO A LOAD BUS	S	20
C		S	21
	Y=BCS(1)	S	22
	UDEL(J1)=BCV(J1)-REAL(Y)	S	23
	UDEL(J2)=BCV(J2)-AIMAG(Y)	S	24
	GO TO 30	S	25
	10 IF (K.NE.1) GO TO 20	S	26
C		S	27
C	SETTING UP VALUES OF ELEMENTS OF UDEL CORRESPONDING TO A GENERATOR	S	28
C		S	29
	UDEL(J1)=BCV(J1)-REAL(BCS(1))	S	30
	UDEL(J2)=BCV(J2)-CABS(V(1))	S	31
	GO TO 30	S	32
C		S	33
C	SETTING UP VALUES OF ELEMENTS OF UDEL CORRESPONDING TO SLACK BUS	S	34
C		S	35
	20 VA=V(1)	S	36
	UDEL(J1)=BCV(J1)-CABS(VA)	S	37
	UDEL(J2)=BCV(J2)-ATAN2(AIMAG(VA),REAL(VA))	S	38
	30 CONTINUE	S	39
	IF (IWRITE.LT.4) GO TO 40	S	40
	WRITE (6,50)	S	41
	WRITE (6,60) (I,UDEL(2*I-1),UDEL(2*I),I=1,N)	S	42
	40 RETURN	S	43
	50 FORMAT (// " VECTOR UDEL OF MISMATCHES OF BUS CONTROL VARIABLES"//	S	44
	1 VALUE OF AN ELEMENT IS PRECEDED BY THE NUMBER OF BUS"/)	S	45
	60 FORMAT (3(2X,14," :",2(1X,E13.7)))	S	46
	END	S	47

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		T	1
		T	2
		T	3
	SUBROUTINE PQ (V, YT, JRYT, ICYT, BCS, N, IWRITE)	T	4
		T	5
	06.05.1982.	T	6
		T	7
	SUBROUTINE PQ CALCULATES VECTOR BCS OF COMPLEX POWERS INJECTED	T	8
	INTO BUSES FOR THE GIVEN VECTOR V OF BUS VOLTAGES	T	9
		T	10
	COMPLEX V(1), YT(1), BCS(1)	T	11
	INTEGER JRYT(1), ICYT(1)	T	12
	DO 10 I=1, N	T	13
	BCS(I)=(0., 0.)	T	14
10	CONTINUE	T	15
	DO 30 I=1, N	T	16
	J1=JRYT(I)	T	17
	J2=JRYT(I+1)-1	T	18
	DO 20 J=J1, J2	T	19
	BCS(I)=BCS(I)+YT(J)*V(ICYT(J))	T	20
20	CONTINUE	T	21
	BCS(I)=V(I)*CONJG(BCS(I))	T	22
30	CONTINUE	T	23
	IF (IWRITE.LT.3) RETURN	T	24
	WRITE (6, 40)	T	25
	WRITE (6, 50) (I, BCS(I), I=1, N)	T	26
	RETURN	T	27
40	FORMAT (// " VECTOR BCS OF COMPLEX POWERS INJECTED INTO BUSES " / " VA	T	28
	1LUE OF AN ELEMENT IS PRECEDED BY THE NUMBER OF BUS " /)	T	29
50	FORMAT (3(3X, I3, " : ", 2(1X, E13.7)))	T	30
	END	T	31

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SUBROUTINE PTELT (T,NT,R,IRT,ICT,IR,IC)

06.05.1982.

SUBROUTINE PTELT PLACES A NONZERO ELEMENT OF THE ADJOINT
MATRIX INTO THE VECTOR T AND STORES ITS ROW AND COLUMN
INDICES IN VECTORS IRT AND ICT

