

Transient Stability Analysis with PowerWorld Simulator



T11: Single Machine Infinite Bus Modeling (SMIB)



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Single Machine Infinite Bus (SMIB) Eigenvalue Analysis



- SMIB Eigenvalue Analysis internally builds a dynamic model of one generator connected to an infinite bus
 - All of that generator's dynamic models (machine model, exciter, governor, stabilizer, etc...) are included
 - A matrix (often called the "A Matrix") of all the dynamic states is constructed at the steady state solution and eigenvalue and eigenvector analysis is performed on this matrix
- These SMIB models can also be saved out as two-bus models consisting of the machine bus and an infinite bus
 - Choose the "Save Two-Bus Equivalent" action
 - These two-bus models can then be further analyzed

SMIB Eigenvalues



- Click Run SMIB Eigen Analysis
 - Positive Eigenvalues = Problem
 - Indicates an unstable dynamic state
 - Negative Eigenvalues with extremely large magnitudes = Problem
 - Indicate a dynamic state that is extremely fast
 - This will cause numerical problems in the integration routines
 - What do these mean?
 - May be a model data error
 - May be a problem with how Simulator is modeling something
- Although this is the last page on the Transient Stability Analysis dialog, it is often one of the first places to look when examining a case

SMIB Eigenvalues



- Extremely large negative eigenvalues are often caused by particular exciter models such as EXST1_GE and REXS which contain extremely fast feedback loops
- These models require special consideration in the numerical integration algorithm and are dealt with by using sub-interval integration

SMIB Eigenvalues Example



- Open the case **WestExample.pwb**
- This case provides an example of using SMIB eigenvalues to identify input parameters which cause instability
- Open the SMIB Eigenvalues page on the Transient Stability Analysis dialog
- Click “Run SMIB Eigen Analysis”
- Different fields available- Number of Eigenvalues, Number of Zero Eigenvalues, Max Eigenvalue, Min Eigenvalue, all eigenvalues
- You can click on the Max Eigenvalue Column to sort by Max Eigenvalue and view the largest eigenvalues; positive eigenvalues are present

Positive Maximum Eigenvalues



Sort by Max Eigenvalue

SMIB Eigenvalues

Run SMIB Eigen Analysis Re-Initialize Eigenvalue Analysis Last Run: 6/8/2010 12:46:52 PM

Records Set Columns Options

	Number of Bus	Name of Bus	ID	Area Name of Gen	Machine	Exciter	Governor	Stabilizer	Calculated	Number of Eigenvalues	Number of Zero Eigenvalues	Max Eigenval	Min Eigenvalue	Eig
1	21083	NLNDGT#2	1	IMPERIALCA	GENROU	ESAC7B		PSS2A	YES	31	9	7.8940	-72.0385	0.0000 +
2	21081	NLNDGT#1	1	IMPERIALCA	GENROU	ESAC7B		PSS2A	YES	31	9	7.8940	-72.0385	0.0000 +
3	57236	MUSKEG4	1	ALBERTA	GENROU	ESAC7B	GGOV1	PSS2A	YES	41	10	6.7283	-54.8035	0.0000 +
4	57836	MUSKEG6	2	ALBERTA	GENROU	ESAC7B	GGOV1	PSS2A	YES	41	10	6.7079	-54.8163	0.0000 +
5	51444	BKL 1S1	1	B.C.HYDRO	GENROU				YES	6	0	1.2363	-45.0378	1.2363 +
6	24123	REDON7 G	H	SOCALIF	GENCC	EXDC1	IEEEG1	WSCCST	YES	23	5	0.8914	-34.0168	0.0000 +
7	24124	REDON8 G	H	SOCALIF	GENCC	EXDC1	IEEEG1	WSCCST	YES	23	5	0.8862	-34.0168	0.0000 +
8	31788	ROCK CK2	1	PG AND E	GENSAL	EXDC4	HYGOV		YES	11	0	0.7285	-38.2124	-0.0178 -
9	24161	ALAMT6 G	H	SOCALIF	GENCC	EXDC1	IEEEG1	WSCCST	YES	23	5	0.6959	-33.8851	0.0000 +
10	66060	NAUGT G2	1	PACE	GENROU	EXST2A	IEEEG1	IEEEST	YES	24	8	0.6863	-39.8968	0.0000 +
11	57273	FIREBAG7	G7	ALBERTA	GENROU	ESAC7B	GGOV1	PSS2A	YES	41	10	0.6749	-49.2406	0.0000 +
12	24123	REDON7 G	L	SOCALIF	GENCC	EXDC1		WSCCST	YES	17	4	0.5097	-29.9290	0.0000 +
13	24124	REDON8 G	L	SOCALIF	GENCC	EXDC1		WSCCST	YES	17	4	0.5088	-29.9313	0.0000 +
14	24161	ALAMT6 G	L	SOCALIF	GENCC	EXDC1		WSCCST	YES	17	4	0.4305	-29.8391	0.0000 +
15	52141	COR-G1	1	FORTISBC	GENSAL	EXDC4	GPWSCC		YES	14	3	0.3621	-132.8893	0.0000 +
16	32171	HIGHWIND3	1	PG AND E	GENWRI	EXWTG1			YES	6	0	0.3449	-35.8820	0.3449 +
17	52143	COR-G3	3	FORTISBC	GENSAL	EXDC4	GPWSCC		YES	14	3	0.2628	-133.0161	0.0000 +
18	46439	ROSS 42	2	NORTHWEST	GENSAL		PIDGOV	PSS2A	YES	31	8	0.1985	-36.9227	0.0000 +
19	16514	DMPCT#1	1	ARIZONA	GENROU	ESAC2A		PSS2A	YES	30	8	0.0747	-80.6089	0.0000 +
20	22487	MEF MR2	1	SANDIEGO	GENROU	EXAC8B	GGOV1	PSS2A	YES	40	8	0.0635	-53.3577	0.0000 +
21	70069	CABCRKA	HA	PSCOLORADO	GENSAL	EXST1_GE	HYGOV	IEEEST	YES	21	7	0.0410	-52.2022	0.0000 +
22	70310	PAWNEE	C1	PSCOLORADO	GENTPF	EXAC3A	GGOV1	WSCCST	YES	27	6	0.0344	-79.4372	0.0000 +
23	51499	HAC 4G1	1	B.C.HYDRO	GENROU				YES	6	0	0.0319	-46.0301	0.0319 +
24	43557	SULIVAN	1	NORTHWEST	GENTPF				YES	6	0	0.0260	-64.6678	0.0260 +
25	50513	PCN 13G1	1	B.C.HYDRO	GENSAL	EXST1_GE	PIDGOV	PSS2A	YES	36	12	0.0119	-98.5026	0.0000 +
26	50515	PCN 13G3	3	B.C.HYDRO	GENSAL	EXST1_GE	PIDGOV	PSS2A	YES	36	12	0.0059	-60.4255	0.0000 +
27	51214	SSH 4G1	1	B.C.HYDRO	GENROU				YES	6	0	0.0029	-44.3948	0.0029 +
28	51213	M3C 4G1	1	B.C.HYDRO	GENROU				YES	6	0	0.0023	-44.6979	0.0023 +
29	31880	SPI-HAYF	1	PG AND E	GENTPF	EXST1_GE	GGOV1		YES	0	0	0.0000	0.0000	0.0000 +

Positive eigenvalues are present

Extremely Large Negative Minimum Eigenvalues



SMIB Eigenvalues

Run SMIB Eigen Analysis Re-Initialize Eigenvalue Analysis Last Run: 6/8/2010 12:46:52 PM

