

SAARC Workshop on Load/Power Flow Studies using PSS/E for Efficient National & Cross Border Interconnected Power Systems in South Asia

Agenda

Day-3

**Thimphu, Bhutan
18th to 20th July 2018**

Day-3 (20-July-2018)

Time	Description
0930-1130	Session-I “Introduction to Dynamic simulation” • Basic logic flow for dynamic simulation activities • Setting up a *.dyr case for dynamic simulation • Dynamics documentation • Defining channels for simulation output • Initializing a dynamics case
1130-1230	Session-II “Dynamic simulation activities” • Applying disturbance • Hands-on exercise on running a basic dynamic simulation

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Session I : Introduction to Dynamic Simulation

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Dynamic Simulation – Overview...(1)

Simulation of the power system response to disturbances.

Disturbances:

- branches and bus faults with or without protection failure (stuck breaker)
- opening of branches without fault
- trip of generators with or without faults
- trip of loads

Dynamic simulation requires the solution of nonlinear differential equations

PSS[®]E calculates the time response of the system by numerical integration of the system differential equations

Dynamic Simulation – Overview...(2)

Differential equations are embedded in the models of the generators, excitation systems, etc. and are expressed in block diagram form

Models are linked through the power system network, which is represented by algebraic equations

Non-linearities such as limits and saturation can be addressed accurately using detailed models

Dynamic Simulation – Network Solution

Network represented by a nodal admittance matrix (Y-bus)

$$\mathbf{Y} \mathbf{v} = \mathbf{i}(\mathbf{x}, \mathbf{v})$$

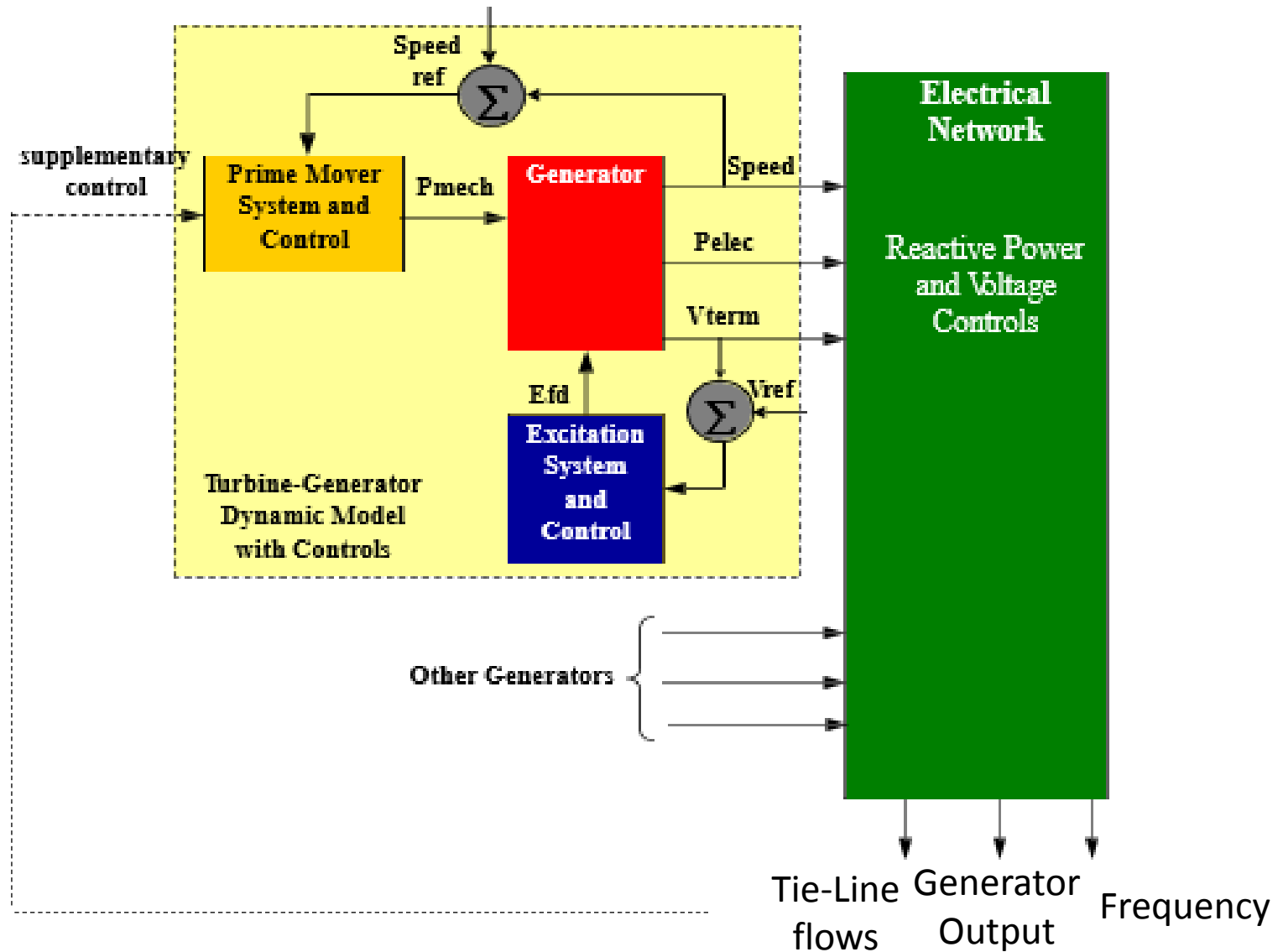
Unlike in EMTP, network dynamics are not represented in stability programs.
Network represented using positive sequence quantities

