Brazil - Argentina Interconnection I		Document Number 1JNL100030-370	No of Pages 16 No of Attached Pages
Prepared Arne Rosén, 1999-09-20		Title Validation of converter model developed for the stability program PSS/E	Reg./Class no. GA-FG-746
Approved Magnus Lalander, 1999-09-28	Resp Dept LST		

Summary

ABB Power Systems AB have developed a digital dynamic model of an HVDC converter for use in the PSS/E stability program. By setting the proper parameter values this model may represent a conventional HVDC converter or a capacitor commutated (CCC) converter. The latter type will be used in the Argentina-Brazil HVDC Interconnection (Garabi) presently being designed. The model has been used in stability studies performed for that project.

The purpose of this investigation has been to validate the performance of the digital PSS/E model. To that effect different fault cases have been run in EMTDC as well as in PSS/E and the results have been compared.

EMTDC is a program that has already been validated against analog simulator results as well as actual field tests. The EMTDC model used in this investigation has been derived from a model used in the Dynamic Performance Verification (DPV) for the Garabi project. However, in the model used in this validation study the ac networks have been simplified, as the purpose of the investigation has been to compare the dynamic behavior of the converter models and not to tune the dynamics of the interconnected networks.

The two models display similar dynamic behavior. Post fault recovery times are however longer in the PSS/E than in the EMTDC model. This is because special control functions have been developed in EMTDC for the DPV. These control functions are not included in the PSS/E model as they were not available when the PSS/E model was created. Consequently the PSS/E model produces more conservative results from a stability point of view. A study using the PSS/E model and displaying satisfactory system stability may therefore be acceptable as it can be assumed that plant performance will be better in reality.

Hence it can be concluded that the PSS/E converter model is valid and ready to use in studies performed in PSS/E.

Rev ind	Revision text	Prepared	Approved

Table of Contents

1 PSS/E system

A description of the PSS/E model is given in Ref.4. Some specific data related to the model used in the validation are given below.

1.1 Network data

1.1.1 Single line diagram

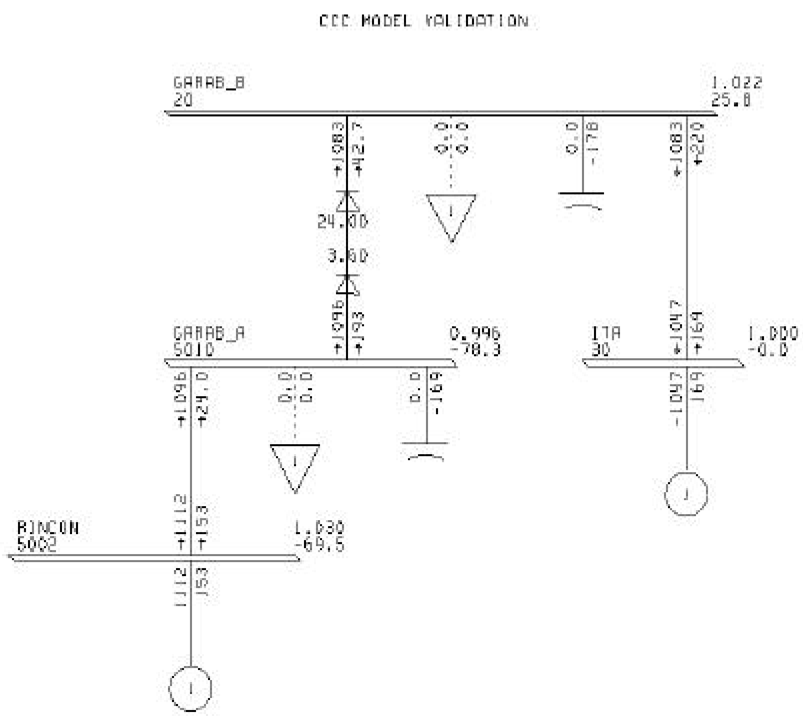

Figure 1 Basic powerflow

The network constitutes a very simple model of the Argentina-Brazil HVDC Interconnection (Garabi) and comprises the following components:

- An infinite voltage source with series impedance representing the Argentinean ac network. The impedance has been chosen so as to model the minimum short circuit capacity at the Rincon 500 kV ac bus.
- A model of the ac line interconnecting the Rincon bus with the 50 Hz converter bus at Garabi (GARAB_A).
- A model of the HVDC interconnection between the 50 Hz converter bus and the 60 Hz converter bus at Garabi. The model comprises one back-to-back converter block rated 1100 MW.
- A model of the ac line interconnecting the 60 Hz converter bus at Garabi (GARAB_B) with the Itá 525 kV ac bus in Brazil.