INTEGER IRT(1), ICT(1)
REAL T(1)
NT=NT+1
T(NT)=R
IRT(NT)=IR
ICT(NT)=IC
RETURN
END

U 1
U 2
U 3
U 4
U 5
U 6
U 7
U 8
U 9
U 10
U 11
U 12
U 13
U 14
U 15
U 16
U 17
U 18
U 19

C		V	1
C		V	2
C		V	3
	SUBROUTINE RDAT (LBINP, LBOUT, LINPG, LINPB, LG, LB, LOUTG, LOUTB, LTAP, BN	V	4
	1R, BTYP, BVMOD, BVARG, BGP, BLP, BLQ, BSTL, JRYT, NB, NTL, NLB, INPT, IWRITE)	V	5
		V	6
	05.05.1982.	V	7
		V	8
	SUBROUTINE RDAT READS INPUT DATA DESCRIBING POWER SYSTEM FROM	V	9
	A FILE CREATED BY SUBROUTINE FORMDTF AND PREPROCESS THIS DATA	V	10
		V	11
	INTEGER LBINP(1), LBOUT(1), BNR(1), BTYP(1), JRYT(1)	V	12
	REAL LINPG(1), LINPB(1), LG(1), LB(1), LOUTG(1), LOUTB(1), LTAP(1), BVMOD	V	13
	1(1), BVARG(1), BGP(1), BLP(1), BLQ(1), BSTL(1), HDLN(12)	V	14
	COMPLEX Z	V	15
	READ (INPT, 110) (HDLN(1), I=1, 12)	V	16
	READ (INPT, 130) X, NB, X, X, NTL	V	17
		V	18
	BECAUSE BUS IS INCIDENT TO ITSELF THEN ALL ELEMENTS OF VECTOR	V	19
	JRYT ARE PRESET TO ONE	V	20
		V	21
	DO 10 I=1, NB	V	22
	JRYT(I)=1	V	23
10	CONTINUE	V	24
	IF (IWRITE.LT.1) GO TO 20	V	25
	WRITE (6, 110) (HDLN(I), I=1, 12)	V	26
	WRITE (6, 150) NB, NTL	V	27
20	READ (INPT, 110) (HDLN(I), I=1, 12)	V	28
	IF (IWRITE.LT.2) GO TO 30	V	29
	WRITE (6, 110) (HDLN(I), I=1, 12)	V	30
30	READ (INPT, 120) (HDLN(I), I=1, 12)	V	31
	DO 40 I=1, NTL	V	32
	READ (INPT, 140) LBINP(I), LBOUT(I), LINPG(I), LINPB(I), LG(I), LB(I), LO	V	33
	1UTG(I), LOUTB(I), LTAP(I)	V	34
		V	35
	DEGREES OF BOTH BUSES INCIDENT TO THE LINE ARE INCREASED	V	36
	BY ONE	V	37
		V	38
	J=LBINP(I)	V	39
	JRYT(J)=JRYT(J)+1	V	40
	J=LBOUT(I)	V	41
	JRYT(J)=JRYT(J)+1	V	42
40	CONTINUE	V	43
	IF (IWRITE.LT.2) GO TO 60	V	44
	WRITE (6, 120) (HDLN(I), I=1, 12)	V	45
	DO 50 I=1, NTL	V	46
	WRITE (6, 140) LBINP(I), LBOUT(I), LINPG(I), LINPB(I), LG(I), LB(I), LOU	V	47
	1TAP(I), LOUTB(I), LTAP(I)	V	48
50	CONTINUE	V	49
60	DO 70 I=1, NTL	V	50
	Z=1./CMLPX(LG(I), LB(I))	V	51
	LG(I)=REAL(Z)	V	52
	LB(I)=AIMAG(Z)	V	53
70	CONTINUE	V	54
	READ (INPT, 110) (HDLN(I), I=1, 12)	V	55
	IF (IWRITE.GT.1) WRITE (6, 110) (HDLN(I), I=1, 12)	V	56
	READ (INPT, 120) (HDLN(I), I=1, 12)	V	57
	NLB=0	V	58
	IX=JRYT(1)	V	59
	JRYT(1)=1	V	60
	JRYT(NB+1)=0	V	61
	DO 80 I=1, NB	V	62
	READ (INPT, 140) L, BTYP(L), BVMOD(L), BVARG(L), BGP(L), BLP(L), BLQ(L), B	V	63
	1STL(L)	V	64
	BNR(L)=I	V	65