Records Set Columns Options

	Number of Bus	Name of Bus	ID	Area Name of Gen	Machine	Exciter	Governor	Stabilizer	Calculated	Number of Eigenvalues	Number of Zero Eigenvalues	Max Eigenvalue	Min Eigenvalue ▲	Eig
1	42711	ELECTRON	2	NORTHWEST	GENSAL	EXST1_GE			YES	10	3	-1.434	-2601.8364	0.0000 +
2	42711	ELECTRON	3	NORTHWEST	GENSAL	EXST1_GE			YES	10	3	-1.629	-2101.6873	0.0000 +
3	42711	ELECTRON	1	NORTHWEST	GENSAL	EXST1_GE			YES	10	3	-1.669	-2101.6638	0.0000 +
4	31804	PIT 5 U1	2	PG AND E	GENSAL	EXDC2_GE	HYGOV		YES	15	2	-0.023	-1784.5602	0.0000 +
5	31804	PIT 5 U1	1	PG AND E	GENSAL	EXDC2_GE	HYGOV		YES	15	2	-0.023	-1784.5602	0.0000 +
6	42711	ELECTRON	4	NORTHWEST	GENSAL	EXST1_GE			YES	10	3	-0.908	-1477.2272	0.0000 +
7	36405	MOSSLND6	H	PG AND E	GENCC	EXST1_GE	IEEEG1	IEEEST	YES	24	10	-0.100	-1296.9645	0.0000 +
8	36406	MOSSLND7	H	PG AND E	GENCC	EXST1_GE	IEEEG1	IEEEST	YES	24	10	-0.100	-1296.9644	0.0000 +
9	54414	RAY RES9	1	ALBERTA	GENSAL	EXST1_GE	GPWSCC		YES	17	2	-0.007	-1042.9824	0.0000 +
10	32150	DG_VADIX	1	PG AND E	GENROU	EXDC2_GE	GGOV1		YES	22	5	-0.105	-1022.5004	0.0000 +
11	34186	DG_PAN1	1	PG AND E	GENROU	EXDC2_GE			YES	12	2	-0.035	-1022.5004	0.0000 +
12	59908	MIL_G5 9	G5	ALBERTA	GENROU	EXST1_GE	IEEEG1	PSS2A	YES	36	12	-0.173	-999.9999	0.0000 +
13	37579	SHASTA5	5	PG AND E	GENSAL	EXST1_GE	HYG3	PSSSB	YES	39	17	-0.037	-999.9999	0.0000 +
14	59208	MIL_G6 9	G6	ALBERTA	GENROU	EXST1_GE	IEEEG1	PSS2A	YES	36	12	-0.177	-999.9999	0.0000 +
15	37578	SHASTA4	4	PG AND E	GENSAL	EXST1_GE	HYG3	PSSSB	YES	39	17	-0.037	-999.9999	0.0000 +
16	37577	SHASTA3	3	PG AND E	GENSAL	EXST1_GE	HYG3	PSSSB	YES	39	17	-0.037	-999.9999	0.0000 +
17	54424	KEEP #2GN	2	ALBERTA	GENROU	EXST1_GE	IEEEG1	IEEEST	YES	24	8	-0.491	-982.4078	0.0000 +
18	54407	CHIN CH9	1	ALBERTA	GENSAL	EXST1_GE	GPWSCC		YES	17	2	-0.007	-918.4131	0.0000 +
19	54422	KEEP #1GN	1	ALBERTA	GENROU	EXST1_GE	IEEEG1	IEEEST	YES	24	8	-0.503	-900.4982	0.0000 +
20	36405	MOSSLND6	L	PG AND E	GENCC	EXST1_GE		IEEEST	YES	18	7	-0.100	-899.4669	0.0000 +
21	36406	MOSSLND7	L	PG AND E	GENCC	EXST1_GE		IEEEST	YES	18	7	-0.100	-899.4667	0.0000 +
22	54268	DOME EA9	1	ALBERTA	GENSAL	EXST1_GE			YES	10	1	-0.786	-799.6945	0.0000 +
23	54288	DOME EC9	1	ALBERTA	GENSAL	EXST1_GE			YES	10	1	-0.858	-771.6895	0.0000 +
24	54287	DOME EB9	1	ALBERTA	GENSAL	EXST1_GE			YES	10	1	-0.786	-771.6854	0.0000 +
25	54268	DOME EA9	E1	ALBERTA	GENSAL	EXST1_GE			YES	10	1	-0.824	-771.6782	0.0000 +
26	54289	DOME EM9	2	ALBERTA	GENSAL	EXST1_GE			YES	10	1	-0.704	-771.6708	0.0000 +
27	54289	DOME EM9	1	ALBERTA	GENSAL	EXST1_GE			YES	10	1	-0.753	-771.6691	0.0000 +
28	54287	DOME EB9	E2	ALBERTA	GENSAL	EXST1_GE			YES	10	1	-0.338	-771.6645	0.0000 +
29	24309	B CRK2-2	4	SOCALIF	GENSAL	EXST1_GE	HYGOV4		YES	14	2	-0.572	-767.4534	0.0000 +

Sort by Min Eigenvalue

SMIB Eigenvalues Example



- Open the Validation page, click “Run Validation”
- There are many errors and warnings
- Correcting these may help fix some of the large eigenvalues
- Click “Run AutoCorrection”
- Then, view Validation Warnings and Informational Messages to see what was changed

Initial errors and warnings for the case

Validation

Run Validation Run AutoCorrection

Unsupported Models
☒ Raise Error
☐ Raise Warning
☐ No Error/Warning

Minimum time constant size as multiple of time step
 4.0

Last Validation
 Time 6/8/2010 1:02:59 PM
 Errors: 4136 Warnings: 123

Validation Errors Validation Warnings Informational Messages

	Element Type	General Type	Model Type	Who Am I	Validation Message
1	Generator	Machine Model	GENROU	REEVE_G1 _ 13.8 (10261)	# Parameter Tdopp must be 4.0 times the time
2	Generator	Governor	GGOV1	REEVE_G1 _ 13.8 (10261)	# Parameter Ta must be 4.0 times the time
3	Generator	Stabilizer	PSS2A	REEVE_G1 _ 13.8 (10261)	# Parameter T2 must be 4.0 times the time
4	Generator	Stabilizer	PSS2A	REEVE_G1 _ 13.8 (10261)	# Parameter T4 must be 4.0 times the time
5	Generator	Machine Model	GENROU	REEVE_G3 _ 13.8 (10263)	# Parameter Tdopp must be 4.0 times the time
6	Generator	Governor	GGOV1	REEVE_G3 _ 13.8 (10263)	# Parameter Ta must be 4.0 times the time
7	Generator	Stabilizer	PSS2A	REEVE_G3 _ 13.8 (10263)	# Parameter T2 must be 4.0 times the time
8	Generator	Stabilizer	PSS2A	REEVE_G3 _ 13.8 (10263)	# Parameter T4 must be 4.0 times the time
9	Generator	Exciter	EXAC3A	SJUAN_G1 _ 22.0 (10318)	# Parameter Ta must be 4.0 times the time
10	Generator	Stabilizer	IEEEEST	SJUAN_G1 _ 22.0 (10318)	# Parameter T2 must be 4.0 times the time
11	Generator	Stabilizer	IEEEEST	SJUAN_G1 _ 22.0 (10318)	# Parameter T4 must be 4.0 times the time
12	Generator	Stabilizer	PSS2A	SJUAN_G2 _ 24.0 (10319)	# Parameter T2 must be 4.0 times the time
13	Generator	Stabilizer	PSS2A	SJUAN_G2 _ 24.0 (10319)	# Parameter T4 must be 4.0 times the time
14	Generator	Exciter	EXST4B	LEF_G1 _ 18.0 (10394)	#1 Parameter Ta must be 4.0 times the time
15	Generator	Stabilizer	PSS2A	LEF_G1 _ 18.0 (10394)	#1 Parameter T2 must be 4.0 times the time
16	Generator	Exciter	EXST4B	LEF_G2 _ 18.0 (10395)	#1 Parameter Ta must be 4.0 times the time
17	Generator	Stabilizer	PSS2A	LEF_G2 _ 18.0 (10395)	#1 Parameter T2 must be 4.0 times the time
18	Generator	Exciter	EXST4B	LEF_S1 _ 18.0 (10396)	#1 Parameter Ta must be 4.0 times the time
19	Generator	Stabilizer	PSS2A	LEF_S1 _ 18.0 (10396)	#1 Parameter T2 must be 4.0 times the time
20	Generator	Stabilizer	PSS2A	LEF_S1 _ 18.0 (10396)	#1 Parameter T4 must be 4.0 times the time
21	Generator	Exciter	EXAC2	AFTONS _ 13.8 (10485)	#1 Parameter Tr must be 4.0 times the time
22	Generator	Exciter	EXAC2	AFTONS _ 13.8 (10485)	#1 Parameter Ta must be 4.0 times the time
23	Generator	Stabilizer	PSS2B	AFTONS _ 13.8 (10485)	#1 Parameter T2 must be 4.0 times the time
24	Generator	Stabilizer	PSS2B	AFTONS _ 13.8 (10485)	#1 Parameter T4 must be 4.0 times the time
25	Generator	Exciter	EXST4B	AFTONG _ 18.0 (10486)	#1 Parameter Ta must be 4.0 times the time
26	Generator	Stabilizer	PSS2B	AFTONG _ 18.0 (10486)	#1 Parameter T2 must be 4.0 times the time
27	Generator	Stabilizer	PSS2B	AFTONG _ 18.0 (10486)	#1 Parameter T4 must be 4.0 times the time
28	Generator	Machine Model	GENROU	LRDSBGG1 _ 13.8 (10491)	# Parameter Tdopp must be 4.0 times the time
29	Generator	Stabilizer	PSS2A	LRDSBGG1 _ 13.8 (10491)	# Parameter T2 must be 4.0 times the time