- An infinite voltage source with series impedance representing the Brazilian network. The impedance has been chosen so as to model the minimum short circuit capacity at the Itá bus.

1.1.2 Base voltages

Argentina	Brazil
500 kV, 50 Hz	525 kV, 60 Hz

1.1.3 Base Power

100 MVA (except for machines which are based on 1000 MVA)

1.1.4 Base impedances

Argentina	Brazil
500^2/100=2500 Ω	525^2/100=2756.25 Ω

1.1.5 Source data

	Argentina	Brazil
Source voltage	1.030 pu	1.000 pu
Source impedance	0.01743+j0.19924	0.01265+j0.14450

pu on a 1000 MVA base.

The source voltages are derived by the PSS/E powerflow calculation illustrated on the above single line diagram, Figure 1.

1.1.6 AC line data

1.1.6.1 Rincon-Garabi

Length	131.7 km
Resistance	3.37 Ω
Reactance	36.21 Ω
Susceptance	5.400 E-04 mho
Shunt reactor(s)	92.5 MVAr at the Garabi end of the line.

1.1.6.2 Garabi-Itá

Length	360 km
Resistance	8.49 Ω
Reactance	114.85 Ω
Susceptance	18.05 E-04 mho
Shunt reactor(s)	250 MVAr at Garabi and 150 MVAr at Itá.

1.2 Converter data

1.2.1 Main circuit data

AC Filters: Argentina 170 MVAr Brazil	170 MVAr
Converter:	one back-to-back converter block consisting of four series connected six pulse bridges constituting the rectifier and another four bridges in series constituting the inverter
Nominal direct voltage:	280 kV
Nominal direct current:	3930 A
Rated power on dc side:	1100 MW
Smoothing reactor	200 mH

Further data are given in Ref. 2.

1.2.2 Control functions

The converter model is equipped with basic current control systems and a superior master control system.

The master control system includes basic power control, damping control and frequency control.

The basic current control system contains functions such as delta alpha as well as alpha maximum and minimum limitations and Voltage Dependent Current Order Limits (VDCOL). A Rectifier Alpha Minimum Limit (RAML) function is also included.

The output from the master control system is a current order and the output from the current control system is an alpha order, which is used by the converter algorithms in the program. Firing pulses are not generated, as the model is a phasor model and not a commutating, instantaneous value model.

The validation study has been performed in current control mode. The damping and frequency control modes have not been employed.

A more detailed description of the control principles applicable to ccc Converters is given in Reference 3.

1.2.3 Time step

A time step (parameter DELT) of 100 µs has been used in the dynamic runs.

1.3 Powerflow calculation

The powerflow illustrated on the single line diagram Figure 1has been calculated by PSS/E, release 26.2 whose standard model library includes a ccc converter model. Before release 26.2 was available it was necessary to use the PSS/E standard two terminal HVDC line model in the powerflow program and then, by using a Matlab program developed by ABB Power Systems AB, calculate the ccc parameter values that would give the same interface to the interconnected ac networks in terms of active and reactive power and bus voltages with a ccc converter. These parameter values would then have to be entered in the dynamic model in connection with initialization of the dynamic model (activity STRT). This procedure has become obsolete with release 26.2 of PSS/E, and the method will not be described further.

2 EMTDC system

The EMTDC system is derived from an EMTDC model used for a Dynamic Performance Study (DPV) of the “Brazil-Argentina Interconnection 1” project.

