EE 5240 - Lecture 8 Wednesday Jan 27, 2021

Topics for Today:

- Questions?
- Note: EE5200 text is great reference, Ch.7 thru Ch.16.
- Homework #2 submission portal; Homework #3 soon posted

Today - system data for computer studies

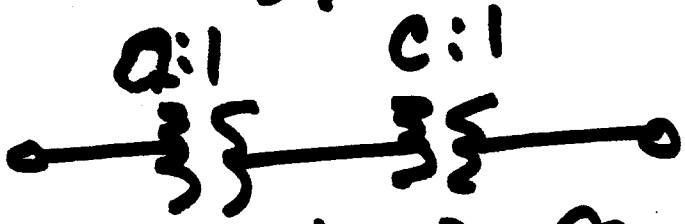
- Transformer Data, tap-changing transformers
- Adding tap changing XFMRs into $[Y_{BUS}]$, CDF files
- Typical Data I/O for loadflow (18-bus New Zealand)
- MatLab - open and read CDF files.

- Coming up - keep studying Chapters 3 & 4.
  - Nonlinear systems of equations
  - Newton Iterative Method
  - Newton-Raphson Load Flow Formulation
  - Loadflow Setup, practical view

TAP-CHANGERS

On One-Line Diags:

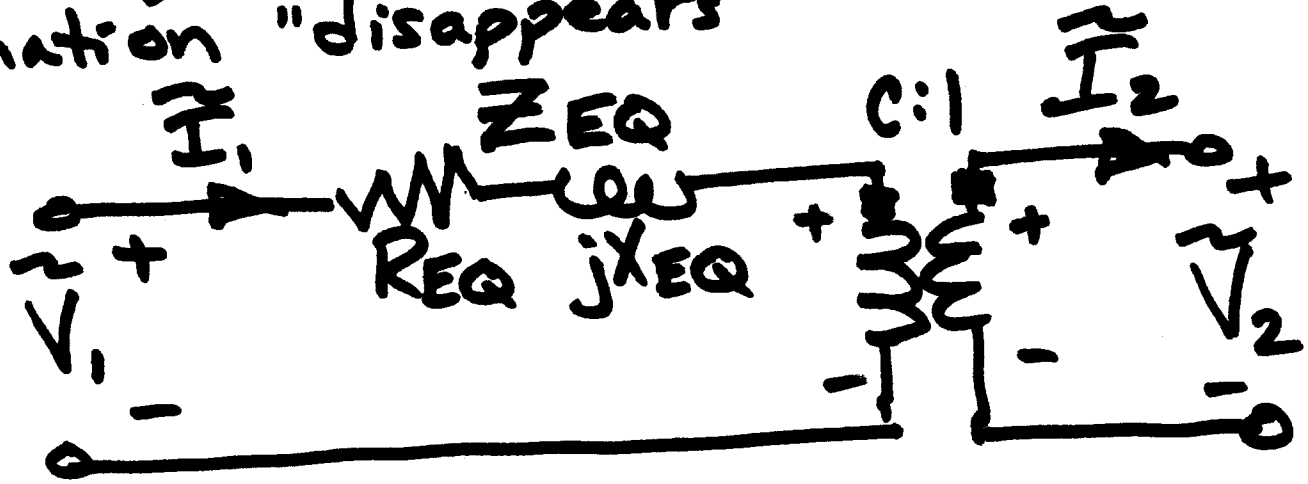
Conceptually:



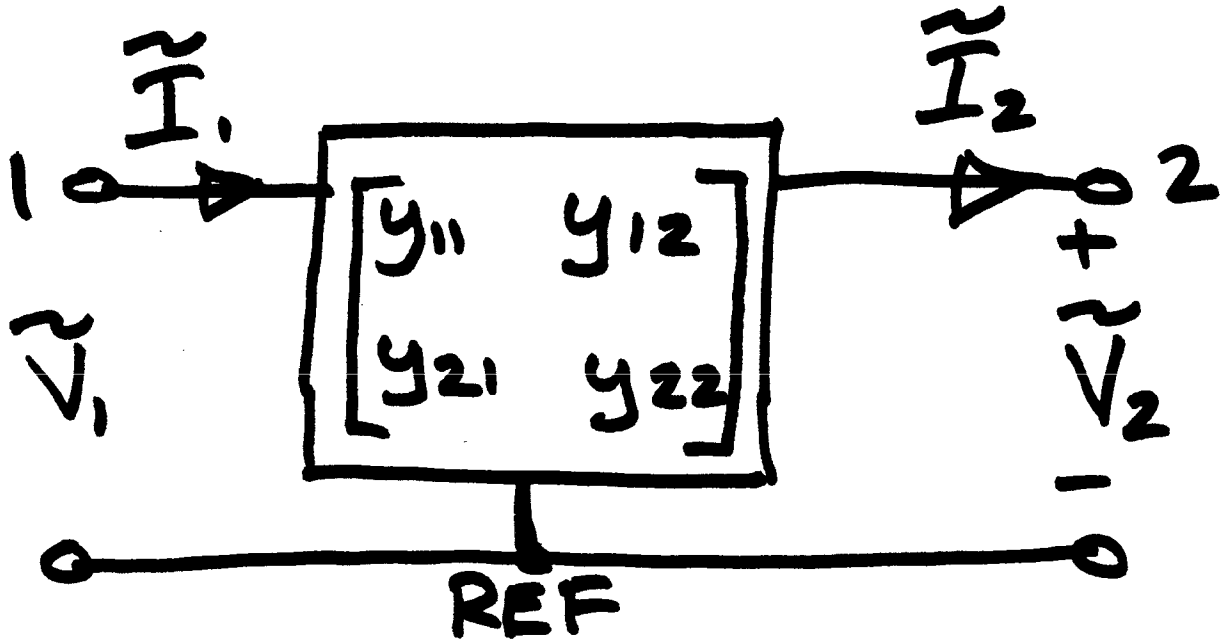
Nominal Voltage Ratio

↑ off-nominal turns ratio due to Tap Changer

In per unit, nominal transformation "disappears"