SMIB Eigenvalues Example



- After AutoCorrection, there are no more errors
- Some warnings and informational messages are still present
- Many of the warnings indicate that certain generators had no machine model, so they are being treated as a negative load

Errors and Warnings after AutoCorrection

Validation

Run Validation Run AutoCorrection

Unsupported Models
☒ Raise Error
☐ Raise Warning
☐ No Error/Warning

Minimum time constant size as multiple of time step
 4.0

Last Validation
 Time 6/15/2010 4:59:31 PM
 Errors: 0 Warnings: 88

Validation Errors Validation Warnings Informational Messages

Element Type	General Type	Model Type	Who Am I	Validation Message
1 Generator			HLWR_4_ 0.7 (10933) #1	Generator does not have machine modeled defined; treated as negative load.
2 Generator			LONEMS_ 0.6 (10997) #1	Generator does not have machine modeled defined; treated as negative load.
3 Generator	Machine Model	GENROU	WPCC4ST1_ 13.8 (14950) #1	Tqop > 5*Tqopp is recommended.
4 Generator	Machine Model	GENROU	SANTAN 1_ 13.8 (15921) #1	Tqop > 5*Tqopp is recommended.
5 Generator	Machine Model	GENROU	SANTAN 2_ 13.8 (15922) #1	Tqop > 5*Tqopp is recommended.
6 Generator	Machine Model	GENROU	SANTAN 3_ 13.8 (15923) #2	Tqop > 5*Tqopp is recommended.
7 Generator	Machine Model	GENROU	SANTAN 4_ 13.8 (15924) #2	Tqop > 5*Tqopp is recommended.
8 Generator	Machine Model	GENROU	ELSTM2-2_ 13.8 (21031) #1	Tqop > 5*Tqopp is recommended.
9 Generator			KUMEYAAY_ 0.7 (22915) #1	Generator does not have machine modeled defined; treated as negative load.
10 Generator			PFC-AVC_ 0.6 (22916) #1	Generator does not have machine modeled defined; treated as negative load.
11 Generator			RERC1G_ 13.8 (24242) #1	Generator does not have machine modeled defined; treated as negative load.
12 Generator			RERC2G_ 13.8 (24243) #1	Generator does not have machine modeled defined; treated as negative load.
13 Generator			TERAWND_ 115.0 (25632) #QF	Generator does not have machine modeled defined; treated as negative load.
14 Generator			CAPWIND_ 115.0 (25633) #QF	Generator does not have machine modeled defined; treated as negative load.
15 Generator			BUCKWIND_ 115.0 (25634) #QF	Generator does not have machine modeled defined; treated as negative load.
16 Generator			ALTWIND_ 115.0 (25635) #Q1	Generator does not have machine modeled defined; treated as negative load.
17 Generator			ALTWIND_ 115.0 (25635) #Q2	Generator does not have machine modeled defined; treated as negative load.
18 Generator			RENWIND_ 115.0 (25636) #Q1	Generator does not have machine modeled defined; treated as negative load.
19 Generator			RENWIND_ 115.0 (25636) #Q2	Generator does not have machine modeled defined; treated as negative load.
20 Generator			TRANWIND_ 115.0 (25637) #QF	Generator does not have machine modeled defined; treated as negative load.
21 Generator			VENWIND_ 115.0 (25645) #Q1	Generator does not have machine modeled defined; treated as negative load.
22 Generator			VENWIND_ 115.0 (25645) #Q2	Generator does not have machine modeled defined; treated as negative load.
23 Generator			SANWIND_ 115.0 (25646) #Q1	Generator does not have machine modeled defined; treated as negative load.
24 Generator			SANWIND_ 115.0 (25646) #Q2	Generator does not have machine modeled defined; treated as negative load.
25 Generator			SEAWEST_ 115.0 (29060) #S1	Generator does not have machine modeled defined; treated as negative load.
26 Generator			SEAWEST_ 115.0 (29060) #S2	Generator does not have machine modeled defined; treated as negative load.
27 Generator			SEAWEST_ 115.0 (29060) #S3	Generator does not have machine modeled defined; treated as negative load.