However, the rectifier and inverter ac networks have been reduced to simple equvivalents comprising an infinite voltage source with series impedance on each side. The impedance values have been chosen to give the same short circiut capacity on the Rincon and Itá buses as in the PSS/E model. The ac lines from Rincon to Garabi and Garabi to Itá are represented in full (same as the DPV setup).

The 1100 MW interconnection is represented by two parallel 550 MW btb blocks.

Further information about the DPV setup is given in Reference 1.

3 Evaluation of results

The following cases have been studied

- 10 % current order step
- Solid three phase, 80 ms fault at rectifier ac bus
- Solid three phase, 80 ms fault at inverter ac bus.

The results are discussed below.

3.1 Current order step

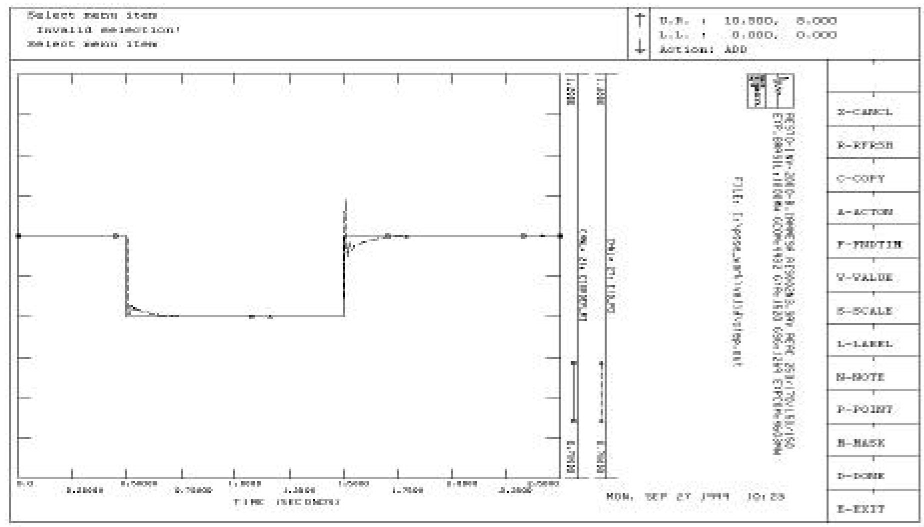

Figure 2 P SS/E current order and response for a 10 % current order step

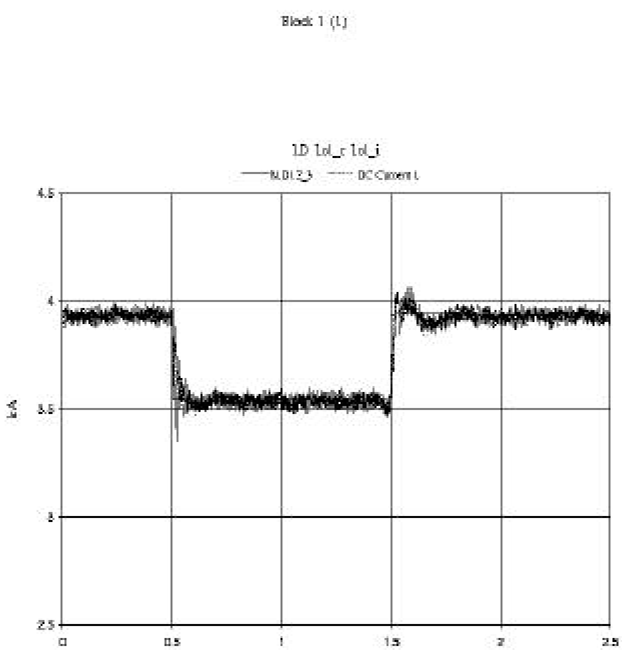

Figure 3 EMTDC current order and response for a 10 % current order step (block1)