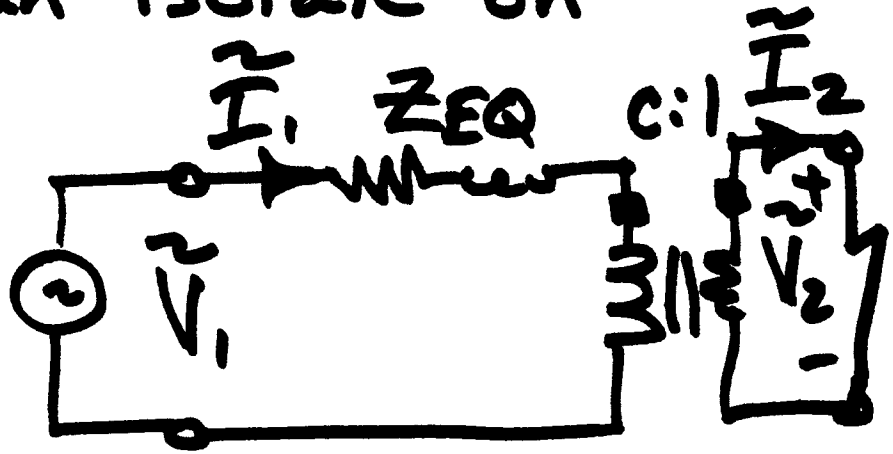
Generically, we can describe this b
as a 2-node [Y]



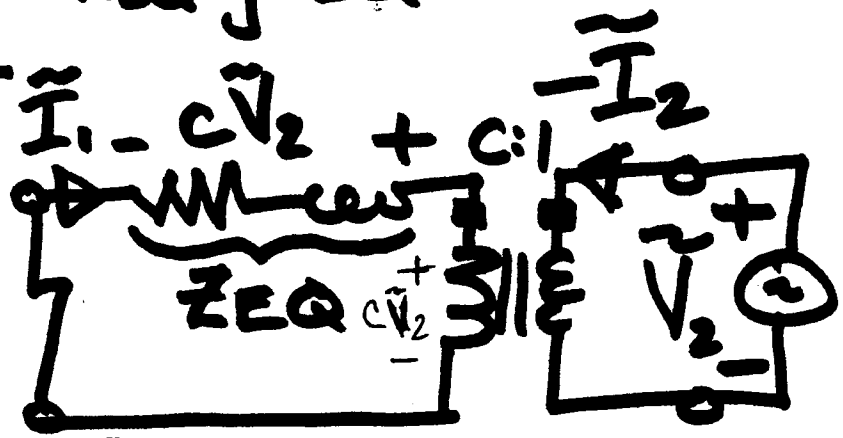
where

$$\begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} \tilde{V}_1 \\ \tilde{V}_2 \end{bmatrix} = \begin{bmatrix} \tilde{I}_1 \\ -\tilde{I}_2 \end{bmatrix}$$

Strategically using shorts [redacted], we can isolate on the values of [Y].



$$y_{11} = \left.\frac{\tilde{I}_1}{\tilde{V}_1}\right|_{\tilde{V}_2=0} = \frac{1}{Z_{EQ}} = Y_{EQ} = \frac{1}{R_{EQ}+jX_{EQ}}$$



$$y_{22} = \left.\frac{-\tilde{I}_2}{\tilde{V}_2}\right|_{\tilde{V}_1=0} = \frac{1}{Z_{EQ}/|c|^2} = |c|^2 Y_{EQ}$$

$$\tilde{I}_1 = -\frac{C\tilde{V}_2}{Z_{EQ}} \; ; \; -\tilde{I}_2 = -\frac{\tilde{I}_1}{\cancel{\quad}} * C^* = -\left[-\frac{C\,\tilde{V}_2}{Z_{EQ}}\right] C^*$$

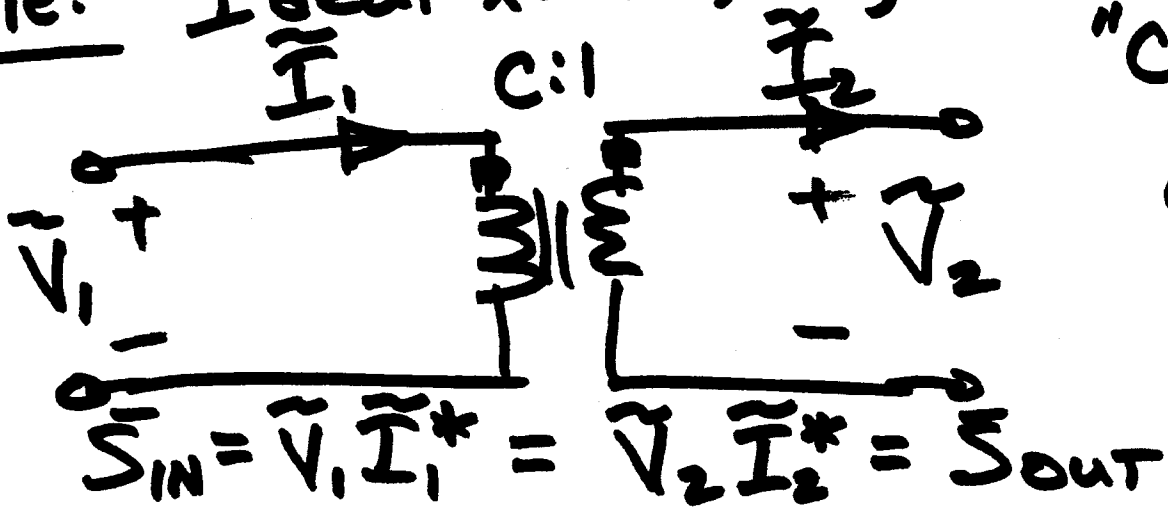
$$= \frac{|C|^2 \tilde{V}_2}{Z_{EQ}}$$

Note: $\frac{I_2}{I_1} = C^*$

$$y_{12} = \left.\frac{\tilde{I}_1}{\tilde{V}_2}\right|_{\tilde{V}_1=0} = \frac{-c\tilde{V}_2/Z_{EQ}}{\tilde{V}_2} = -cY_{EQ}$$

$$y_{21} = \left.\frac{-\tilde{I}_2}{\tilde{V}_1}\right|_{\tilde{V}_2=0} = \frac{-c^*\tilde{I}_1}{\tilde{V}_1} = -c^*Y_{EQ}$$

Note: Ideal XFMR, by definition, has "c" is voltage ratio.