Numerical Integration Method :

- Uses Modified Euler method
- PSS/E integration method requires the integration step to be smaller than the smallest time constant

Programs like TSAT (DSA Tools) use Runge Kutta Method of integration (Faster, More robust)

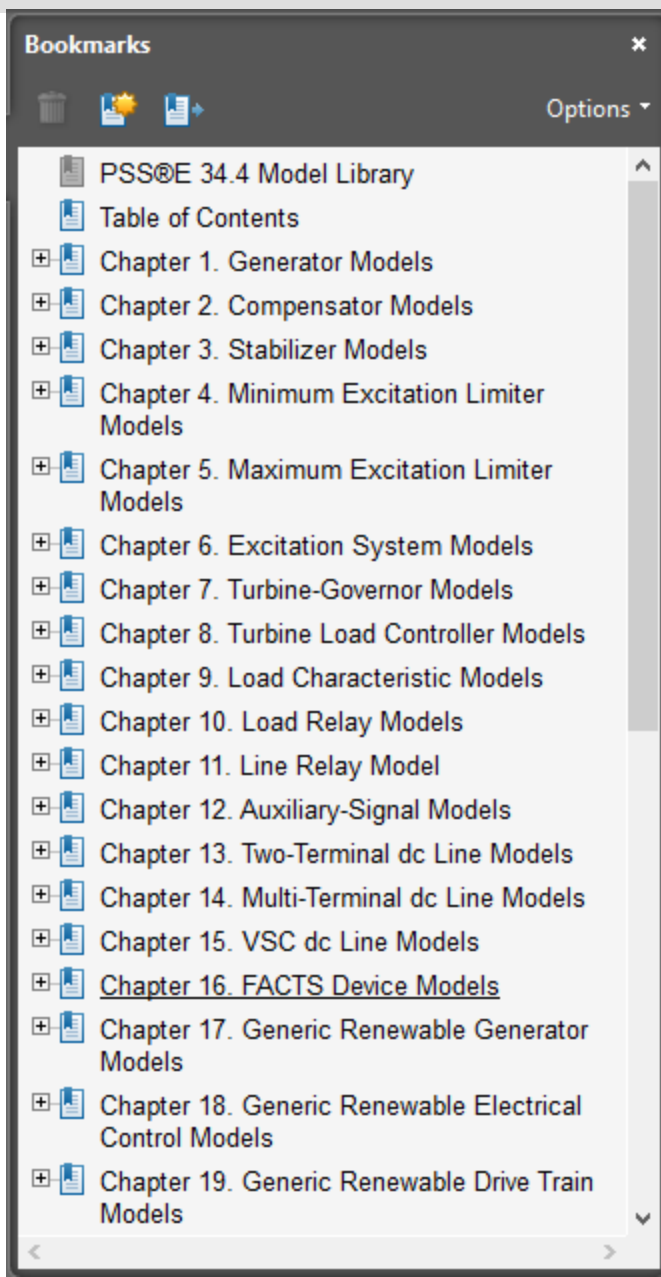
Dynamic Simulation – P-f and Q-V loops



Dynamic Simulation – Common file types

Files	Activities	
Raw Data	RAWD	.RAW
Saved Cases	SAVE CASE	.SAV .CNV
Response Files (Commands)	IDEV	.IDV
Dynamics Raw Data	DYRE	.DYR
Dynamics Cases	SNAP	.SNP
Dynamics Plot Files (channel output)	STRT (also ESTR,GSTR)	.OUT
Slider Diagram Files	One-line diagrams	.SLD
PYTHON	Command line input & program automation	.PY
Sequence Data	SAV	.SEQ