- | SMIB Eigenvalues | | | | | | | | | | | | |
|---|------------------|------------|---------|----------|------------|------------|-----------------------|----------------------------|--------------|----------------|-------------------|------------------|
| Run SMIB Eigen Analysis Re-Initialize Eigenvalue Analysis Last Run: 6/8/2010 1:10:29 PM | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| ID | Area Name of Gen | Machine | Exciter | Governor | Stabilizer | Calculated | Number of Eigenvalues | Number of Zero Eigenvalues | Max Eigenval | Min Eigenvalue | Eigenvalue 1 | |
| 1 | ALBERTA | GENROU | ESAC7B | GGOV1 | PSS2A | YES | 41 | 12 | 3.5259 | -49.0241 | 0.0000 + j0.0000 | |
| 2 | ALBERTA | GENROU | ESAC7B | GGOV1 | PSS2A | YES | 41 | 10 | 3.5183 | -49.0229 | 0.0000 + j0.0000 | |
| 3 | B.C.HYDRO | GENROU | | | | YES | 6 | 0 | 1.2363 | -45.0365 | 1.2363 + j0.0000 | |
| 4 | SOCALIF | GENCC | EXDC1 | IEEEG1 | WSCCST | YES | 23 | 5 | 0.8914 | -34.0168 | 0.0000 + j0.0000 | |
| 5 | SOCALIF | GENCC | EXDC1 | IEEEG1 | WSCCST | YES | 23 | 5 | 0.8862 | -34.0168 | 0.0000 + j0.0000 | |
| 6 | PG AND E | GENSAL | EXDC4 | HYGOV | | YES | 11 | 0 | 0.7285 | -38.2124 | -0.0178 + j0.0000 | |
| 7 | SOCALIF | GENCC | EXDC1 | IEEEG1 | WSCCST | YES | 23 | 5 | 0.6959 | -33.8851 | 0.0000 + j0.0000 | |
| 8 | PACE | GENROU | EXST2A | IEEEG1 | IEEEST | YES | 24 | 8 | 0.6818 | -37.9506 | 0.0000 + j0.0000 | |
| 9 | GB | PSCOLORADO | GENROU | ESAC7B | GGOV1 | PSS2A | YES | 41 | 11 | 0.5446 | -60.0024 | 0.0000 + j0.0000 |
| 10 | GC | PSCOLORADO | GENROU | ESAC7B | GGOV1 | PSS2A | YES | 41 | 11 | 0.5372 | -60.0024 | 0.0000 + j0.0000 |
| 11 | L | SOCALIF | GENCC | EXDC1 | | WSCCST | YES | 17 | 4 | 0.5097 | -29.9290 | 0.0000 + j0.0000 |
| 12 | L | SOCALIF | GENCC | EXDC1 | | WSCCST | YES | 17 | 4 | 0.5088 | -29.9313 | 0.0000 + j0.0000 |
| 13 | L | SOCALIF | GENCC | EXDC1 | | WSCCST | YES | 17 | 4 | 0.4305 | -29.8391 | 0.0000 + j0.0000 |
| 14 | 1 | PG AND E | GENWRI | EXWTG1 | | YES | 6 | 0 | 0.3408 | -25.9035 | 0.3408 + j0.0000 | |
| 15 | 2 | NORTHWEST | GENSAL | | PIDGOV | PSS2A | YES | 31 | 8 | 0.1985 | -33.3192 | 0.0000 + j0.0000 |
| 16 | 1 | PG AND E | GENROU | EXAC8B | GAST_GE | PSS2A | YES | 35 | 10 | 0.1350 | -44.2651 | 0.0000 + j0.0000 |
| 17 | 2 | PG AND E | GENROU | EXAC8B | GAST_GE | PSS2A | YES | 35 | 10 | 0.1350 | -44.2651 | 0.0000 + j0.0000 |
| 18 | 1 | FORTISBC | GENSAL | EXDC4 | GPWSCC | YES | 14 | 1 | 0.0688 | -78.5339 | 0.0000 + j0.0000 | |
| 19 | HA | PSCOLORADO | GENSAL | EXST1_GE | HYGOV | IEEEST | YES | 21 | 7 | 0.0410 | -52.2022 | 0.0000 + j0.0000 |
| 20 | 1 | B.C.HYDRO | GENROU | | | YES | 6 | 0 | 0.0316 | -46.0420 | 0.0316 + j0.0000 | |
| 21 | 1 | NORTHWEST | GENTPF | | | YES | 6 | 0 | 0.0260 | -64.6678 | 0.0260 + j0.0000 | |
| 22 | 1 | B.C.HYDRO | GENSAL | EXST1_GE | PIDGOV | PSS2A | YES | 36 | 11 | 0.0119 | -98.3342 | 0.0000 + j0.0000 |
| 23 | 3 | B.C.HYDRO | GENSAL | EXST1_GE | PIDGOV | PSS2A | YES | 36 | 12 | 0.0059 | -50.0000 | 0.0000 + j0.0000 |
| 24 | 1 | B.C.HYDRO | GENROU | | | YES | 6 | 0 | 0.0029 | -44.3947 | 0.0029 + j0.0000 | |
| 25 | 1 | B.C.HYDRO | GENROU | | | YES | 6 | 0 | 0.0023 | -44.6980 | 0.0023 + j0.0000 | |
| 26 | 1 | PG AND E | GENROU | EXAC8B | GGOV1 | PSS2A | YES | 40 | 9 | 0.0000 | -49.9895 | 0.0000 + j0.0000 |
| 27 | 1 | PG AND E | GENTPF | EXST1_GE | | YES | 0 | 0 | 0.0000 | 0.0000 | 0.0000 | |

SMIB Eigenvalues Dialog



- Some of the positive eigenvalues are gone, but there are still a lot left
- Right-click on the first line, then “Show SMIB Dialog”
- Three tabs are available- General Info, A Matrix, Eigenvalues

Click to display the SMIB dialog

SMIB Eigenvalues

Run SMIB Eigen Analysis Re-Initialize Eigenvalue Analysis Last Run: 6/15/2010 3:34:13 PM

Records Set Columns Options

	Number of Bus	Name of Bus	ID	Area Name of Gen	Machine	Exciter	Governor	Stabilizer	Calculated	Number of Eigenvalues	Number of Zero Eigenvalues	Max Eigenvalue	Min Eigenvalue
1	57236	MUSKEG4		ALBERTA	GENROU	ESAC7B	GGOV1	PSS2A	YES	41	12	3.5259	-49.0241
2	57836	MUSKEG6					GGOV1	PSS2A	YES	41	10	3.5183	-49.0229
3	51444	BKL 1S1							YES	6	0	1.2363	-45.0365
4	24123	REDON7 G					IEEEG1	WSCCST	YES	23	5	0.8914	-34.0168
5	24124	REDON8 G					IEEEG1	WSCCST	YES	23	5	0.8862	-34.0168
6	31788	ROCK CK2					HYGOV		YES	11	0	0.7285	-38.2124
7	24161	ALAMT6 G					IEEEG1	WSCCST	YES	23	5	0.6959	-33.8851
8	66060	NAUGT G2					IEEEG1	IEEEEST	YES	24	8	0.6818	-37.9506
9	70568	RAWHIDEB					GGOV1	PSS2A	YES	41	11	0.5446	-60.0024
10	70569	RAWHIDEC					GGOV1	PSS2A	YES	41	13	0.5372	-60.0024
11	24123	REDON7 G						WSCCST	YES	17	4	0.5097	-29.9290
12	24124	REDON8 G						WSCCST	YES	17	4	0.5088	-29.9313
13	24161	ALAMT6 G						WSCCST	YES	17	4	0.4305	-29.8391
14	32171	HIGHWIND3							YES	6	0	0.3408	-25.9035
15	46439	ROSS 42					PIDGOV	PSS2A	YES	31	8	0.1985	-33.3192
16	34329	STAR_GT2					GAST_GE	PSS2A	YES	35	10	0.1350	-44.2651
17	34328	STAR_GT1					GAST_GE	PSS2A	YES	35	10	0.1350	-44.2651
18	52141	COR-G1					GPWSCC		YES	14	1	0.0688	-78.5339
19	70069	CABCRKA					HYGOV	IEEEEST	YES	21	7	0.0410	-52.2022
20	51499	HAC 4G1							YES	6	0	0.0316	-46.0420
21	43557	SULIVAN							YES	6	0	0.0260	-64.6678
22	50513	PCN 13G1					PIDGOV	PSS2A	YES	36	11	0.0119	-98.3342
23	50515	PCN 13G3					PIDGOV	PSS2A	YES	36	12	0.0059	-50.0000
24	51214	SSH 4G1							YES	6	0	0.0029	-44.3947
25	51213	M3C 4G1							YES	6	0	0.0023	-44.6980
26	54062	SHERRITT							YES	0	0	0.0000	0.0000
27	64120	TRACY G4	1	STEDRA	GENROU	EVST4B	GGOV1	PSS2A	YES	30	10	0.0000	-37.0748

Context Menu:

- Show SMIB Dialog
- Save Two Bus Equivalent
- Show Dialog...
- Display/Column Options...
- Search for Text...
- Transient Generator records
- Set/Toggle/Columns
- Copy/Paste/Send
- Advanced Row Filter...
- Advanced Row Sort...
- Advanced Column Filter...
- Advanced Column Sort...
- f(x) Define Expression...
- Refresh Display
- Help (F1)
- Form Control

SMIB Eigenvalues Dialog



- General Info Tab
 - Generator MVA Base
 - Infinite bus magnitude and angle, terminal voltage and current magnitude and angle
 - Network impedance on System MVA base and Generator MVA Base

SMIB dialog-
General Info tab

The screenshot shows the 'Generator SMIB Eigenvalue Information' dialog box. The 'General Info' tab is selected. The 'Bus Number' is 57236, 'Bus Name' is MUSKEG4, and 'ID' is 1. The 'Status' is 'Closed'. The 'Area Name' is 'ALBERTA (54)'. The 'Generator Information (on Generator MVA Base)' section includes fields for 'Generator MVA Base' (104.700), 'Infinite Bus Voltage Magnitude (pu)' (1.0467), 'Infinite Bus Angle (deg)' (113.2669), 'Terminal Current Magnitude (pu)' (0.6884), 'Terminal Current Angle (deg)' (131.653), 'Terminal Voltage Magnitude (pu)' (1.0000), and 'Terminal Voltage Angle (deg)' (129.0251). The 'Network Impedance on Generator MVA Base' section includes 'Network R (Gen Base)' (0.00828) and 'Network X (Gen Base)' (0.41297). The 'Network Impedance on System MVA Base' section includes 'Network R (System Base)' (0.00791) and 'Network X (System Base)' (0.39443). The dialog has 'OK', 'Save', 'Cancel', 'Help', and 'Print' buttons at the bottom.