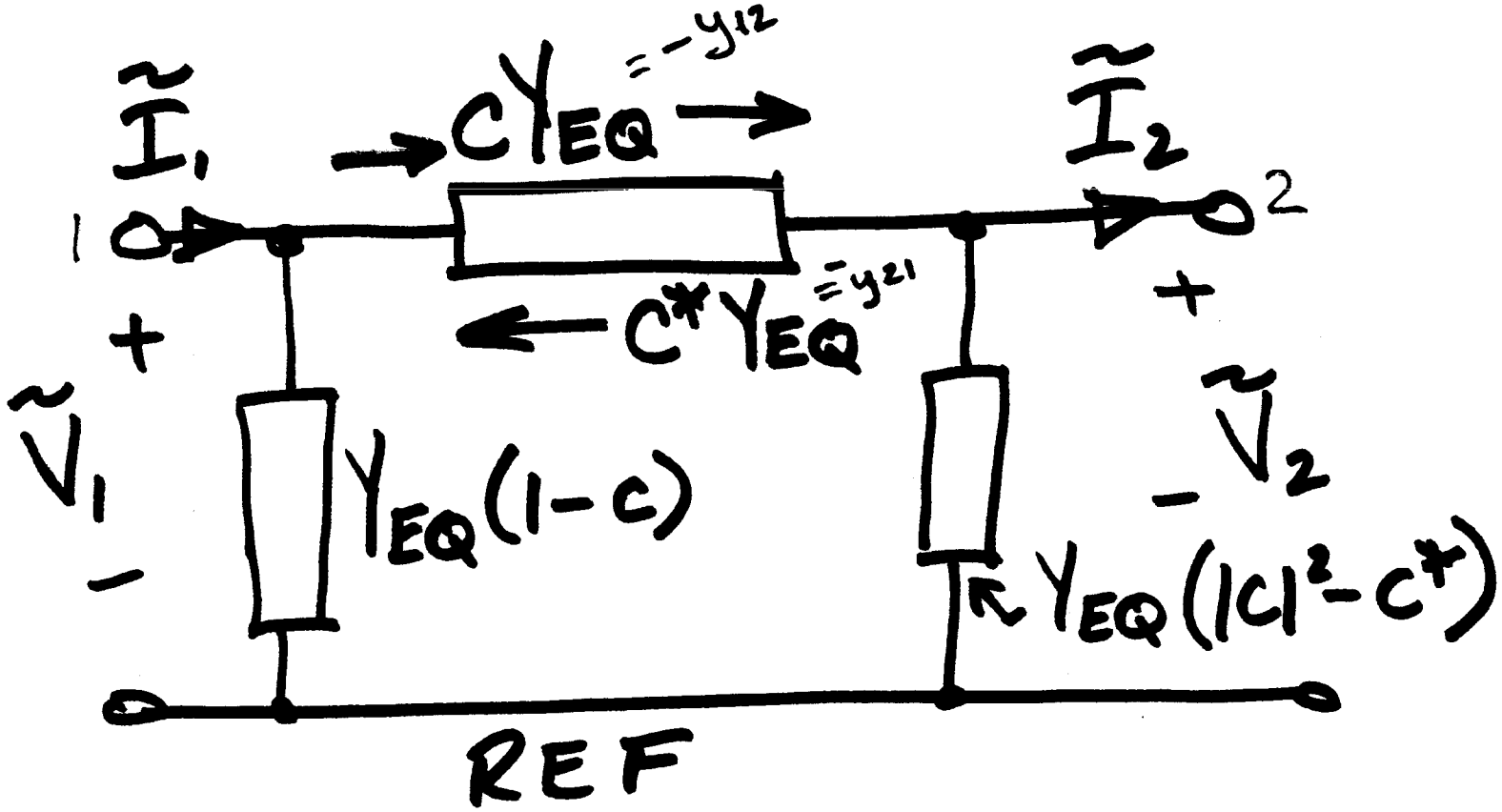


$$c = \frac{\tilde{V}_1}{\tilde{V}_2} \Rightarrow$$

$$c = \frac{\tilde{I}_2^*}{\tilde{I}_1^*} \Rightarrow \frac{\tilde{I}_2}{\tilde{I}_1} = c^*$$

If we "reverse engineer" our [Y] into an equivalent 2-bus network, then

e)



Observations:

- LTC (TCUL) has a c that is Real.

∴ Transfer Admittances

$$cY_{EQ} = c^* Y_{EQ}$$

$\Rightarrow$ Bilateral. $(y_{12} = y_{21})$

- Phase-Shifter (PS) has complex c.

∴ Transfer admittances

$$cY_{EQ} \neq c^* Y_{EQ}$$

$$y_{12} \neq y_{21}$$

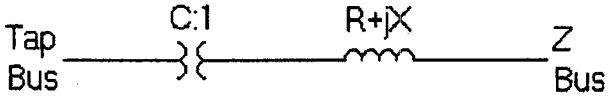
Not Bilateral.

[Y] not symm. about main diag.

Transformer LTC's in the CDF File Format

Tap and impedance location specified in first two entries in branch data section.

- **entry 1 is bus non-unity tap is connected to**
- **entry 2 is bus device impedance is connected to**

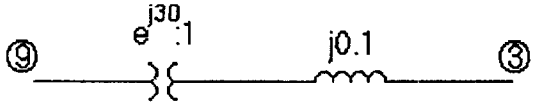


Complex turns ratio due to phase shifting transformer split to two entries

- **entry 15 is transformer final turns ratio**
- **entry 16 is transformer (phase shifter) final angle**

Examples:

Entry:	1	2	15	16
	4	7	.975	0



Entry:	1	2	15	16
	9	3	1	30

|c|

← Field no.