Documentation...Model Library



PSS® E 34.4 Model Library
April 2018

SIEMENS

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Siemens Power Technologies International
400 State Street, PO Box 1058
Schenectady, NY 12301-1058 USA
+1 518-395-5000
www.siemens.com/power-technologies

Documentation...Model Library...Examples(1)

1.21. GENSAL

Salient Pole Generator Model (Quadratic Saturation on d-Axis)

CONs	Value	Description
J		$T'_{do} (>0)$ (sec)
J+1		$T''_{do} (>0)$ (sec)
J+2		$T'''_{qo} (>0)$ (sec)
J+3		H, Inertia
J+4		D, Speed damping
J+5		X_d
J+6		X_q
J+7		X'_d
J+8		$X''_d = X''_q$
J+9		X_l
J+10		S(1.0)
J+11		S(1.2)

Note: X_d , X_q , X'_d , X''_d , X''_q , X_l , H, and D are in pu, machine MVA base.

X''_q must be equal to X''_d .

STATES	Description
K	E'_q
K+1	ψ'_{kd}
K+2	ψ''_q
K+3	Δ speed (pu)
K+4	Angle (radians)

IBUS, 'GENSAL', ID, CON(J) to CON(J+11) /

Documentation...Model Library...Examples(2)

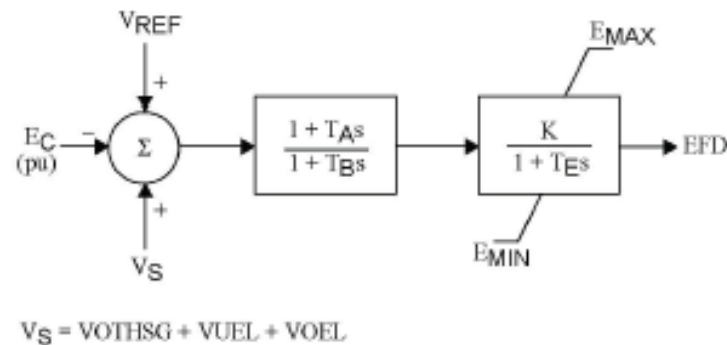
6.71. SEXS

Simplified Excitation System

CONs	Value	Description
J		T_A/T_B
J+1		$T_B (>0)$ (s)
J+2		K
J+3		T_E (s)
J+4		E_{MIN} (pu on EFD base)
J+5		E_{MAX} (pu on EFD base)

STATES	Description
K	First integrator
K+1	Second integrator

IBUS, 'SEXS', ID, CON(J) to CON(J+5) /



DYR file contents

savnw - Notepad							
File	Edit	Format	View	Help			
101	'GENROU'	1	6.5000	0.60000E-01	0.20000	0.50000E-01	
	4.0000		0.0000	1.8000	1.7500	0.60000	
	0.80000	0.30000	0.15000	0.90000E-01	0.38000	/	
101	'IEEEET1'	1	0.0000	400.00	0.40000E-01	7.3000	
	-7.3000	1.0000	0.80000	0.30000E-01	1.0000		
	0.0000	2.4700	0.35000E-01	4.5000	0.47000	/	
101	'TGOV1'	1	0.50000E-01	0.50000E-01	1.0500	0.30000	
	1.0000	1.0000	0.0000	/			
102	'GENROU'	1	6.5000	0.60000E-01	0.20000	0.50000E-01	
	4.0000	0.0000	1.8000	1.7500	0.60000		
	0.80000	0.30000	0.15000	0.90000E-01	0.38000	/	
102	'IEEEET1'	1	0.0000	400.00	0.40000E-01	7.3000	
	-7.3000	1.0000	0.80000	0.30000E-01	1.0000		
	0.0000	2.4700	0.35000E-01	4.5000	0.47000	/	
102	'TGOV1'	1	0.50000E-01	0.50000E-01	1.0500	0.30000	
	1.0000	1.0000	0.0000	/			

Dynamics Data – Spreadsheet View

Network data

Dynamics data ×

	Bus Number	Bus Name	Mbase (MVA)	In Service	Generator	In Service	Type	Exciter	In Service	Type	Turbine Governor	In Service	Type	
	101	NUC-A 21.600	1	900.00	☒	GENROU	☒	Stnd	IEEET1	☒	Stnd	TGOV1	☒	Stnd
	102	NUC-B 21.600	1	900.00	☒	GENROU	☒	Stnd	IEEET1	☒	Stnd	TGOV1	☒	Stnd
	206	URBGEN 18.000	1	1000.00	☒	GENROU	☒	Stnd	IEEET1	☒	Stnd	TGOV1	☒	Stnd
	211	HYDRO_G 20.000	1	725.00	☒	GENSAL	☒	Stnd	SCRX	☒	Stnd	HYGOV	☒	Stnd
	3011	MINE_G 13.800	1	1000.00	☒	GENROU	☒	Stnd	SEXS	☒	Stnd	None	☐	
	3018	CATDOG_G 13.800	1	130.00	☒	GENROU	☒	Stnd	SEXS	☒	Stnd	None	☐	