Generator SMIB Eigenvalue Information			
Bus Number	57236	Find By Number	Status
Bus Name	MUSKEG4	Find By Name	☐ Open ☒ Closed
ID	1	Find ...	Area Name
ALBERTA (54)			
Generator Information (on Generator MVA Base)			
General Info A Matrix Eigenvalues			
Generator MVA Base			
104.700			
Infinite Bus Voltage Magnitude (pu)	1.0467	Infinite Bus Angle (deg)	113.2669
Terminal Current Magnitude (pu)	0.6884	Terminal Current Angle (deg)	131.653
Terminal Voltage Magnitude (pu)	1.0000	Terminal Voltage Angle (deg)	129.0251
Network Impedance on Generator MVA Base		Network Impedance on System MVA Base	
Network R (Gen Base)	0.00828	Network R (System Base)	0.00791
Network X (Gen Base)	0.41297	Network X (System Base)	0.39443
OK Save Cancel Help Print			

SMIB Eigenvalues Dialog



- A Matrix Tab

- Sensitivity of each SMIB dynamic state equation to each state of the generator
- Values in Eigenvalues tab are evaluated from this matrix
- Can right click and save out SMIB info
 - CSV
 - Excel
 - Aux file

Generator Information (on Generator MVA Base)

General Info A Matrix Eigenvalues							
	Row Name	Machine Angle	Machine Speed w	Machine Eqp	Machine PsiDp	Machine PsiQpp	Machine Ed
1	Machine Angle	0.0000	376.9911	0.0000	0.0000	0.0000	0.0000
2	Machine Speed w	-0.1303	-0.0597	-0.0339	-0.0996	0.0445	0.0000
3	Machine Eqp	-0.0913	0.1518	-1.5851	1.2686	-0.0686	-0.0000
4	Machine PsiDp	-5.7158	-4.2609	28.5027	-34.3953	-0.0799	-0.0000
5	Machine PsiQpp	3.6571	-6.4801	0.0361	0.1058	-29.0847	19.7000
6	Machine Edp	0.2110	-0.3738	-0.2778	-0.8154	7.9077	-11.9000
7	Exciter VE	-20.2035	-3.5418	-324.0990	265.4092	-6.6733	-0.8000
8	Exciter Sensed Vt	-4.5998	33.0865	5.1140	15.0121	23.5102	2.9000
9	Exciter Kir	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	Exciter Kdr (Ignored)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	Exciter VA	-2.2503	-1.6775	-39.0852	31.2806	-1.6907	-0.2000
12	Exciter Feedback (Ignored)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13	Governor PElec Measured	3.1098	1.4256	0.8104	2.3789	-1.0608	-0.1000
14	Governor Governor Differential	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15	Governor Governor Integral Co	0.0000	-7.0000	0.0000	0.0000	0.0000	0.0000
16	Governor Turbine Actuator	0.0000	-21.2500	0.0000	0.0000	0.0000	0.0000
17	Governor Turbine LL	0.0000	4.9412	0.0000	0.0000	0.0000	0.0000
18	Governor Turbine Load Limiter	0.0000	0.1757	0.0000	0.0000	0.0000	0.0000
19	Governor Turbine Load Integra	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20	Governor Supervisory Load Co	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21	Governor Accel Control	0.0000	-100.0000	0.0000	0.0000	0.0000	0.0000
22	Governor Temp Detection LL	0.0000	0.0264	0.0000	0.0000	0.0000	0.0000
23	Stabilizer WOTW1	0.0000	-0.5000	0.0000	0.0000	0.0000	0.0000
24	Stabilizer WOTW2	0.0000	-0.5000	0.0000	0.0000	0.0000	0.0000
25	Stabilizer Transducer1 (Ignore	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
26	Stabilizer WOTW3	-0.7775	-0.3564	-0.2026	-0.5947	0.2652	0.0000
27	Stabilizer WOTW4 (Ignored)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28	Stabilizer Transducer2	0.1322	0.0606	0.0344	0.1011	-0.0451	-0.0000
29	Stabilizer LL1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
30	Stabilizer LL2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
31	Stabilizer RampFilter1	0.0000	99999.9925	0.0000	0.0000	0.0000	0.0000
32	Stabilizer RampFilter2	0.0000	49999.9963	0.0000	0.0000	0.0000	0.0000
33	Stabilizer RampFilter3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
34	Stabilizer RampFilter4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
35	Stabilizer RampFilter5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

SMIB Eigenvalues Dialog



- Eigenvalues
 - The SMIB eigenvalues
 - Each row corresponds to an eigenvalue
 - Columns contain real part, imaginary part, damping ratio, damping frequency, participation factors, and more
 - Participation factors show how system states contribute to (“participate in”) a particular eigenvalue

SMIB dialog- Eigenvalues tab

Participation factors

Generator Information (on Generator MVA Base)

General Info | A Matrix | **Eigenvalues**

	Real Part	Imag Part	Magnitude	Damping Ratio	Damped Freq (Hz)	Damped Period (Sec)	Undamped Freq (Hz)	Machine Angle	Machine Speed w	Machir
1	-49.0241	0.0000	49.0241	1.0000	0.0000		7.8024	0.0003	0.0002	
2	-44.1959	13.1958	46.1239	0.9582	2.1002	0.4762	7.3408	0.0056	0.0048	
3	-44.1959	-13.1958	46.1239	0.9582	-2.1002	-0.4762	7.3408	0.0056	0.0048	
4	-35.3913	0.0000	35.3913	1.0000	0.0000		5.6327	0.0001	0.0002	
5	-8.8505	18.7317	20.7173	0.4272	2.9812	0.3354	3.2973	0.0527	0.2181	
6	-8.8505	-18.7317	20.7173	0.4272	-2.9812	-0.3354	3.2973	0.0527	0.2181	
7	-17.0016	0.0000	17.0016	1.0000	0.0000		2.7059	0.0003	0.2521	
8	-11.8386	5.5089	13.0576	0.9066	0.8768	1.1405	2.0782	0.0001	0.2994	
9	-11.8386	-5.5089	13.0576	0.9066	-0.8768	-1.1405	2.0782	0.0001	0.2994	
10	-14.3392	0.0000	14.3392	1.0000	0.0000		2.2822	0.0001	0.0365	
11	-7.7361	5.1468	9.2918	0.8326	0.8191	1.2208	1.4788	0.0001	0.4132	
12	-7.7361	-5.1468	9.2918	0.8326	-0.8191	-1.2208	1.4788	0.0001	0.4132	
13	-10.0000	0.0000	10.0000	1.0000	0.0000		1.5915	0.0000	0.0000	
14	3.5259	0.6539	3.5860	-0.9832	0.1041	9.6086	0.5707	0.7290	0.1382	
15	3.5259	-0.6539	3.5860	-0.9832	-0.1041	-9.6086	0.5707	0.7290	0.1382	
16	-5.5946	0.0000	5.5946	1.0000	0.0000		0.8904	0.0006	0.0001	
17	-1.9552	2.8598	3.4643	0.5644	0.4551	2.1971	0.5514	0.0168	0.5008	