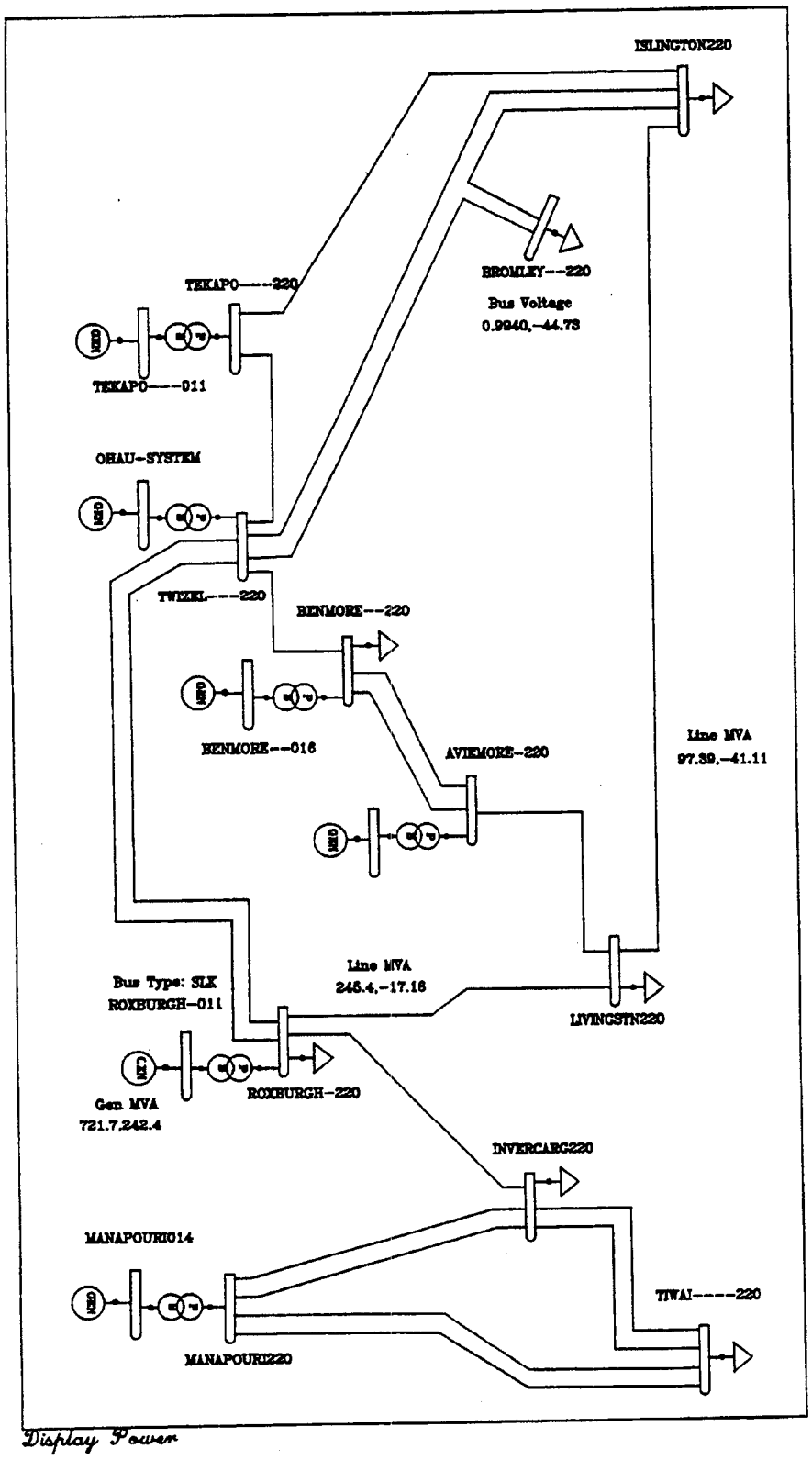


Figure 2.12
Reduced primary a.c. system for the South Island of New Zealand

From: Arrillaga & Arnold
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e.g. on the transmission angle and the voltage drop across each line, can be included in the program to automatically monitor the solution.

Finally, a practical load-flow program should include some automatic test to discontinue the solution if it is diverging, to avoid unnecessary waste of computation, and to avoid overflow in the computer. A suitable test is to check at each iteration whether any voltage magnitude is outside the arbitrary range 0.5–1.5 p.u., since it is highly unlikely in any practical power system that a meaningful voltage solution lies outside this range.

2.13 *NUMERICAL EXAMPLE*

The test network illustrated in Fig. 2.12, drawn by *Display Power* as described in Chapter 11, involves the main generating and loading points of New Zealand's South Island, with the h.v.d.c. convertor represented as a load, i.e. by specified P and Q.

The following computer print out illustrates the numerical input and output information for the specified conditions.

LOAD FLOW PROGRAM

DEPARTMENT OF ELECTRICAL & ELECTRONIC ENGINEERING, UNIVERSITY OF CANTERBURY, NEW ZEALAND

SYSTEM NO. 2 23 MAR 90

THE SLACK BUS IS	6		
MAXIMUM NUMBER OF ITERATIONS	10	NUMBER OF BUSES	17
POWER TOLERANCE	.00100	NUMBER OF LINES	20
PRINTOUT INDICATOR	000000000	NO OF TRANSFORMERS	6