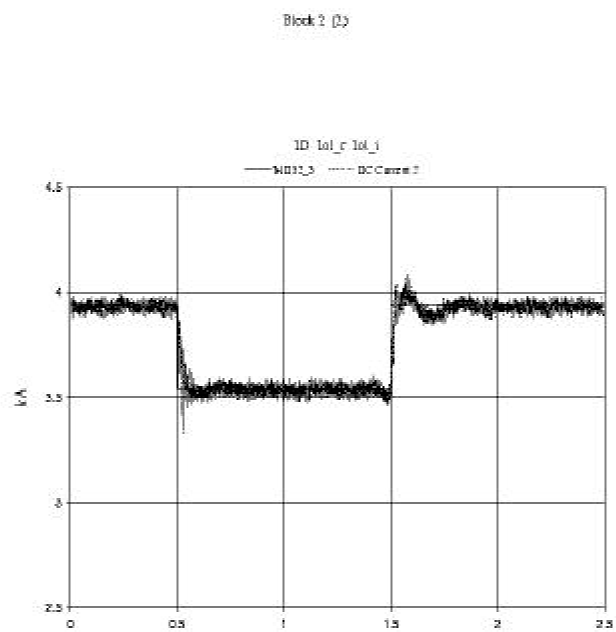

Figure 4 EMTDC current order and response for a 10 % current order step (block2)

3.1.1 Evaluation

The two models behave very similar. The EMTDC model is the most detailed model and is expected to reveal more details in terms of higher frequency components. For the purpose of studying angle stability the differences would be negligible.

3.2 Solid three phase fault at rectifier ac bus

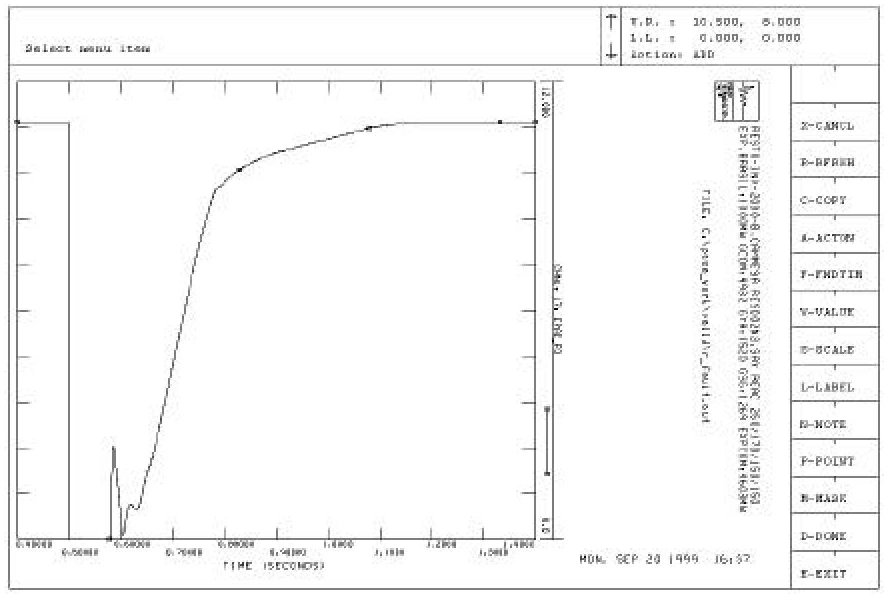

Figure 5 PSS/E power recovery from rectifier ac fault

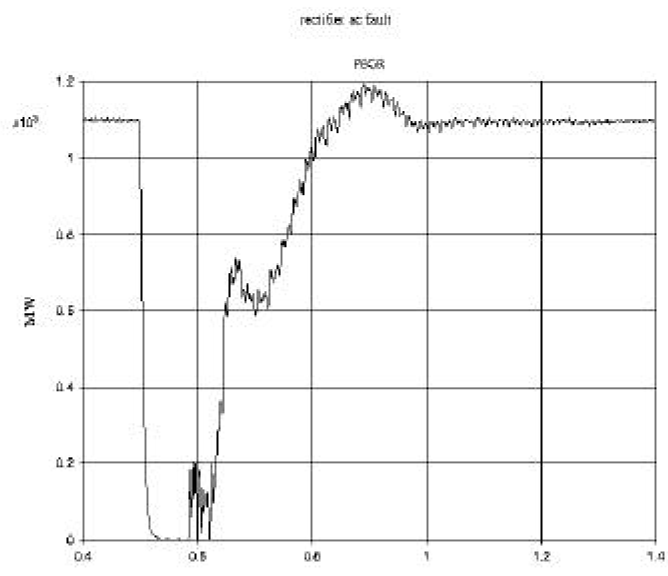

Figure 6 EMTDC power recovery from rectifier ac f ault

3.2.1 Evaluation

Both models recover well. The EMTDC model recovers significantly faster than the PSS/E model to 90 % of prefault power. The reason is that special boost functions for speeding up post fault recovery have been developed in the EMTDC controls during a Dynamic Performance Study. These control functions are not included in the PSS/E model.