SMIB Eigenvalues Dialog



Pole locations $s = -\sigma \pm j\omega_d$

$$\sigma = \zeta \omega_n$$

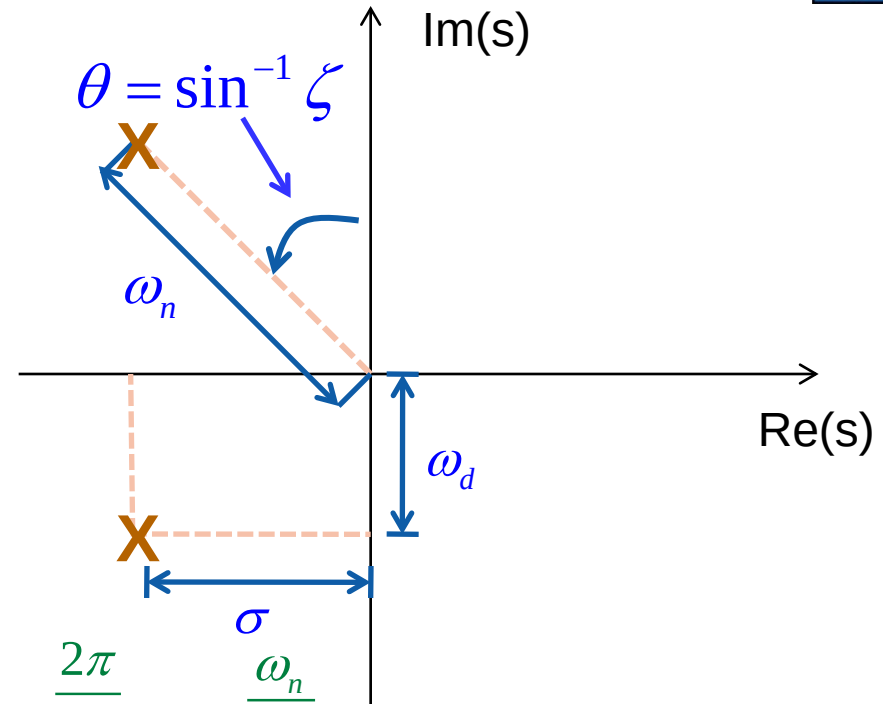
$$\omega_d = \omega_n \sqrt{1 - \zeta^2}$$

Damping ratio ζ

Damped natural frequency ω_d

Undamped natural frequency ω_n

Decay rate of exponential envelope σ



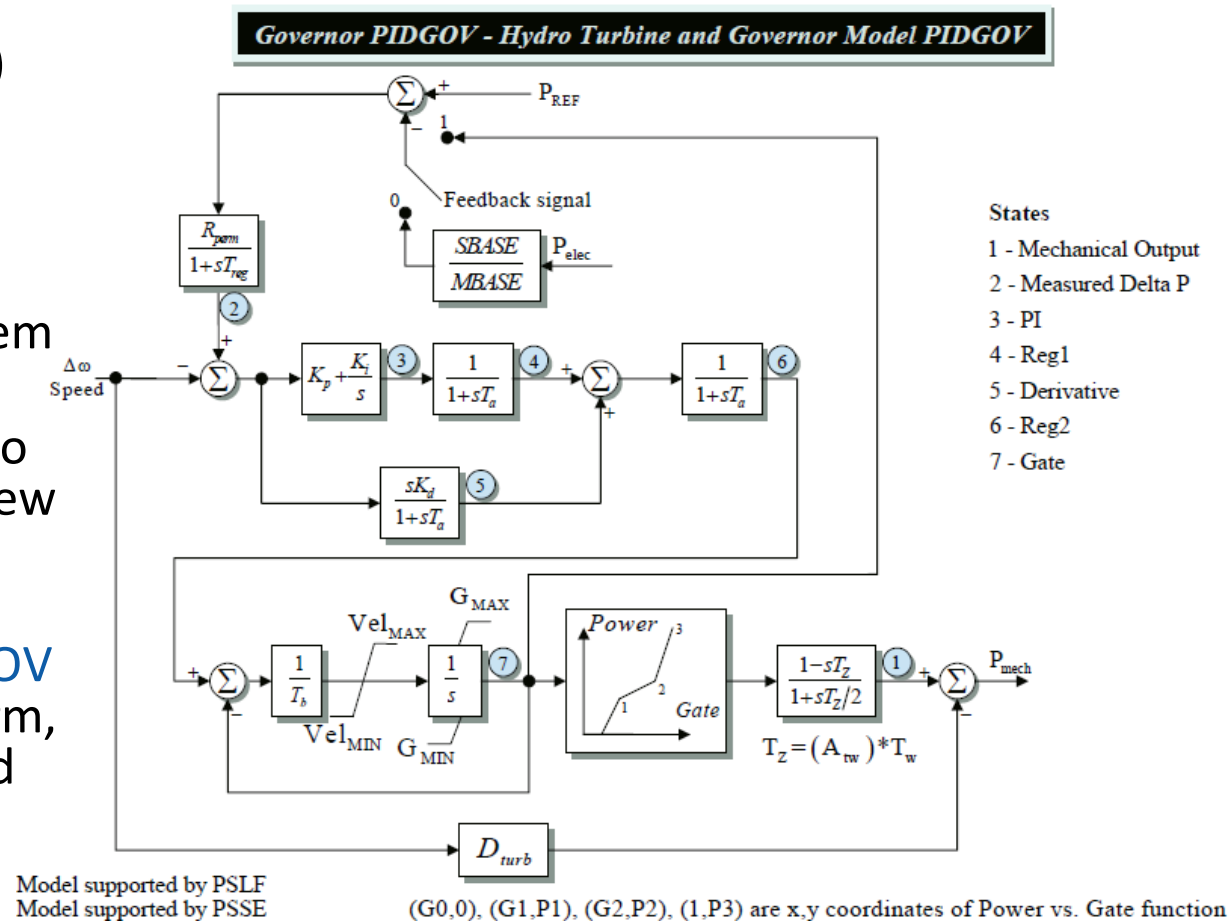
General Info A Matrix Eigenvalues							
	Real Part	Imag Part	Magnitude	Damping Ratio	Damped Freq (Hz)	Damped Period (Sec)	Undamped Freq (Hz)
1	-49.0241	0.0000	49.0241	1.0000	0.0000		7.8024
2	-44.1959	13.1958	46.1239	0.9582	2.1002	0.4762	7.3408
3	-44.1959	-13.1958	46.1239	0.9582	-2.1002	-0.4762	7.3408
4	-35.3013	0.0000	35.3013	1.0000	0.0000		5.6377

G. F. Franklin, J. D. Powell, A. Emami-Naeini, *Feedback Control of Dynamic Systems*, 5th edition, Prentice Hall, 2006.

SMIB Eigenvalues Example



- One problem is that several **PIDGOV** models have parameters R_{perm} (droop) which are negative
- This creates a positive feedback instead of a negative feedback and eventually causes the system to become unstable
- Open the Model Explorer to the Governors page and view the data for the **PIDGOV** models
- There are two active **PIDGOV** models with negative R_{perm} , located at buses 50515 and 50513

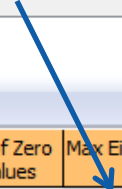


SMIB Eigenvalues Example



- Going back to the SMIB page, we can confirm that these generators are associated with positive eigenvalues