<

>

Machine

Renewable Machine

Induction Machine

2-Term DC

VSC DC

Multi-Term DC

FACTS

Switched Shunt

Load - Bus

Load - Owner

Load - Zone

Load - A

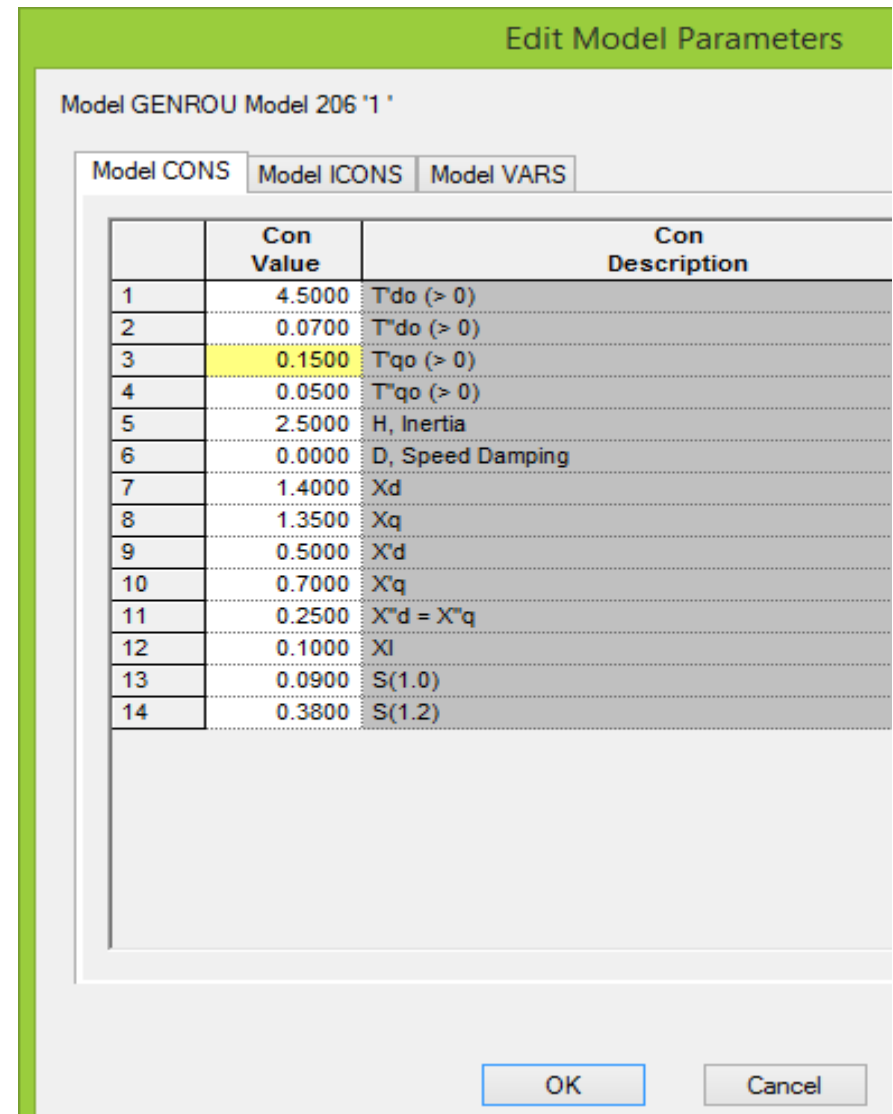
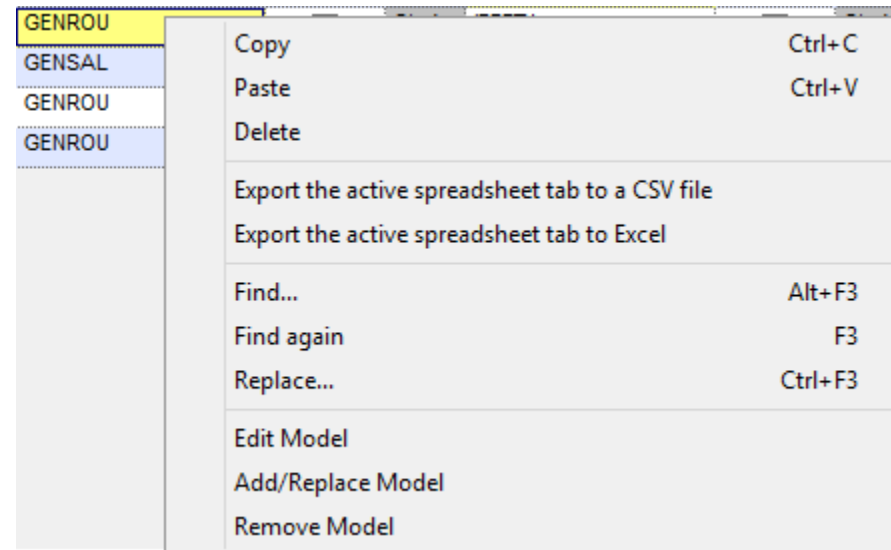
Device Models