IF (BTYP(L).EQ.0) NLB=NLB+1	V	66
J=I+1	V	67
IY=JRYT(J)	V	68
JRYT(J)=JRYT(I)+IX	V	69
IX=IY	V	70
80 CONTINUE	V	71
IF (IWRITE.LT.2) GO TO 100	V	72
WRITE (6,120) (HDLN(I),I=1,12)	V	73
DO 90 I=1,NB	V	74
WRITE (6,140) BNR(I),BTYP(I),BVMOD(I),BVARC(I),BCP(I),BLP(I),BLQ(I),BSTL(I)	V	75
90 CONTINUE	V	76
100 RETURN	V	77
110 FORMAT (//12A10/)	V	78
120 FORMAT (12A10)	V	79
130 FORMAT (1X,A5,I3,2A5,I4)	V	80
140 FORMAT (2(1X,I5),2X,7(2X,E13.7))	V	81
150 FORMAT (" NB = ",I3.3," ", "NTL = ",I4.3)	V	82
END	V	83
	V	84

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		W	1
		W	2
		W	3
	SUBROUTINE READDT (LBINP, LBOUT, LINPG, LINPB, LR, LX, LOUTG, LOUTB, LTAP,	W	4
	1BNR, BTYP, BVMOD, BVARC, BGP, BLP, BLQ, BSTL, NB, NTL, INPT)	W	5
		W	6
	27.04.1982.	W	7
		W	8
	SUBROUTINE READDT READS INPUT DATA DESCRIBING THE POWER SYSTEM	W	9
	FROM AN UNFORMATTED FILE WITH THE USE OF PACKAGE PWRDD	W	10
		W	11
	LIBRARY : LIBSPWR (PACKAGE PWRDD)	W	12
		W	13
	INTEGER LBINP(1), LBOUT(1), BNR(1), BTYP(1), KK(2)	W	14
	REAL LINPG(1), LINPB(1), LR(1), LX(1), LOUTG(1), LOUTB(1), LTAP(1), BVMOD	W	15
	1(1), BVARC(1), BGP(1), BLP(1), BLQ(1), BSTL(1), RLB(17), RL(9), RB(8)	W	16
	EQUIVALENCE (RLB(1), RL(1)), (RLB(10), RB(1))	W	17
	DATA RLB/"LINEBINP", "LINEBOUT", "LINEINPC", "LINEINPS", "LINER", "LINE	W	18
	1X", "LINEOUTC", "LINEOUTS", "LINETAP", "BUSNR", "BUSTYPE", "BUSVMOD", "BU	W	19
	2SVARG", "BUSGP", "BUSLP", "BUSLQ", "BUSSTL"/	W	20
	R=ATAN(1.)/45.	W	21
	CALL DD00DF (INPT, NB, NS, NTL, TN, ICODE)	W	22
	IF (ICODE.LT.0) GO TO 70	W	23
	CALL DD00DN (RLB, 17, IE)	W	24
	IF (IE.NE.0) GO TO 30	W	25
	CALL DD11DR (1, RL, 9, IE)	W	26
	IF (IE.NE.0) GO TO 90	W	27
	CALL DD11DR (2, RB, 8, IE)	W	28
	IF (IE.NE.0) GO TO 100	W	29
	DO 10 I=1, 2	W	30
	ICODE=ICODE/10	W	31
	KK(1)=MOD(ICODE, 10)	W	32
10	CONTINUE	W	33
	I=1	W	34
20	CALL DD11GS (1, IE)	W	35
	IF (IE.EQ.0) GO TO 30	W	36
	CALL DD11IN (LBINP(1), IE)	W	37
	CALL DD11IN (LBOUT(1), IE)	W	38
	CALL DD11RN (LINPG(1), IE)	W	39
	CALL DD11RN (LINPB(1), IE)	W	40
	CALL DD11RN (LR(1), IE)	W	41
	CALL DD11RN (LX(1), IE)	W	42
	CALL DD11RN (LOUTG(1), IE)	W	43
	CALL DD11RN (LOUTB(1), IE)	W	44
	CALL DD11RN (LTAP(1), IE)	W	45
	I=I+1	W	46
	GO TO 20	W	47
30	IF (KK(2).LT.KK(1)) GO TO 40	W	48
	REWIND INPT	W	49
40	I=1	W	50
50	CALL DD11GS (2, IE)	W	51
	IF (IE.EQ.0) GO TO 60	W	52
	CALL DD11IN (BNR(1), IE)	W	53
	CALL DD11IN (BTYP(1), IE)	W	54
	CALL DD11RN (BVMOD(1), IE)	W	55
	CALL DD11RN (ALPHA, IE)	W	56
	BVARC(1)=ALPHA*R	W	57
	CALL DD11RN (BGP(1), IE)	W	58
	CALL DD11RN (BLP(1), IE)	W	59
	CALL DD11RN (BLQ(1), IE)	W	60
	CALL DD11RN (BSTL(1), IE)	W	61
	I=I+1	W	62
	GO TO 50	W	63
60	RETURN	W	64
70	JD=1	W	65