Generator with the highest SMIB eigenvalue



	Number of Bus	Name of Bus	ID	Area Name of Gen	Machine	Exciter	Governor	Stabilizer	Calculated	Number of Eigenvalues	Number of Zero Eigenvalues	Max Eigenvalue ▼
1	57236	MUSKEG4	1	ALBERTA	GENROU	ESAC7B	GGOV1	PSS2A	YES	41	12	3.5259
2	57836	MUSKEG6	2	ALBERTA	GENROU	ESAC7B	GGOV1	PSS2A	YES	41	10	3.5183
3	51444	BKL 1S1	1	B.C.HYDRO	GENROU				YES	6	0	1.2363
4	24123	REDON7 G	H	SOCALIF	GENCC	EXDC1	IEEEG1	WSCCST	YES	23	5	0.8914
5	24124	REDON8 G	H	SOCALIF	GENCC	EXDC1	IEEEG1	WSCCST	YES	23	5	0.8862
6	31788	ROCK CK2	1	PG AND E	GENSAL	EXDC4	HYGOV		YES	11	0	0.7285
7	24161	ALAMT6 G	H	SOCALIF	GENCC	EXDC1	IEEEG1	WSCCST	YES	23	5	0.6959
8	66060	NAUGT G2	1	PACE	GENROU	EXST2A	IEEEG1	IEEEEST	YES	24	8	0.6818
9	70568	RAWHIDE B	GB	PSCOLORADO	GENROU	ESAC7B	GGOV1	PSS2A	YES	41	11	0.5446
10	70569	RAWHIDE C	GC	PSCOLORADO	GENROU	ESAC7B	GGOV1	PSS2A	YES	41	11	0.5372
11	24123	REDON7 G	L	SOCALIF	GENCC	EXDC1		WSCCST	YES	17	4	0.5097
12	24124	REDON8 G	L	SOCALIF	GENCC	EXDC1		WSCCST	YES	17	4	0.5088
13	24161	ALAMT6 G	L	SOCALIF	GENCC	EXDC1		WSCCST	YES	17	4	0.4305
14	32171	HIGHWND3	1	PG AND E	GENWRI	EXWTG1			YES	6	0	0.3408
15	46439	ROSS 42	2	NORTHWEST	GENSAL		PIDGOV	PSS2A	YES	31	8	0.1985
16	34328	STAR_GT1	1	PG AND E	GENROU	EXAC8B	GAST_GE	PSS2A	YES	35	10	0.1350
17	34329	STAR_GT2	2	PG AND E	GENROU	EXAC8B	GAST_GE	PSS2A	YES	35	10	0.1350
18	52141	COR-G1	1	FORTISBC	GENSAL	EXDC4	GPWSCC		YES	14	1	0.0688
19	70069	CABCRKA	HA	PSCOLORADO	GENSAL	EXST1_GE	HYGOV	IEEEEST	YES	21	7	0.0410
20	51499	HAC 4G1	1	B.C.HYDRO	GENROU				YES	6	0	0.0316
21	43557	SULLIVAN	1	NORTHWEST	GENTPF				YES	6	0	0.0260
22	50513	PCN 13G1	1	B.C.HYDRO	GENSAL	EXST1_GE	PIDGOV	PSS2A	YES	36	11	0.0119
23	50515	PCN 13G3	3	B.C.HYDRO	GENSAL	EXST1_GE	PIDGOV	PSS2A	YES	36	12	0.0059
24	51214	SSH 4G1	1	B.C.HYDRO	GENROU				YES	6	0	0.0029
25	51213	M3C 4G1	1	B.C.HYDRO	GENROU				YES	6	0	0.0023

Two PIDGOV models with negative Rperm

SMIB Two-Bus Equivalent



- Let's save out the two-bus equivalent for the bus 50513
- Save it as **Gen_50513_1.pwb** (this should be the default name that appears in the save dialog) Save two-bus equivalent for this bus

SMIB Eigenvalues

Run SMIB Eigen Analysis Re-Initialize Eigenvalue Analysis Last Run: 6/15/2010 1:55:28 PM

Records Set Columns Options

	Number of Bus	Name of Bus	ID	Area Name of Gen	Machine	Exciter	Governor	Stabilizer	Calculated	Number of Eigenvalues	Number of Zero Eigenvalues	Max Eigenvalue	Min Eigenvalue
1	21081	NLNDGT#1	1	IMPERIALCA	GENROU	ESAC7B		PSS2A	YES			7.8940	-72.0385
2	21083	NLNDGT#2	1	IMPERIALCA	GENROU	ESAC7B		PSS2A	YES			7.8940	-72.0385
3	57236	MUSKEG4	1	ALBERTA	GENROU	ESAC7B	GGOV1	PSS2A	YES			6.7283	-54.8035
4	57836	MUSKEG6	2	ALBERTA	GENROU	ESAC7B	GGOV1	PSS2A	YES			6.7079	-54.8163
5	51444	BKL 1S1	1	B.C.HYDRO	GENROU				YES			1.2363	-45.0378
6	24123	REDON7 G	H	SOCALIF	GENCC	EXDC1	IEEEG1	WSCCST	YES			0.8914	-34.0168
7	24124	REDON8 G	H	SOCALIF	GENCC	EXDC1	IEEEG1	WSCCST	YES			0.8862	-34.0168
8	31788	ROCK CK2	1	PG AND E	GENSAL	EXDC4	HYGOV		YES			0.7285	-38.2124
9	24161	ALAMT6 G	H	SOCALIF	GENCC	EXDC1	IEEEG1	WSCCST	YES			0.6959	-33.8851
10	66060	NAUGT G2	1	PACE	GENROU	EXST2A	IEEEG1	IEEEEST	YES			0.6863	-39.8968
11	57273	FIREBAG7	G7	ALBERTA	GENROU	ESAC7B	GGOV1	PSS2A	YES			0.6749	-49.2406
12	24123	REDON7 G	L	SOCALIF	GENCC	EXDC1		WSCCST	YES			0.5097	-29.9290
13	24124	REDON8 G	L	SOCALIF	GENCC	EXDC1		WSCCST	YES			0.5088	-29.9313
14	24161	ALAMT6 G	L	SOCALIF	GENCC	EXDC1		WSCCST	YES			0.4305	-29.8391
15	52141	COR-G1	1	FORTISBC	GENSAL	EXDC4	GPWSCC		YES			0.3621	-132.8893
16	32171	HIGHWND3	1	PG AND E	GENWRI	EXWTG1			YES			0.3449	-35.8820
17	52143	COR-G3	3	FORTISBC	GENSAL	EXDC4	GPWSCC		YES			0.2628	-133.0161
18	46439	ROSS 42	2	NORTHWEST	GENSAL		PIDGOV	PSS2A	YES			0.1985	-36.9227
19	16514	DMPCCCT#1	1	ARIZONA	GENROU	ESAC2A		PSS2A	YES			0.0747	-80.6089
20	22487	MEF MR2	1	SANDIEGO	GENROU	EXAC8B	GGOV1	PSS2A	YES			0.0635	-53.3577
21	70069	CABCRKA	HA	PSCOLORADO	GENSAL	EXST1_GE	HYGOV	IEEEEST	YES			0.0410	-52.2022
22	70310	PAWNEE	C1	PSCOLORADO	GENTPF	EXAC3A	GGOV1	WSCCST	YES			0.0344	-79.4372
23	51499	HAC 4G1	1	B.C.HYDRO	GENROU				YES			0.0319	-46.0301
24	43557	SULLIVAN	1	NORTHWEST	GENTPF				YES			0.0260	-64.6678
25	50513	PCN 13G1	1	B.C.HYDRO	GENSAL	EXST1_GE	PIDGOV	PSS2A	YES			0.0119	-98.5026
26	50515	PCN 13G3	3	B.C.HYDRO	GENSAL	EXST1_GE	PIDGOV	PSS2A	YES			0.0059	-60.4255
27	51214	SSH 4G1	1	B.C.HYDRO	GENROU				YES			0.0029	-44.3948
28	51213	M3C 4G1	1	B.C.HYDRO	GENROU				YES			0.0023	-44.6979
29	65513	GANDRY 5	1	PACE	GENROU	EXAC8B	GGOV1	PSS2A	YES			0.0000	-54.2438

Context menu for row 25:

- Show SMIB Dialog
- Save Two Bus Equivalent
- Show Dialog...
- Display/Column Options...
- Search for Text...
- Transient Generator records
- Set/Toggle/Columns
- Copy/Paste/Send
- Advanced Row Filter...
- Advanced Row Sort...
- Advanced Column Filter...
- Advanced Column Sort...
- f(x) Define Expression...
- Refresh Display
- Help (F1)
- Form Control

SMIB Two-Bus Equivalent



- Now open **Gen_50513_1.pwb**, the two-bus equivalent
- Open the Model Explorer to the bus records or the Models in Use to see some of what is in this case