BUS DATA

BUS	NAME	TYPE	VOLTS	LOAD MW	LOAD MVAR	GENERATION MW	GENERATION MVAR	MINIMUM MVAR	MAXIMUM MVAR	SHUNT SUSCEPTANCE
1	INVERCARG220	0	0.0000	200.00	51.00	0.00	0.00	0.00	0.00	0.000
2	ROXBURGH-220	0	0.0000	150.00	60.00	0.00	0.00	0.00	0.00	0.000
3	MANAPOURI220	0	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.000
4	MANAPOURI014	1	1.0450	0.00	0.00	690.00	0.00	0.00	0.00	0.000
5	TIVAI——220	0	0.0000	420.00	185.00	0.00	0.00	0.00	0.00	0.000
6	ROXBURGH-011	1	1.0500	0.00	0.00	0.00	0.00	0.00	0.00	0.000
7	BENMORE—220	0	0.0000	500.00	200.00	0.00	0.00	0.00	0.00	0.000
8	BENMORE—016	1	1.0600	0.00	0.00	0.00	0.00	0.00	0.00	0.000
9	AVIEMORE-220	0	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.000
10	AVIEMORE-011	1	1.0450	0.00	0.00	200.00	0.00	0.00	0.00	0.000
11	OHAU-SYSTEM	1	1.0500	0.00	0.00	350.00	0.00	0.00	0.00	0.000
12	LIVINGSTN220	0	0.0000	150.00	60.00	0.00	0.00	0.00	0.00	0.000
13	ISLINGTON220	1	1.0000	500.00	300.00	0.00	0.00	0.00	0.00	0.000
14	BROMLEY—220	0	0.0000	100.00	60.00	0.00	0.00	0.00	0.00	0.000
15	TEKAPO——011	0	1.0500	0.00	0.00	150.00	0.00	0.00	0.00	0.000
16	TEKAPO——220	0	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.000
17	TWIZEL——220	0	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.000

LINE DATA

BUS	NAME	BUS	NAME	RESISTANCE	REACTANCE	SUSCEPTANCE
1	INVERCARG220	3	MANAPOURI220	0.01300	0.09000	0.25000
1	INVERCARG220	3	MANAPOURI220	0.01300	0.09000	0.25000
3	MANAPOURI220	5	TIWAI——220	0.01000	0.10000	0.29000
3	MANAPOURI220	5	TIWAI——220	0.01000	0.10000	0.29000
1	INVERCARG220	5	TIWAI——220	0.00200	0.01000	0.04000
1	INVERCARG220	5	TIWAI——220	0.00200	0.01000	0.04000
1	INVERCARG220	2	ROXBURGH-220	0.01000	0.11000	0.17000
2	ROXBURGH-220	17	TWIZEL——220	0.01600	0.14000	0.24000
2	ROXBURGH-220	17	TWIZEL——220	0.01600	0.14000	0.24000
2	ROXBURGH-220	12	LIVINGSTN220	0.03000	0.12000	0.18000
7	BENMORE—220	17	TWIZEL——220	0.00400	0.03000	0.07000
12	LIVINGSTN220	9	AVIEMORE-220	0.00700	0.03000	0.05000
9	AVIEMORE-220	7	BENMORE—220	0.00400	0.05000	0.02000
9	AVIEMORE-220	7	BENMORE—220	0.00400	0.05000	0.02000
12	LIVINGSTN220	13	ISLINGTON220	0.03000	0.18000	0.35000
17	TWIZEL——220	16	TEKAPO——220	0.00200	0.01000	0.02000
16	TEKAPO——220	13	ISLINGTON220	0.02000	0.13000	0.35000
17	TWIZEL——220	14	BROMLEY—220	0.02000	0.14000	0.45000
14	BROMLEY—220	13	ISLINGTON220	0.00200	0.01000	0.05000
17	TWIZEL——220	13	ISLINGTON220	0.02000	0.14000	0.45000

TRANSFORMER DATA

BUS	NAME	BUS	NAME	RESISTANCE	REACTANCE	TAP	CODE
3	MANAPOURI220	4	MANAPOURI014	0.00060	0.01600	1.000	0
2	ROXBURGH-220	6	ROXBURGH-011	0.00200	0.04000	1.000	0
17	TWIZEL——220	11	OHAU-SYSTEM	0.00400	0.03200	1.000	0
9	AVIEMORE-220	10	AVIEMORE-011	0.00150	0.04500	1.000	0
7	BENMORE—220	8	BENMORE—016	0.00120	0.03200	1.000	0
16	TEKAPO——220	15	TEKAPO——011	0.00300	0.05600	1.000	0

SOLUTION CONVERGED IN 5 P-D AND 5 Q-V ITERATIONS

LOAD		GENERATION		AC LOSSES		MISMATCH		SHUNTS
MW	MVAR	MW	MVAR	MW	MVAR	MW	MVAR	MVAR
2020.00	916.00	2113.71	1420.67	93.92	504.69	-0.21	-0.02	0.00