IE= ICODE	W	66
GO TO 110	W	67
80 JD=2	W	68
GO TO 110	W	69
90 JD=3	W	70
GO TO 110	W	71
100 JD=4	W	72
110 WRITE (6,120) JD, IE	W	73
STOP	W	74
120 FORMAT (///1X, "INCORRECT INPUT DATA. STOP", I2, ". IFLAG =", I2/)	W	75
END	W	76

C		X	1
C		X	2
C		X	3
	SUBROUTINE SENSIT (LBINP, LBOUT, YT, JRYT, ICYT, V, BTYP, BCS, RHST, CCV, IC	X	4
	1V, PDR, SENS, T, IRT, ICT, ICN, IKEEP, IW, NB, NCV, IVT, MODE, IFLAG, OTPT, IWRIT	X	5
	2E)	X	6
		X	7
	12.08.1982.	X	8
		X	9
	SUBROUTINE SENSIT IS THE HIGHEST LEVEL SUBROUTINE TO CALCULATE	X	10
	VECTOR OF SENSITIVITIES OF A REAL FUNCTION OF THE POWER SYSTEM	X	11
	STATE AND CONTROL VARIABLES W.R.T. CONTROL VARIABLES DEFINED BY	X	12
	VECTORS CCV, ICV USING A SPARSE MATRIX TECHNIQUE (HARWELL PACKAGE	X	13
	MA28) AND THE TELLEGEN THEOREM METHOD	X	14
		X	15
	LIBRARY : LIBRHSM (HARWELL PACKAGE MA28)	X	16
		X	17
	INTEGER LBINP(1), LBOUT(1), JRYT(1), ICYT(1), BTYP(1), CCV(1), ICV(1), IR	X	18
	IT(1), ICT(1), ICN(1), IKEEP(1), IW(1), OTPT	X	19
	REAL RHST(1), T(1), SENS(1), HD(5)	X	20
	COMPLEX YT(1), V(1), BCS(1), PDR(1)	X	21
	COMMON /T00/ NT, LICN, LIRN	X	22
	DATA HD/"EXACT", "DECOUPLED", "APPROXIM", "APPR DEC", "MIXED"/	X	23
	IFLAG=0	X	24
	N=NB-1	X	25
	NR=N+N	X	26
	MTYPE=1	X	27
	IF (IWRITE.LT.3) GO TO 10	X	28
	WRITE (OTPT, 130) MODE, HD(IVT)	X	29
	10 IF (MODE.LE.3.OR.MODE.GE.1) GO TO 20	X	30
	IFLAG=-2	X	31
	RETURN	X	32
	20 IF (MODE.EQ.3) GO TO 120	X	33
		X	34
	IF MODE=3 THEN MATRIX T OF ADJOINT EQUATIONS IS NOT CHANGED	X	35
	STRUCTURALLY AND NUMERICALLY FROM THE PREVIOUS CALL TO	X	36
	SUBROUTINE SENSIT, STEP OR LFTTM	X	37
		X	38
	IF (IVT.LE.5.OR.IVT.GE.1) GO TO 30	X	39
	IFLAG=-3	X	40
	RETURN	X	41
	30 IF (IVT.LE.2.OR.IVT.EQ.5) CALL PQ (V, YT, JRYT, ICYT, BCS, NB, IWRITE-1)	X	42
	GO TO (40, 50, 60, 70, 80), IVT	X	43
		X	44
	PARAMETER IVT IS TO SELECT VERSION OF ADJOINT EQUATIONS	X	45
		X	46
	40 CALL FORMTE (YT, JRYT, ICYT, BCS, V, BTYP, T, IRT, ICT, N, NT, OTPT, IWRITE)	X	47
	GO TO 90	X	48
	50 CALL FORMTD (YT, JRYT, ICYT, BCS, V, BTYP, T, IRT, ICT, N, NT, OTPT, IWRITE)	X	49
	GO TO 90	X	50
	60 CALL FORMTA (YT, JRYT, ICYT, BTYP, T, IRT, ICT, N, NT, OTPT, IWRITE)	X	51
	GO TO 90	X	52
	70 CALL FORMTAD (YT, JRYT, ICYT, BTYP, T, IRT, ICT, N, NT, OTPT, IWRITE)	X	53
	GO TO 90	X	54
	80 CALL FORMTM (YT, JRYT, ICYT, BCS, V, BTYP, T, IRT, ICT, N, NT, OTPT, IWRITE)	X	55
	90 IF (MODE.EQ.2) GO TO 110	X	56
		X	57
	IF MODE=2 THEN MATRIX T OF ADJOINT EQUATIONS IS NOT CHANGED	X	58
	STRUCTURALLY FROM THE PREVIOUS CALL TO SUBROUTINE SENSIT,	X	59
	STEP OR LFTTM	X	60
		X	61
	LICN=3*NT	X	62
	LIRN=NR+NT	X	63
	U=0.1	X	64
	DO 100 I=1, NT	X	65