Protection Models

Other Models

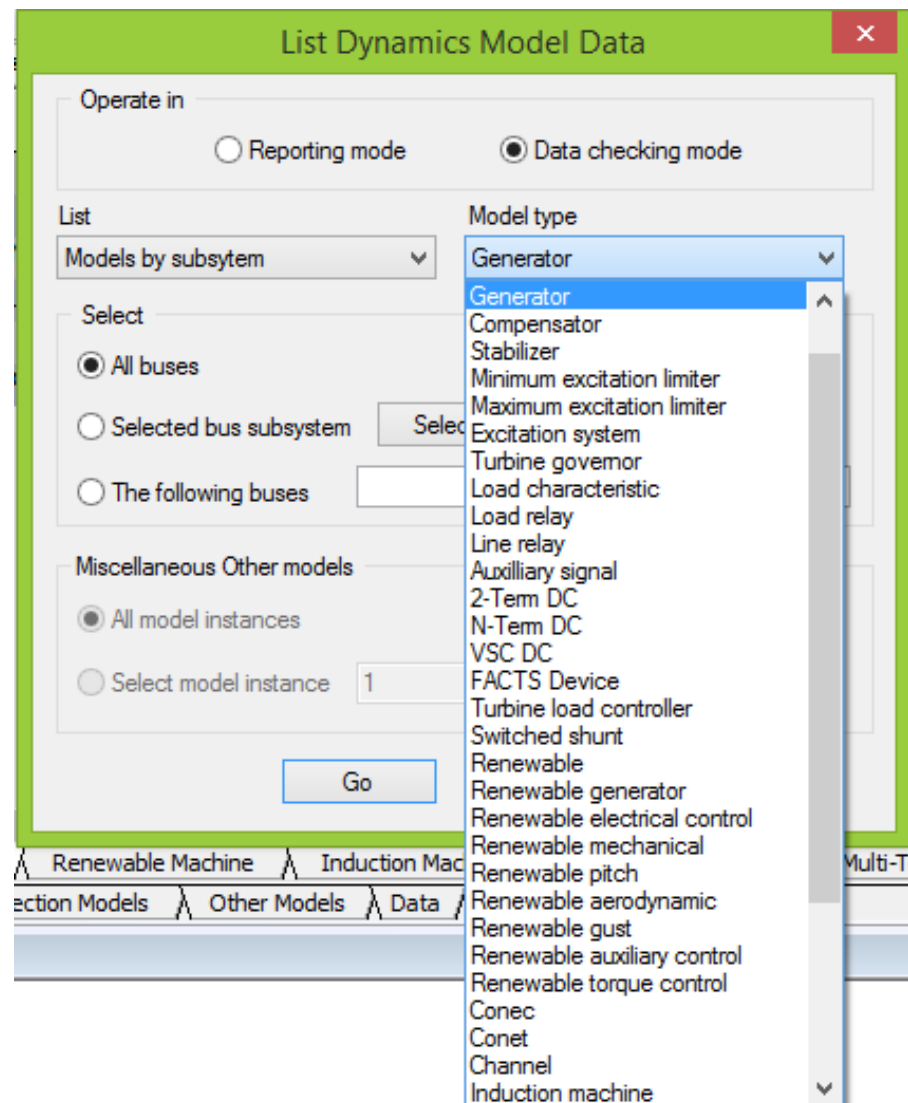
Data

Dynamics Data – Spreadsheet View...(2)



Data Checking...(1)

- To ensure model parameters are within acceptable limits
- Necessary for stable simulation model
- ***Dynamics -> Model List -> Models and Data (DOCU) -> Data checking mode***



Data Checking...(2)

```
1      PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS(R)E      SUN, JUL 08 2018  14:54
PSS(R)E PROGRAM APPLICATION GUIDE EXAMPLE
BASE CASE INCLUDING SEQUENCE DATA
```

PLANT MODELS

DATA CHECK FOR GENERATOR MODELS AT ALL BUSES

Model GENROU Bus 206 [URBGEN 18.000] Machine "1 " :
T'Q0 = .150000, outside of range $\geq .200000$ and ≤ 1.50000