POWER TRANSFERS

BUS DATA

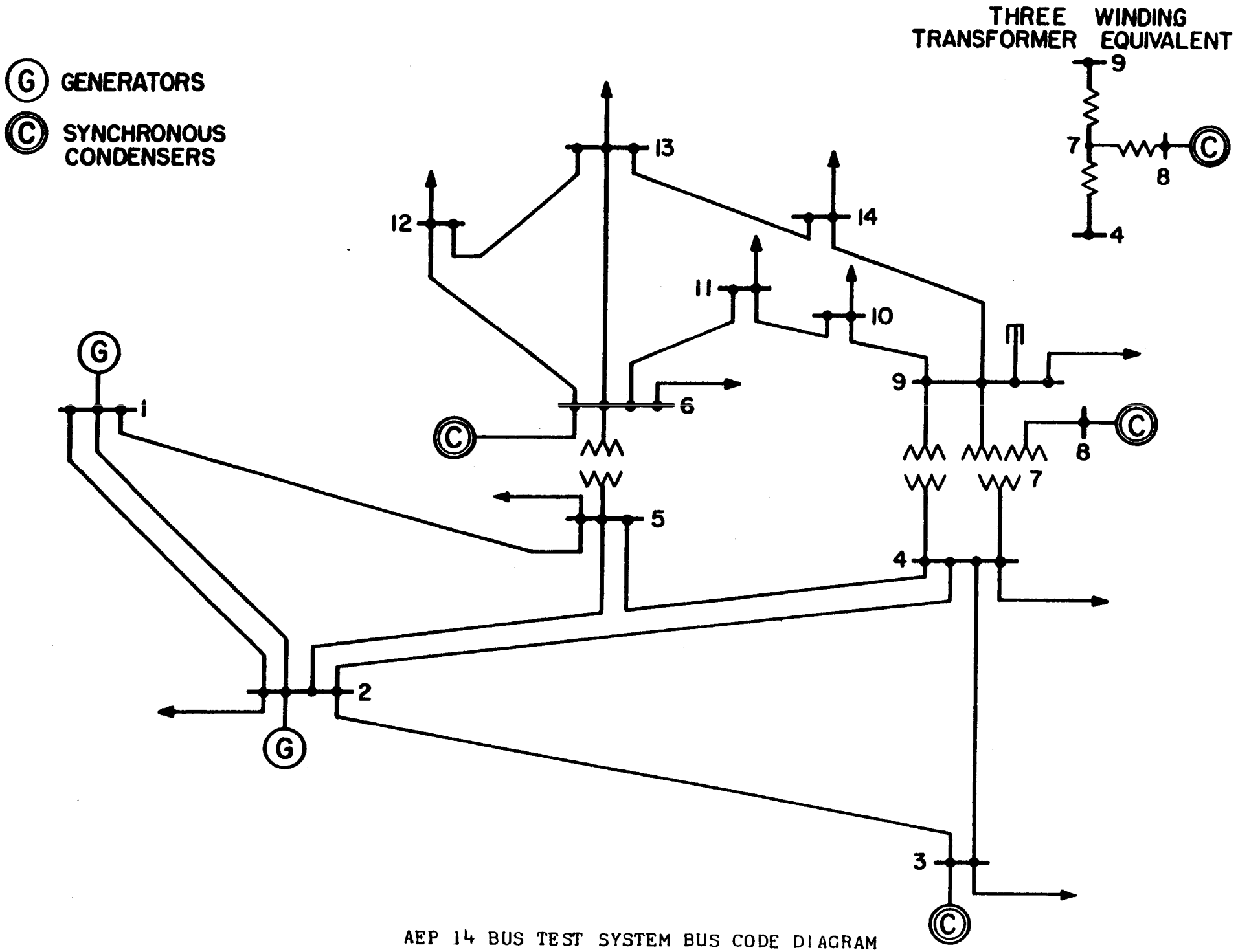
BUS	NAME	VOLTS	ANGLE	GENERATION MW	GENERATION MVAR	LOAD MW	LOAD MVAR	SHUNT MVAR
1	INVERCARG220	0.936	-12.26	0.00	0.00	200.00	51.00	0.00
2	ROXBURGH-220	0.982	-16.02	0.00	0.00	150.00	60.00	0.00
3	MANAPOURI220	1.002	-2.84	0.00	0.00	0.00	0.00	0.00
4	MANAPOURI014	1.045	3.12	690.00	288.73	0.00	0.00	0.00
5	TIVAI----220	0.931	-12.53	0.00	0.00	420.00	185.00	0.00
6	ROXBURGH-011	1.050	0.000	723.71	242.37	0.00	0.00	0.00
7	BENMORE---220	0.993	-36.85	0.00	0.00	500.00	200.00	0.00
8	BENMORE---016	1.060	-37.00	0.00	223.40	0.00	0.00	0.00
9	AVIEMORE-220	0.996	-34.28	0.00	0.00	0.00	0.00	0.00
10	AVIEMORE-011	1.045	-29.41	200.00	115.46	0.00	0.00	0.00
11	OHAU-SYSTEM	1.050	-25.43	350.00	113.38	0.00	0.00	0.00

BUS	NAME	MW	MVAR
3	MANAPOURI220	-174.88	-40.45
3	MANAPOURI220	-174.88	-40.45
5	TIVAI----220	49.34	39.65
5	TIVAI----220	49.34	39.65
2	ROXBURGH-220	51.09	-49.40
MISMATCH		-0.014	-0.004
1	INVERCARG220	-50.59	39.24
17	TWIZEL----220	184.16	-25.51
17	TWIZEL----220	184.16	-25.51
12	LIVINGSTN220	245.35	-17.18
6	ROXBURGH-011	-713.14	-31.03
MISMATCH		0.076	-0.009
1	INVERCARG220	179.54	49.24
1	INVERCARG220	179.54	49.24
5	TIVAI----220	163.87	54.14
5	TIVAI----220	163.87	54.14
4	MANAPOURI014	-686.91	-206.77
MISMATCH		0.088	-0.003
3	MANAPOURI220	689.98	288.73
MISMATCH		0.020	0.000
3	MANAPOURI220	-160.72	-49.83
3	MANAPOURI220	-160.72	-49.83
1	INVERCARG220	-49.24	-42.66
1	INVERCARG220	-49.24	-42.66
MISMATCH		-0.067	-0.016
2	ROXBURGH-220	723.71	242.37
MISMATCH		0.000	0.000
17	TWIZEL----220	-323.19	6.63
9	AVIEMORE-220	-88.64	1.28
9	AVIEMORE-220	-88.64	1.28
8	BENMORE---016	0.53	-209.19
MISMATCH		-0.061	-0.005
7	BENMORE---220	0.01	223.40
MISMATCH		-0.006	0.000
12	LIVINGSTN220	21.37	92.02
7	BENMORE---220	88.96	0.73
7	BENMORE---220	88.96	0.73
10	AVIEMORE-011	-199.26	-93.49
MISMATCH		-0.023	-0.000
9	AVIEMORE-220	199.99	115.46
MISMATCH		0.007	0.000
17	TWIZEL----220	350.00	113.38
MISMATCH		-0.004	0.000

12	LIVINGSTN220	0.966	-34.27	0.00	0.00	150.00	60.00	0.00
13	ISLINGTON220	1.000	-45.17	0.00	437.32	500.00	300.00	0.00
14	BROMLEY---220	0.994	-44.73	0.00	0.00	100.00	60.00	0.00
15	TEKAPO----011	1.008	-26.72	150.00	0.00	0.00	0.00	0.00
16	TEKAPO----220	1.007	-31.47	0.00	0.00	0.00	0.00	0.00
17	TWIZEL----220	1.007	-31.27	0.00	0.00	0.00	0.00	0.00