	ICN(I) = ICT(I)	X	66
100	CONTINUE	X	67
	CALL MA28A (NR, NT, T, LICN, IRT, LIRN, ICN, U, IKEEP, IW, BCS, IFLAG)	X	68
	GO TO 120	X	69
110	CALL MA28B (NR, NT, T, LICN, IRT, ICT, ICN, IKEEP, IW, BCS, IFLAG)	X	70
120	CALL MA28C (NR, T, LICN, ICN, IKEEP, RHST, BCS, MTYPE)	X	71
	CALL DERIV (LBINP, LBOUT, YT, JRYT, ICYT, V, RHST, CCV, ICV, PDR, SENS, NCV, I	X	72
	WRITE)	X	73
	RETURN	X	74
130	FORMAT (////" SENSITIVITY CALCULATION. MODE = ", I2/" VERSION OF ADJ	X	75
	JOINT EQUATIONS: ", A9)	X	76
	END	X	77

C		Y	1
C		Y	2
C		Y	3
	SUBROUTINE STEP (YT, JRYT, ICYT, V, VD, BTYP, BCV, BCS, UDEL, T, IRT, ICT, ICN	Y	4
	1, RHST, IKEEP, IW, CCVF, ICVF, SENS, NB, IVT, MODE, IP, EPS, OTPT, IWRITE)	Y	5
		Y	6
	03.08.1982.	Y	7
		Y	8
	SUBROUTINE STEP PERFORMS ONE ITERATION OF THE SOLUTION OF	Y	9
	THE LOAD FLOW PROBLEM USING THE TELLEGEN THEOREM METHOD	Y	10
		Y	11
	LIBRARY : LIBRHSM (HARWELL PACKAGE MA28)	Y	12
		Y	13
	INTEGER JRYT(1), ICYT(1), BTYP(1), IRT(1), ICT(1), ICN(1), IKEEP(1), IW(1	Y	14
	1), CCVF(1), ICVF(1), LBINP(1), LBOUT(1), OTPT	Y	15
	REAL HD(7), BCV(1), UDEL(1), T(1), RHST(1), SENS(1)	Y	16
	COMPLEX YT(1), V(1), VD(1), BCS(1), Z, Y, CRP	Y	17
	COMMON /T00/ NT, LICN, LIRN	Y	18
	DATA HD/"EXACT", "DECOUPLED", "APPROXIM", "APPR DEC", "MIXED", "RECTANG	Y	19
	1", "POLAR"/	Y	20
		Y	21
	THIS FUNCTION STATEMENT IS TO CONVERSE COMPLEX NUMBERS FROM	Y	22
	RECTANGULAR INTO POLAR COORDINATES	Y	23
		Y	24
	CRP(Y)=CMLPX(CABS(Y), ATAN2(AIMAG(Y), REAL(Y)))	Y	25
	N=NB-1	Y	26
	NR=2*N	Y	27
	MTYPE=1	Y	28
	EPS=0.	Y	29
	RHST(NR+1)=0.	Y	30
	RHST(NR+2)=0.	Y	31
	IF (IWRITE.LT.2) GO TO 10	Y	32
	I=6	Y	33
	IF (IP.EQ.1) I=7	Y	34
	WRITE (OTPT,240) MODE, HD(1), HD(IVT)	Y	35
	10 IF (IP.NE.1) GO TO 30	Y	36
		Y	37
	VECTOR V OF INITIAL BUS VOLTAGES GIVEN IN POLAR COORDINATES	Y	38
	IS CONVERSED INTO RECTANGULAR COORDINATES	Y	39
		Y	40
	DO 20 I=1, NB	Y	41
	R1=REAL(V(I))	Y	42
	R2=AIMAG(V(I))	Y	43
	V(I)=CMLPX(R1*COS(R2), R1*SIN(R2))	Y	44
	20 CONTINUE	Y	45
	30 CALL PQ (V, YT, JRYT, ICYT, BCS, N, IWRITE)	Y	46
	CALL MISM (BCV, BCS, V, BTYP, UDEL, N, IWRITE)	Y	47
	IF (MODE.EQ.3) GO TO 120	Y	48
		Y	49
	IF MODE=3 THEN MATRIX T OF ADJOINT EQUATIONS IS NOT CHANGED	Y	50
	STRUCTURALLY AND NUMERICALLY FROM THE PREVIOUS CALL TO	Y	51
	SUBROUTINE STEP, LFTTM OR SENSIT	Y	52
		Y	53
	GO TO (40,50,60,70,80), IVT	Y	54
		Y	55
	PARAMETER IVT IS TO SELECT VERSION OF ADJOINT EQUATIONS	Y	56
		Y	57
	40 CALL FORMTE (YT, JRYT, ICYT, BCS, V, BTYP, T, IRT, ICT, N, NT, OTPT, IWRITE)	Y	58
	GO TO 90	Y	59
	50 CALL FORMTD (YT, JRYT, ICYT, BCS, V, BTYP, T, IRT, ICT, N, NT, OTPT, IWRITE)	Y	60
	GO TO 90	Y	61
	60 CALL FORMTA (YT, JRYT, ICYT, BTYP, T, IRT, ICT, N, NT, OTPT, IWRITE)	Y	62
	GO TO 90	Y	63
	70 CALL FORMTAD (YT, JRYT, ICYT, BTYP, T, IRT, ICT, N, NT, OTPT, IWRITE)	Y	64
	GO TO 90	Y	65