Hence the PSS/E model deliver the most conservative results. Therefore, if a PSS/E study shows satisfactory system stability with the PSS/E model it would be safe to assume that the real system would exhibit even better performance from a stability point of view.

3.3 Solid three phase fault at inverter ac bus

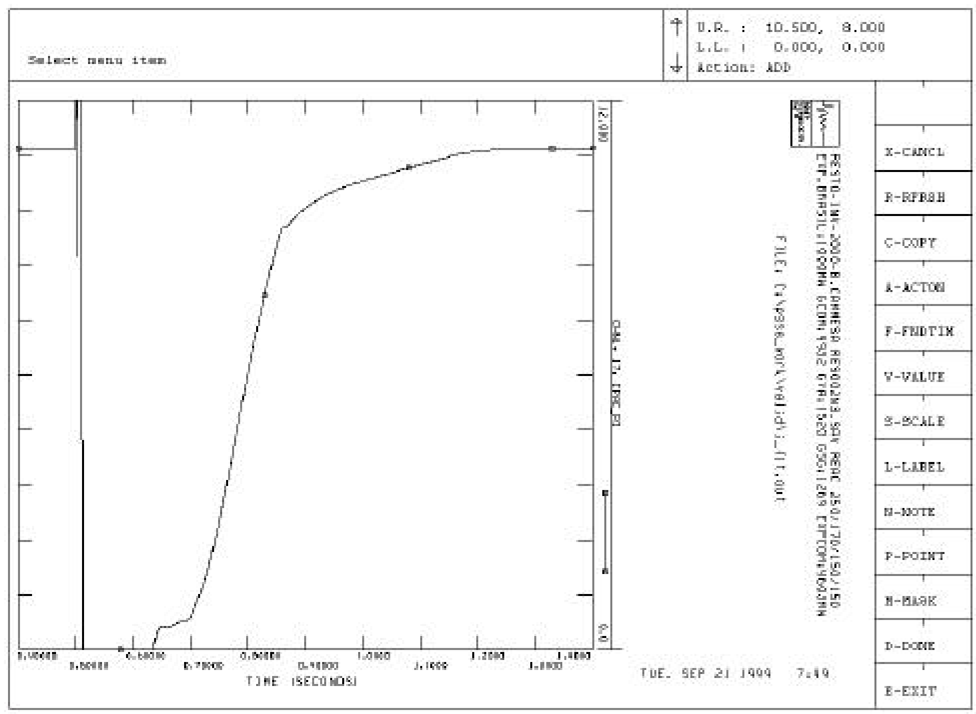

Figure 7 PSS/E recovery from inverter ac fault

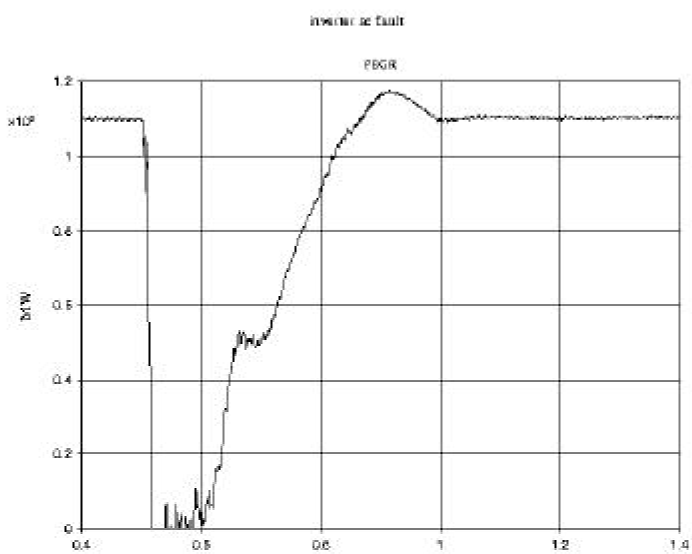

Figure 8 EMTDC recovery from inverter ac fault

3.3.1 Evaluation

Like in the case of a rectifier ac fault the EMTDC model recovers faster than the PSS/E model. The reasons are even in this case the special booster functions included in the EMTDC model.