C O N S S T A T E S
29-42 13-18

MBASE Z S O R C E X T R A N GENTAP
1000.0 0.01000+J 0.25000 0.00000+J 0.00000 1.00000

T'D0	T''D0	T'Q0	T''Q0	H	DAMP	XD	XQ	X'D	X'Q	X''D	XL
4.50	0.070	0.15	0.050	2.50	0.00	1.4000	1.3500	0.5000	0.7000	0.2500	0.1000

S(1.0) S(1.2)
0.0900 0.3800

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Session II : Dynamic Simulation Activities

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Logic Flow for Simulation...(1)

- Start with a solved PSS/E power flow case (RAW / SAV formats)
 - Ideally solution in 1-2 iterations
- Prepare power flow case for dynamic simulation:
 - Convert loads and generators
Power flow → Convert Loads and Generators
CONL and CONG
 - Optimally order network matrix
Power flow → Solution → Order Network...
ORDR
 - Factorize network admittance matrix (Y-bus matrix)
Power flow → Solution → Factorize admittance matrix
FACT
 - Solve converted case
Power flow → Solution → Solution for switching studies
TYSL

Logic Flow for Simulation...(2)

- Note with Load Conversion activity:
 - Using 100% constant P, Q is conservative approach (from Voltage stability point)
 - Use Real power = 100% Constant I, Reactive power = 100% Constant Z
- **Load dynamics raw data and simulate:**
 - Load Dynamics raw data (*.dyr format)
File -> Open -> DYRE
 - Define Channels for recording simulation output
Dynamics -> Define simulation output / Define simulation output by subsystem
CHAN / CHSB
 - Initialize dynamics case
Dynamics -> Simulation -> Perform Simulation -> Initialize
STRT
 - Run dynamics case in time steps
Dynamics -> Simulation -> Perform Simulation ->
RUN

Models summary

Output Bar

Generator models use:

CONS	1-	82
STATES	1-	35

Excitation System models use:

CONS	83-	144
STATES	36-	53
VARs	1-	3

Turbine Governor models use:

CONS	145-	177
STATES	54-	63
VARs	4-	8

SUMMARY OF MODELS READ:

GENS:	GENROU	GENSAL
	5	1

EXSYS:	IEEE1	SCRX	SEXS
	3	1	2

GOVS:	TGOV1	HYGOV
	3	1

NEXT AVAILABLE ADDRESSES ARE:

CON	STATE	VAR	ICON
178	64	9	1

Only PSS/E supplied models in case. Compilation is not required

STRRT/RUN

Perform Dynamic Simulation

Initialization options

Channel output file: Run1.out

☒ Automatically GNET for missing machine models

Simulation options

Run to: -0.0200 0.0100 secs

Print every: 0 time steps

Write every: 1 time steps

Plot every: 0 time steps

☒ Display network convergence monitor

Run Close Initialize

Print

- How often to write channel data to progress window

Write

- How often to write channel data to channel output file

Plot

- How often to plot selected channels on CRT

Simulation Options

Dynamic Simulation Options

Range and Thresholds
Voltage Violation
Simulation

☐ Network frequency dependence

☐ Scan out-of-step conditions

☐ Scan active subsystem only
☒ Monitor only
☐ Monitor and trip

☐ Scan generators exceeding angle threshold

☐ Scan active subsystem only

180.00

Degrees

0.00

MBase threshold (MVA)

☒ Monitor only
☐ Monitor and trip

☐ Scan generators exceeding power unbalance threshold

1.10

Threshold (pu)

☒ Set relative machine angles

☐ Relative to machine
☒ Relative to system average angle
☐ Relative to system weighted average angle

Bus (Number)

Machine ID

Select...

☐ Scan circuits against generic relay zones

☐ Scan active subsystem only

☐ Scan buses outside of voltage range

☐ Scan active subsystem only

1.50

Voltage max. (pu)

0.50

Voltage min. (pu)

☐ Scan generators exceeding speed deviation threshold

☐ Scan active subsystem only

10.00

Threshold (%)