	80 CALL FORMTM (YT, JRYT, ICYT, BCS, V, BTYP, T, IRT, ICT, N, NT, OTPT, IWRITE)	Y 66
	90 IF (MODE.EQ.2) GO TO 110	Y 67
C		Y 68
C	IF MODE=2 THEN MATRIX T OF ADJOINT EQUATIONS IS NOT CHANGED	Y 69
C	STRUCTURALLY FROM THE PREVIOUS CALL TO SUBROUTINE STEP,	Y 70
C	LFTTM OR SENSIT	Y 71
C		Y 72
	LICN=3*NT	Y 73
	LIRN=NR+NT	Y 74
	U=0.1	Y 75
	DO 100 I=1,NT	Y 76
	ICN(I)=ICT(I)	Y 77
100	CONTINUE	Y 78
	CALL MA28A (NR, NT, T, LICN, IRT, LIRN, ICN, U, IKEEP, IW, SENS, IFLAG)	Y 79
	GO TO 120	Y 80
110	CALL MA28B (NR, NT, T, LICN, IRT, ICT, ICN, IKEEP, IW, SENS, IFLAG)	Y 81
120	DO 210 I=1, NR	Y 82
C		Y 83
C	I IS THE INDEX OF STATE VARIABLE. IN THIS LOOP CORRECTIONS	Y 84
C	OF ALL STATE VARIABLES ARE CALCULATED	Y 85
C		Y 86
	COR=0.	Y 87
	K=MOD(I,2)	Y 88
	L=(I+K)/2	Y 89
C		Y 90
C	L IS THE INDEX OF BUS ASSOCIATED WITH THE ITH STATE VARIABLE	Y 91
C	IF ITH STATE VARIABLE IS REAL(V(L)) OR MOD(V(L)) THEN K=1	Y 92
C	IF ITH STATE VARIABLE IS AIMAG(V(L)) OR ARG(V(L)) THEN K=0	Y 93
C		Y 94
	ITYP=BTYP(L)	Y 95
	IF (ITYP.NE.1.OR.K.NE.1.OR.IP.NE.1) GO TO 130	Y 96
C		Y 97
C	IF THE STATE VARIABLE IS A MODULUS OF GENERATOR VOLTAGE THEN	Y 98
C	ADJOINT EQUATIONS ARE HOMOGENEOUS AND NEED NOT BE SOLVED	Y 99
C		Y 100
	Z=CPLX(0.,0.)	Y 101
	GO TO 210	Y 102
130	CALL EXCT (V, ITYP, I, RHST, NR, IP, IWRITE)	Y 103
	CALL MA28C (NR, T, LICN, ICN, IKEEP, RHST, SENS, MTYPE)	Y 104
	CALL DERIV (LBINP, LBOUT, YT, JRYT, ICYT, V, RHST, CCVF, ICVF, PDR, SENS, NR,	Y 105
	IWRITE)	Y 106
C		Y 107
C	CALCULATION OF THE VALUE OF CORRECTION COR OF THE ITH STATE	Y 108
C	VARIABLE	Y 109
C		Y 110
	IF (IP.EQ.1) GO TO 150	Y 111
C		Y 112
C	RECTANGULAR VERSION OF THE POWER FLOW EQUATIONS	Y 113
C		Y 114
	DO 140 J=1, NR	Y 115
	R=0.	Y 116
C		Y 117
C	VARIABLE R HOLDS THE VALUE OF PARTIAL DERIVATIVE OF ITH STATE	Y 118
C	VARIABLE W.R.T. JTH CONTROL VARIABLE	Y 119
C		Y 120
	IF (CCVF(J).EQ.9.AND.I.EQ.(J-1)) R=REAL(V(L))/CABS(V(L))	Y 121
	IF (CCVF(J).EQ.9.AND.I.EQ.J) R=AIMAG(V(L))/CABS(V(L))	Y 122
	COR=COR+(R-SENS(J))*UDEL(J)	Y 123
140	CONTINUE	Y 124
	GO TO 170	Y 125
C		Y 126
C	POLAR VERSION OF THE POWER FLOW EQUATIONS	Y 127
C		Y 128
	150 DO 160 J=1, NR	Y 129
	COR=COR-SENS(J)*UDEL(J)	Y 130