2	ROXBURGH-220	-226.60	75.10
9	AVIEMORE-220	-20.71	-94.00
13	ISLINGTON220	97.39	-41.11
MISMATCH		-0.082	0.006
12	LIVINGSTN220	-94.14	26.75
16	TEKAPO----220	-176.86	26.13
14	BROMLEY---220	-61.68	67.19
17	TWIZEL----220	-167.23	17.24
MISMATCH		-0.085	0.000
17	TWIZEL----220	-161.84	11.30
13	ISLINGTON220	61.85	-71.30
MISMATCH		-0.009	0.002
16	TEKAPO----220	149.98	0.00
MISMATCH		0.017	-0.000
17	TWIZEL----220	-34.17	5.86
13	ISLINGTON220	183.50	-18.25
15	TEKAPO----011	-149.32	12.39
MISMATCH		-0.007	0.001
2	ROXBURGH-220	-178.50	51.27
2	ROXBURGH-220	-178.50	51.27
7	BENMORE---220	327.44	18.21
16	TEKAPO----220	34.19	-7.77
14	BROMLEY---220	167.37	-17.69
13	ISLINGTON220	173.14	-21.21
11	OHAU-SYSTEM	-345.09	-74.09
MISMATCH		-0.052	0.010

THE MAXIMUM MISMATCH IS 0.0881 MVA ON BUS 3 (MANAPOURI220)
THE SLACK BUS GENERATION IS 723.709 MW 242.372 MVAR



AEP 14 BUS TEST SYSTEM BUS CODE DIAGRAM

```
 08/19/93 UW ARCHIVE           100.0  1962 W IEEE 14 Bus Test Case
BUS DATA FOLLOWS                                  14 ITEMS
   1 Bus 1      HV  1  1  3 1.060    0.0      0.0      0.0    232.4   -16.9      0.0 1.060      0.0      0.0  0.0      0.0        0
   2 Bus 2      HV  1  1  2 1.045   -4.98     21.7     12.7     40.0    42.4      0.0 1.045     50.0    -40.0  0.0      0.0        0
   3 Bus 3      HV  1  1  2 1.010  -12.72     94.2     19.0      0.0    23.4      0.0 1.010     40.0      0.0  0.0      0.0        0
   4 Bus 4      HV  1  1  0 1.019  -10.33     47.8     -3.9      0.0     0.0      0.0 0.0        0.0      0.0  0.0      0.0        0
   5 Bus 5      HV  1  1  0 1.020   -8.78      7.6      1.6      0.0     0.0      0.0 0.0        0.0      0.0  0.0      0.0        0
   6 Bus 6      LV  1  1  2 1.070  -14.22     11.2      7.5      0.0    12.2      0.0 1.070     24.0     -6.0  0.0      0.0        0
   7 Bus 7      ZV  1  1  0 1.062  -13.37      0.0      0.0      0.0     0.0      0.0 0.0        0.0      0.0  0.0      0.0        0
   8 Bus 8      TV  1  1  2 1.090  -13.36      0.0      0.0      0.0    17.4      0.0 1.090     24.0     -6.0  0.0      0.0        0
   9 Bus 9      LV  1  1  0 1.056  -14.94     29.5     16.6      0.0     0.0      0.0 0.0        0.0      0.0  0.0     0.19        0
  10 Bus 10     LV  1  1  0 1.051  -15.10      9.0      5.8      0.0     0.0      0.0 0.0        0.0      0.0  0.0      0.0        0
  11 Bus 11     LV  1  1  0 1.057  -14.79      3.5      1.8      0.0     0.0      0.0 0.0        0.0      0.0  0.0      0.0        0
  12 Bus 12     LV  1  1  0 1.055  -15.07      6.1      1.6      0.0     0.0      0.0 0.0        0.0      0.0  0.0      0.0        0
  13 Bus 13     LV  1  1  0 1.050  -15.16     13.5      5.8      0.0     0.0      0.0 0.0        0.0      0.0  0.0      0.0        0
  14 Bus 14     LV  1  1  0 1.036  -16.04     14.9      5.0      0.0     0.0      0.0 0.0        0.0      0.0  0.0      0.0        0
-999
BRANCH DATA FOLLOWS                               20 ITEMS
   1    2  1  1 1 0  0.01938   0.05917   0.0528   0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
   1    5  1  1 1 0  0.05403   0.22304   0.0492   0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
   2    3  1  1 1 0  0.04699   0.19797   0.0438   0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
   2    4  1  1 1 0  0.05811   0.17632   0.0340   0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
   2    5  1  1 1 0  0.05695   0.17388   0.0346   0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
   3    4  1  1 1 0  0.06701   0.17103   0.0128   0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
   4    5  1  1 1 0  0.01335   0.04211   0.0      0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
   4    7  1  1 1 0  0.0       0.20912   0.0      0   0   0   0 0  0.978   0.0 0.0   0.0     0.0   0.0   0.0
   4    9  1  1 1 0  0.0       0.55618   0.0      0   0   0   0 0  0.969   0.0 0.0   0.0     0.0   0.0   0.0
   5    6  1  1 1 0  0.0       0.25202   0.0      0   0   0   0 0  0.932   0.0 0.0   0.0     0.0   0.0   0.0
   6   11  1  1 1 0  0.09498   0.19890   0.0      0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
   6   12  1  1 1 0  0.12291   0.25581   0.0      0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
   6   13  1  1 1 0  0.06615   0.13027   0.0      0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
   7    8  1  1 1 0  0.0       0.17615   0.0      0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
   7    9  1  1 1 0  0.0       0.11001   0.0      0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
   9   10  1  1 1 0  0.03181   0.08450   0.0      0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
   9   14  1  1 1 0  0.12711   0.27038   0.0      0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
  10   11  1  1 1 0  0.08205   0.19207   0.0      0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
  12   13  1  1 1 0  0.22092   0.19988   0.0      0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
  13   14  1  1 1 0  0.17093   0.34802   0.0      0   0   0   0 0  0.0     0.0 0.0   0.0     0.0   0.0   0.0
-999
LOSS ZONES FOLLOWS                        1 ITEMS
  1 IEEE 14 BUS
-99
INTERCHANGE DATA FOLLOWS                      1 ITEMS
 1    2 Bus 2      HV     0.0  999.99  IEEE14  IEEE 14 Bus Test Case
-9
TIE LINES FOLLOWS                         0 ITEMS
-999
END OF DATA
```

Partial Description of the IEEE Common Data Format for the Exchange of Solved Load Flow Data

The complete description can be found in the paper "Common Data Format for the Exchange of Solved Load Flow Data", Working Group on a Common Format for the Exchange of Solved Load Flow Data, _IEEE Transactions on Power Apparatus and Systems_, Vol. PAS-92, No. 6, November/December 1973, pp. 1916-1925.