☒ Monitor only
☐ Monitor and trip

OK

Cancel

Initialisation OK

INITIAL CONDITION LOAD FLOW USED 1 ITERATIONS

```

----- MACHINE INITIAL CONDITIONS -----
BUS#-SCT X-- NAME --X BASKV ID  ETERM  EFD    POWER    VARS    P.F.  ANGLE  ID    IQ
 101      NUC-A      21.600 1   1.0200 2.0563  750.00    81.20  0.9942  63.47  0.6571 0.4934
 102      NUC-B      21.600 1   1.0200 2.0563  750.00    81.20  0.9942  63.47  0.6571 0.4934
 206      URBGEN      18.000 1   1.0236 2.5618  800.00   600.00  0.8000  23.53  0.8733 0.4380
 211      HYDRO_G     20.000 1   1.0404 1.6150  600.00    17.74  0.9996  42.14  0.4089 0.6827
3011      MINE_G      13.800 1   1.0400 1.4655  258.66   104.04  0.9278  16.02  0.1648 0.2114
3018      CATDOG_G    13.800 1   1.0218 2.9374  100.00    80.00  0.7809  22.53  0.8757 0.4033
 1  0.48E-02    154  [DOWNTN      230.00]  -0.4755E-06    0.7397E-07

```

INITIAL CONDITIONS CHECK O.K.

Channel output file is "Run1.out"

Initial Conditions suspect

Executing activity STRT

```
GENROU AT BUS      101 MACHINE 1 : X'' =0.12000 IM(ZSORCE) =0.30000
GENROU AT BUS      102 MACHINE 1 : X'' =0.12000 IM(ZSORCE) =0.30000
IEEET1 AT BUS      101 MACHINE 1  INITIALIZED OUT OF LIMITS
IEEET1 AT BUS      102 MACHINE 1  INITIALIZED OUT OF LIMITS
SCRX AT BUS        201 MACHINE 1  INITIALIZED OUT OF LIMITS
TGOV1 AT BUS        206 MACHINE 1  INITIALIZED OUT OF LIMITS
```

INITIAL CONDITION LOAD FLOW USED 1 ITERATIONS

```
-----MACHINE INITIAL CONDITIONS-----
X----- BUS -----X ID  ETERM  EFD    POWER  VARS   P.F.  ANGLE  ID    IQ
101 NUC-A    21.6 1   1.0200 2.3091 750.00 151.11 0.9803 62.50 0.7010 0.4507
102 NUC-B    21.6 1   1.0200 2.3091 750.00 151.11 0.9803 62.50 0.7010 0.4507
201 HYDRO    500 1   1.014912.0906 600.00 400.00 0.8320 30.58 0.8186 0.5388
206 URBGEN   18.0 1   0.9717 2.4921 800.00 600.00 0.8000 26.85 0.9358 0.4283
3001 MINE     230 1   1.0500 1.6566 248.88 187.25 0.7991 13.60 0.2291 0.1884
3008 CATDOG  230 1   0.9517 2.8515 100.00 80.00 0.7809 22.06 0.9583 0.3913
```

INITIAL CONDITIONS SUSPECT:

I	DSTATE (I)	STATE (I)	MODEL	STATE	BUS	X---	NAME	---X	ID
13	-1.4181	2.0860	GENSAL	K	201	HYDRO	500.00		1
22	-0.24039E-01	0.0000	GENROU	K+4	206	URBGEN	18.000		1
38	-2.0250	2.3091	IEEET1	K+2	101	NUC-A	21.600		1
42	-2.0250	2.3091	IEEET1	K+2	102	NUC-B	21.600		1
63	-0.24039	4.8636	TGOV1	K+1	206	URBGEN	18.000		1

Save simulation data

- To Save dynamics simulation data:
 - Save Converted power flow case as *.cnv file
 - Save Dynamics model data as *.dyr (RAW file) or *.snp (Snapshot file)
 - Save Channels as *.idv file
 - Simulation is automatically stored in *.out / *.outx file

Creating a Disturbance and Clearing it

Branch Selection

System buses

From bus

0	[None]	
101	[NUC-A]	21.600]
102	[NUC-B]	21.600]
151	[NUCPANT]	500.00]
152	[MID500]	500.00]
153	[MID230]	230.00]
154	[DOWNIN]	230.00]
201	[HYDRO]	500.00]
202	[EAST500]	500.00]
203	[EAST230]	230.00]
204	[SUB500]	500.00]
205	[SUB230]	230.00]
206	[URBGEN]	18.000]
211	[HYDRO_G]	20.000]
3001	[MINE]	230.00]
3002	[E. MINE]	500.00]
3003	[S. MINE]	230.00]
3004	[WEST]	500.00]
3005	[WEST]	230.00]

Bus number

☐ Include multi-section lines

Filter not applied

Bus name mask

Bus number range

Bus kV range

Filter

Bus types

☐ Type 1

☐ Type 2

☐ Type 3

☐ Type 4

To bus

To Bus	Circuit Id
201 [HYDRO 500.00]	1
205 [SUB230 230.00]	1

OK Cancel

Apply a Line Fault

☒ Apply fault on branch

☐ Apply fault on 3 winding transformer

From bus (Number) To bus (Number) Last bus (Number) Circuit ID

204, 201, '1'