160	CONTINUE	Y 131
170	IF (K.EQ.0) GO TO 180	Y 132
	Z=CMPLX(COR,0.)	Y 133
	GO TO 210	Y 134
180	Z=Z+CMPLX(0.,COR)	Y 135
C		Y 136
C	VARIABLE Z HOLDS THE VALUE OF VOLTAGE CORRECTION OF THE LTH BUS	Y 137
C		Y 138
	IF (IP.EQ.1) GO TO 190	Y 139
	X=CABS(Z)	Y 140
	VD(L)=V(L)+Z	Y 141
	GO TO 200	Y 142
190	VD(L)=CRP(V(L))+Z	Y 143
	R1=REAL(VD(L))	Y 144
	R2=AIMAG(VD(L))	Y 145
	X=CABS(CMPLX(R1*COS(R2),R1*SIN(R2))-V(L))	Y 146
C		Y 147
C	VARIABLE X HOLDS THE VALUE OF THE MODULUS OF THE BUS VOLTAGE	Y 148
C	CORRECTION. VD(L) IS THE UPDATED VOLTAGE OF THE LTH BUS	Y 149
C		Y 150
200	IF (X.GT.EPS) EPS=X	Y 151
210	CONTINUE	Y 152
	DO 220 I=1,N	Y 153
	V(I)=VD(I)	Y 154
220	CONTINUE	Y 155
	IF (IP.EQ.1) V(NB)=CRP(V(NB))	Y 156
	IF (IWRITE.LT.2) GO TO 230	Y 157
	WRITE (OTPT,250)	Y 158
	WRITE (OTPT,260) (L,V(L),L=1,N)	Y 159
230	RETURN	Y 160
240	FORMAT (///" RESULTS OF ITERATION. MODE = ",I2/" VERSION OF POWER F	Y 161
	ILOW EQUATIONS: ",A9/" VERSION OF ADJOINT EQUATIONS: ",A9)	Y 162
250	FORMAT (// " VECTOR V OF BUS VOLTAGES "/" VALUE OF VOLTAGE IS PRECED	Y 163
	IED BY THE NUMBER OF BUS")	Y 164
260	FORMAT (3(2X,I4," :",2(1X,E13.7)))	Y 165
	END	Y 166