4 Conclusions

The response to a current order step is very similar in the two models.

The EMTDC model recovers faster than the PSS/E model after clearing of a solid three-phase fault on a converter bus. This is due to the fact that special control functions are included in the EMTDC model but not in the PSS/E model. From a stability point of view the PSS/E model thus delivers the most conservative results.

The times to recovery of 90 % of prefault power are tabulated below for comparison. The times are measured from the instant of disconnecting an 80 ms fault until 90 % of prefault power has been restored. The active power is measured on the ac side of the rectifier.

Fault type	PSS/E recovery time	EMTDC recovery time
Rectifier fault	271 ms	214 ms
Inverter fault	351 ms	237 ms

5 References

1. 1JNL100030-046 Dynamic Performance Verification with the Incorporation of the Santo Angelo tap
2. 1JNL100029-389 DYNAMIC.HVDC MODEL IN PSS/E Program version 26.2
3. 1JNL100004-959 Capacitor Commutated HVDC, Control Principles

6 Appendices

6.1 PSS/E indata

The input data for the PSS/E model used in this investigation comprises the following data files.

- “val_int.raw” (PSS/E powerflow raw data file, see below)
- “val.dyr” (PSS/E dynamics raw data file, see below)
- “cfc_model_926.f” (Fortran file, actual source code for the converter model, saved in PowDoc as a separate document with identity 99LST0139Rev.00)
- “data_btb_926.f” (Fortran file, parameter values for the converter model, saved in PowDoc as a separate document with identitiy 99LST0146Rev.00)