Select

Base kV

Units

☒ MVA

☐ MHO's

☐ OHM's

Admittance

R

X

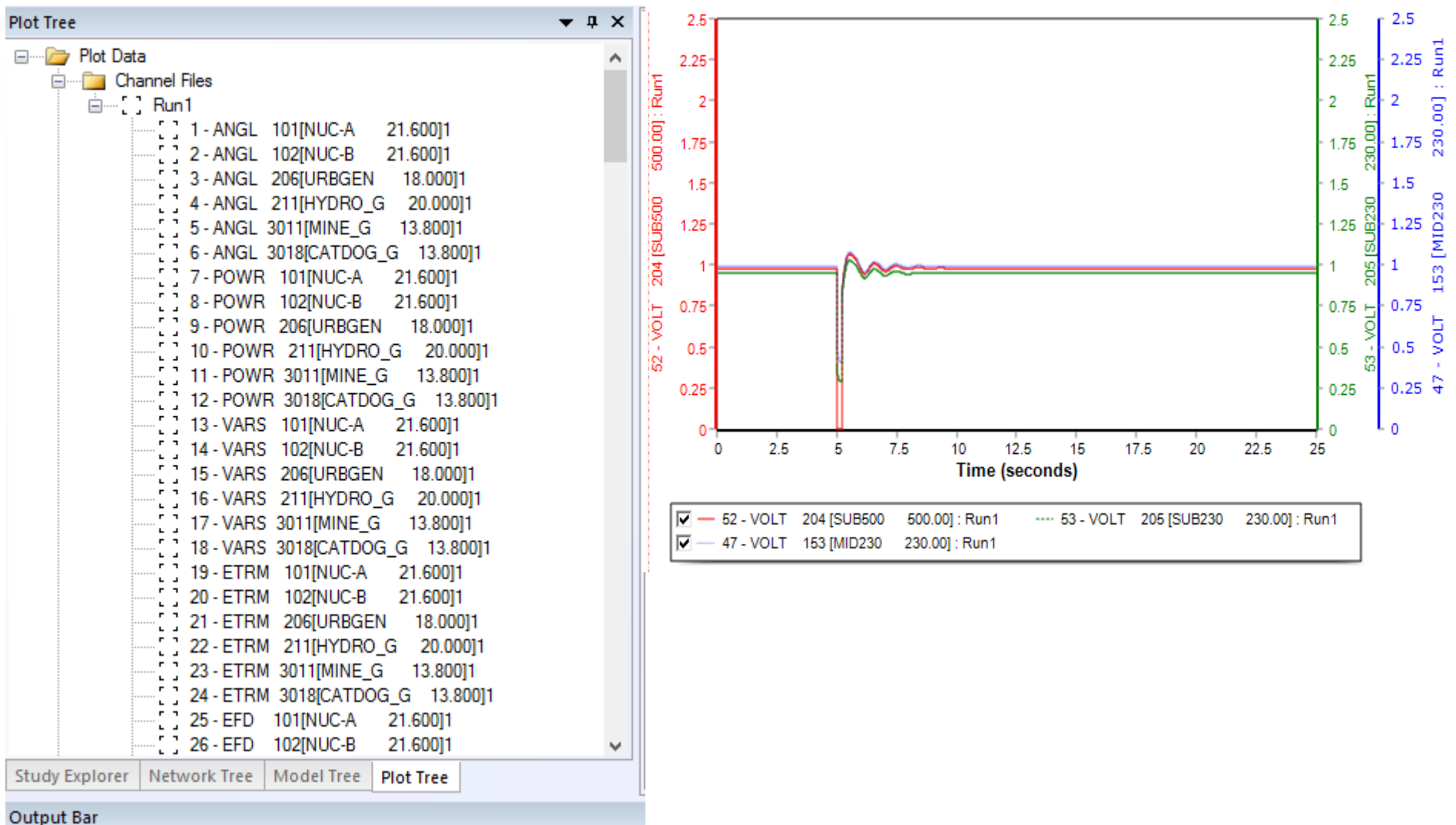
OK Cancel

Select existing fault

1	204	[SUB500 500.00]	201	[HYDRO 500.00]	1
---	-----	-----------------	-----	----------------	---

Go Close

Viewing Simulation results



References

- 1) PSSE 34.4 Documentation
- 2) Power System Stability and Control, P.Kundur
- 3) Ewart, D.N.; DeMello, F.P., "A Digital Computer Program for the Automatic Determination of Dynamic Stability Limits," Power Apparatus and Systems, IEEE Transactions on , vol.PAS-86, no.7, pp.867,875, July 1967

Thank You !!