The data file has lines of up to 128 characters. The lines are grouped into sections with section headers. Data items are entered in specific columns. No blank items are allowed, enter zeros instead. Floating point items should have explicit decimal point. No implicit decimal points are used.

Data type codes: A - Alphanumeric (no special characters)
I - Integer
F - Floating point
* - Mandatory item

Title Data

First card in file.

Columns 2- 9 Date, in format DD/MM/YY with leading zeros. If no date provided, use 0b/0b/0b where b is blank.

Columns 11-30 Originator's name (A)

Columns 32-37 MVA Base (F*)

Columns 39-42 Year (I)

Column 44 Season (S - Summer, W - Winter)

Column 46-73 Case identification (A)

Bus Data *

Section start card *:

Columns 1-16 BUS DATA FOLLOWS (not clear that any more than BUS in 1-3 is significant) *

Columns ?- ? NNNNN ITEMS (column not clear, I would not count on this)

Bus data cards *:

Columns 1- 4 Bus number (I) *
Columns 7-17 Name (A) (left justify) *
Columns 19-20 Load flow area number (I) Don't use zero! *
Columns 21-23 Loss zone number (I)
Columns 25-26 Type (I) *
0 - Unregulated (load, PQ)
1 - Hold MVAR generation within voltage limits, (PQ)
2 - Hold voltage within VAR limits (gen, PV)

3 - Hold voltage and angle (swing, V-Theta) (must always
have one)
Columns 28-33 Final voltage, p.u. (F) *
Columns 34-40 Final angle, degrees (F) *
Columns 41-49 Load MW (F) *
Columns 50-59 Load MVAR (F) *
Columns 60-67 Generation MW (F) *
Columns 68-75 Generation MVAR (F) *
Columns 77-83 Base KV (F)
Columns 85-90 Desired volts (pu) (F) (This is desired remote voltage if
this bus is controlling another bus.
Columns 91-98 Maximum MVAR or voltage limit (F)
Columns 99-106 Minimum MVAR or voltage limit (F)
Columns 107-114 Shunt conductance G (per unit) (F) *
Columns 115-122 Shunt susceptance B (per unit) (F) *
Columns 124-127 Remote controlled bus number

Section end card:

Columns 1- 4 -999

Branch Data *
==========

Section start card *:

Columns 1-16 BRANCH DATA FOLLOWS (not clear that any more than BRANCH is significant) *

Columns 40?- ? NNNNN ITEMS (column not clear, I would not count on this)

Branch data cards *:

Columns 1- 4 Tap bus number (I) *
For transformers or phase shifters, the side of the model
the non-unity tap is on
Columns 6- 9 Z bus number (I) *
For transformers and phase shifters, the side of the model
the device impedance is on.
Columns 11-12 Load flow area (I)
Columns 13-14 Loss zone (I)
Column 17 Circuit (I) * (Use 1 for single lines)
Column 19 Type (I) *
0 - Transmission line
1 - Fixed tap
2 - Variable tap for voltage control (TCUL, LTC)
3 - Variable tap (turns ratio) for MVAR control
4 - Variable phase angle for MW control (phase shifter)
Columns 20-29 Branch resistance R, per unit (F) *
Columns 30-40 Branch reactance X, per unit (F) * No zero impedance lines
Columns 41-50 Line charging B, per unit (F) * (total line charging, +B)

```
Columns 51-55   Line MVA rating No 1 (I) Left justify!
Columns 57-61   Line MVA rating No 2 (I) Left justify!
Columns 63-67   Line MVA rating No 3 (I) Left justify!
Columns 69-72   Control bus number
Column  74      Side (I)
                 0 - Controlled bus is one of the terminals
                 1 - Controlled bus is near the tap side
                 2 - Controlled bus is near the impedance side (Z bus)
Columns 77-82   Transformer final turns ratio (F)
Columns 84-90   Transformer (phase shifter) final angle (F)
Columns 91-97   Minimum tap or phase shift (F)
Columns 98-104  Maximum tap or phase shift (F)
Columns 106-111 Step size (F)
Columns 113-119 Minimum voltage, MVAR or MW limit (F)
Columns 120-126 Maximum voltage, MVAR or MW limit (F)

Section end card:
-----------------

Columns  1- 4   -999

Loss Zone Data
==============

Section start card
------------------

Columns  1-16   LOSS ZONES FOLLOWS (not clear that any more than LOSS
                is significant)

Columns 40?- ?  NNNNN ITEMS (column not clear, I would not count on
this)

Loss Zone Cards:
----------------

Columns  1- 3   Loss zone number  (I)
Columns  5-16   Loss zone name (A)

Section end card:
-----------------

Columns  1- 3   -99

Interchange Data *
==================

Section start card
------------------

Columns  1-16   INTERCHANGE DATA FOLLOWS (not clear that any more than
                first word is significant).
Columns 40?- ?  NNNNN ITEMS (column not clear, I would not count on
this)

Interchange Data Cards *:
-------------------------

Columns  1- 2   Area number (I) no zeros! *
Columns  4- 7   Interchange slack bus number (I) *
Columns  9-20   Alternate swing bus name (A)
```

Columns 21-28 Area interchange export, MW (F) (+ = out) *
Columns 30-35 Area interchange tolerance, MW (F) *
Columns 38-43 Area code (abbreviated name) (A) *
Columns 46-75 Area name (A)

Section end card:

Columns 1- 2 -9

Tie Line Data
==========

Section start card

Columns 1-16 TIE LINES FOLLOW (not clear that any more than·TIE is significant)

Columns 40?- ? NNNNN ITEMS (column not clear, I would not count on this)

Tie Line Cards:

Columns 1- 4 Metered bus number (I)
Columns 7-8 Metered area number (I)
Columns 11-14 Non-metered bus number (I)
Columns 17-18 Non-metered area number (I)
Column 21 Circuit number

Section end card:

Columns 1- 3 -999