6.1.1 val_int.raw

```
0,   100.00          / TUE, JUL 13 1999  15:59
RESTO-INV-2000-B.CAMMESA RES002N3.SAV REAC
250/170/150/150
EXP.BRASIL:1000MW GCOM:4932 GYA:1520 GSG:1269
EXPCOM:4603MW
   20,'GARAB_B ', 525.0000,1,     0.000,     0.000,
1,   1,1.02245,  25.7763,   1
   30,'ITA     ', 525.0000,3,     0.000,     0.000,
1,   1,1.00000,   0.0000,   1
 5002,'RINCON  ', 500.0000,3,     0.000,     0.000,
5,   6,1.03000, -69.4874,   1
 5010,'GARAB_A ', 500.0000,1,     0.000,     0.000,
5,   6,0.99576, -78.3478,   1
0  / END OF BUS DATA, BEGIN LOAD DATA
   20,'1 ',0,   1,   1,  1100.000,    51.700,
0.000,     0.000,     0.000,     0.000,   1
 5010,'1 ',0,   5,   6,  1112.000,   159.000,
0.000,     0.000,     0.000,     0.000,   1
0 / END OF LOAD DATA, BEGIN GENERATOR DATA
   30,'1 ', -1047.215,   168.928,  9999.000, -
9999.000,1.00000,    0,  1000.000,   0.01265,
0.14450,   0.00000,   0.00000,1.00000,1,  100.0,
9999.000, -9999.000,   1,1.0000
 5002,'1 ',  1111.921,   152.785,  9999.000, -
9999.000,1.03000,    0,  1000.000,   0.01743,
0.19924,   0.00000,   0.00000,1.00000,1,  100.0,
9999.000, -9999.000,   1,1.0000
0 / END OF GENERATOR DATA, BEGIN BRANCH DATA
   20,    30,'1 ',   0.00308,   0.04167,   4.97500,
0.00,    0.00,    0.00,,,  0.00000, -2.50000,  0.00000,
-1.50000,1,   0.00,   1,1.0000
 5002,  5010,'1 ',   0.00135,   0.01448,   1.35000,
1732.10, 1732.10, 1732.10,,,  0.00000,  0.00000,
0.00000, -0.92500,1,   0.00,   1,1.0000
0 / END OF BRANCH DATA, BEGIN TRANSFORMER ADJUSTMENT
DATA
0 / END OF TRANSFORMER ADJUSTMENT DATA, BEGIN AREA DATA
0 / END OF AREA DATA, BEGIN TWO-TERMINAL DC DATA
  1,2,    0.8000,   3930.00,    280.00,      0.00,
0.8000,   0.10000,'R',      0.00, 100,   0.30000
 5010, 4, 5.00, 0.00, 0.0001, 1.1180,
500.0,0.10360,0.98268,1.50000,0.51000,0.01313,    0,
0,    0,'1 ', 3.7267
   20, 4,24.00,24.00, 0.0001, 1.3660,
525.0,0.09866,1.03500,1.50000,0.51000,0.01250,    0,
0,    0,'1 ', 6.4504
0 / END OF TWO-TERMINAL DC DATA, BEGIN SWITCHED SHUNT
DATA
   20,0,1.00000,1.00000,    0,  170.00, 1, 170.00
 5010,0,1.00000,1.00000,    0,  170.00, 1, 170.00
```

```
0 / END OF SWITCHED SHUNT DATA, BEGIN IMPEDANCE
CORRECTION DATA
0 / END OF IMPEDANCE CORRECTION DATA, BEGIN MULTI-
TERMINAL DC DATA
0 / END OF MULTI-TERMINAL DC DATA, BEGIN MULTI-SECTION
LINE DATA
0 / END OF MULTI-SECTION LINE DATA, BEGIN ZONE DATA
0 / END OF ZONE DATA, BEGIN INTER-AREA TRANSFER DATA
0 / END OF INTER-AREA TRANSFER DATA, BEGIN OWNER DATA
0 / END OF OWNER DATA, BEGIN FACTS CONTROL DEVICE DATA
0 / END OF FACTS CONTROL DEVICE DATA
```

6.1.2 val.dyr

```
30, 'GENCLS', 1, 0.0, 0.0 /  Update 971105, 971119,
980421, 980515, 990226, 990520,990702
 5002, 'GENCLS', 1, 0.0, 0.0 /
  /1  'USRMDL'  0 'CBTBMD' 7 1
  /                        8 35 28 90
  /                       1 0 0 0 0 0 0 0
  /                        4.02
  /                        280.0  3.930
  /                        50.00  1.  60.0  1.0  1.03702
171.939
  /                        200
  /                        0.06 0.0 0.2000 0.072 0.0
0.3400
  /                        0.002 0.05 0.80 0.2 0.1 2.0
0.2
  /                        0.002 0.07 0.80 0.2 0.1 2.0
0.2
  /                        80.0 0.0005 60.0 0.0004
  /                        27.8341/
  /1  'USRMDL'  0 'CDCAB2' 7 1
  /                         8 35 28 90
  /                        1 0 0 0 0 0 0 0
  /                         4.37
  /                          280.0  3.930
  /                          50.00  1.  60.0  1.0
1.03702  171.939
  /                          200
  /                          0.06 0.0 0.2000 0.072 0.0
0.3400
  /                          0.005 0.06 0.80 0.2 0.1 2.0
0.3
  /                          0.005 0.055 0.80 0.2 0.1 2.0
0.3
  /                          80.0 0.0015 40.0 0.00056
 1 'USRMDL'  0 'CDCAB2' 7 1
                       10 44 30 100
                       1 0 0 0 0 0 0 0 3 2
                       4.02
                       280.0  3.930
                       50.00  0  60.0  0  0  0
                       0 0 0 0 0 0 0 0
                       200 0 0 0 0 0 0
                       0.005 0.06 0.80 0.2 0.1 2.0 0.3
                       0.005 0.055 0.80 0.2 0.1 2.0 0.3
                       80.0 0.0005 40.0 0.0004
                       0 0/CON element zero added July
2, 1999
/
```