Model Explorer: Buses

Explore Fields

Recent Network

Branches E
Branches I
Branches S
Buses
DC Transm
Generators

Open New Explore

Search Search Now Options

Number	Name	Area Name	Nom kV	PU Volt	Volt (kV)	Angle (Deg)	Load MW	Load Mvar	Gen MW	Gen Mvar	Switched Shunts Mvar	Act G Shunt MW	Act B Shunt Mvar	Area Num	Zone Num
1	Slack	1	13.80	1.00687	13.895	0.00			0.00	0.00		0.00	0.00	1	1
2	50513 PCN 13G1	1	13.80	0.98995	13.661	8.25			174.80	-11.20		0.00	0.00	1	1

Model Explorer: Models in Use

Explore Fields

Optimal Power Flow
Transient Stability
Summary
Generator Model Use
Model Support Status
Models in Use
DC Line Models
Exciter
Generator Other Models

Transient Stability Model Summary Form

Model Support Status Gen Summary Stabilizer Buses Governor

Records Set Columns

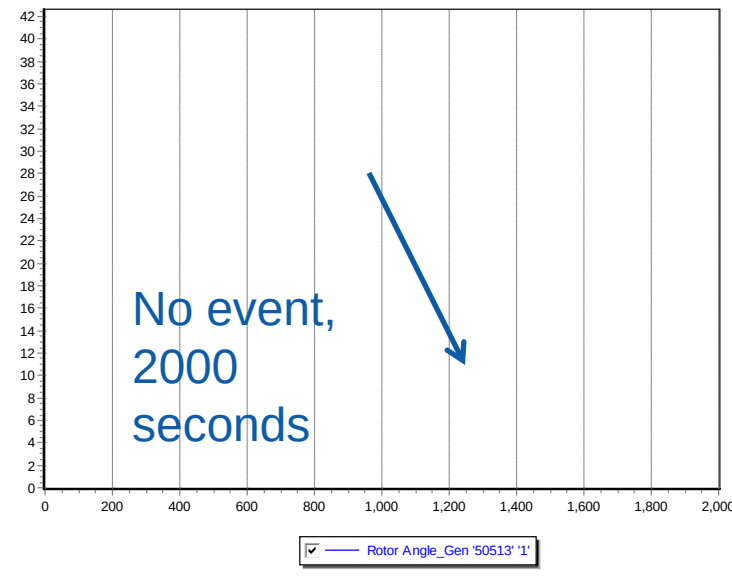
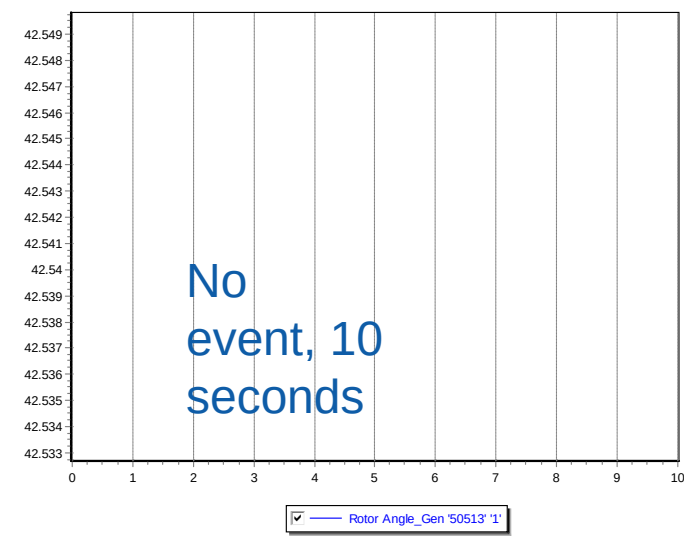
Filter Find... Remove

	Model Class	Object Type	Active and Online Count	Active Count	Inactive Count	Fully Supported
1	Machine Model	GENSAL	1	1	0	YES
2	Exciter	EXST1_GE	1	1	0	YES
3	Governor	PIDGOV	1	1	0	YES
4	Stabilizer	PSS2A	1	1	0	YES

SMIB Two-Bus Equivalent



- Open the Transient Stability Analysis dialog
- Go to the Plots tab and quickly create a plot definition for the Rotor Angle of bus 50513
- Do not insert any events; keep the End Time set to the default 10 seconds
- Click “Run Transient Stability”
- Now change the simulation time to 2000 seconds and run it again



The
model is
unstable

SMIB Participation Factors



- Open the SMIB Eigenvalue Information dialog
- Open the Eigenvalues tab and sort by “Real Part” so that the positive eigenvalue is at the top
- Scroll over and look at the participation factors for this eigenvalue
- These tell how the states map to a particular eigenvalue

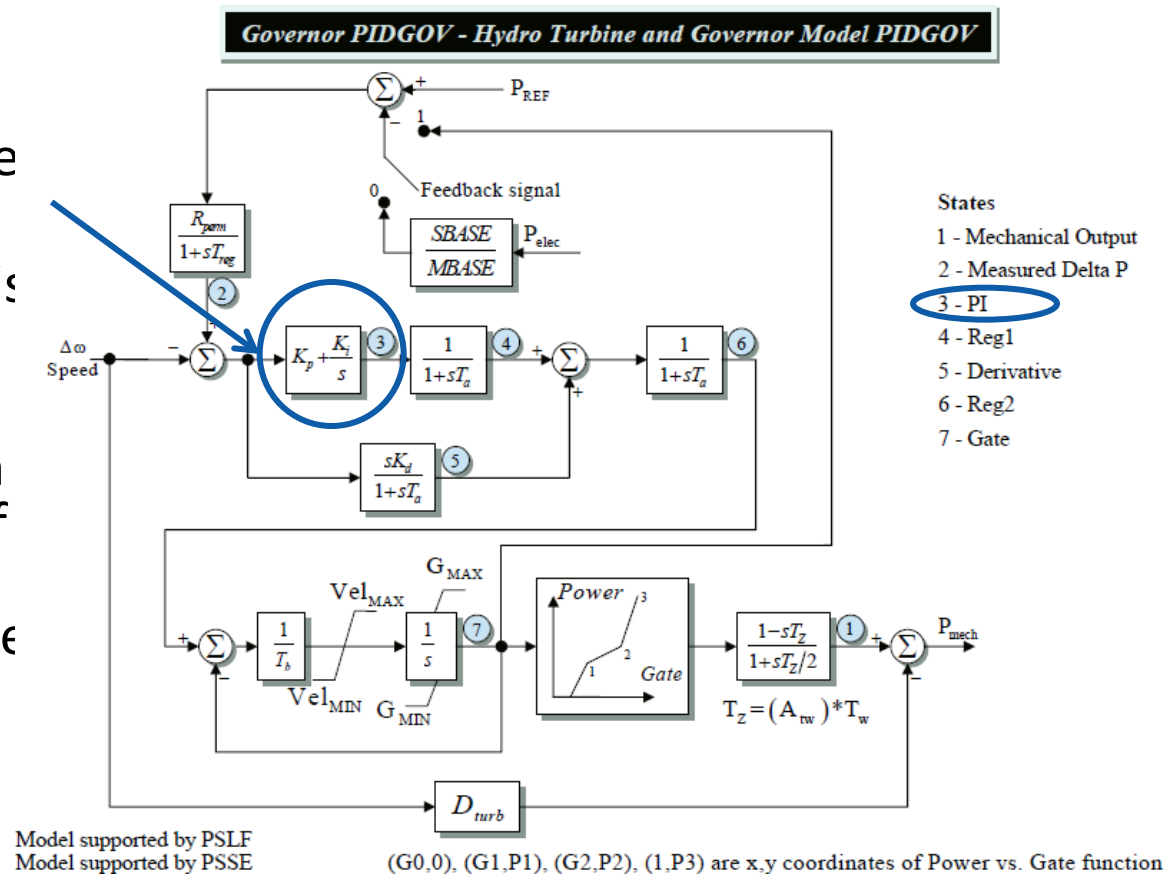
	Exciter VLL1 (Ignored)	Governor Mechanical Output	Governor Measured Delta P	Governor PI	Governor Reg1	Governor Derivative
1	0.0000	0.0263	0.0002	0.9996	0.0062	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000
14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000

The state “Governor PI” makes a large contribution (0.9996) to the positive eigenvalue, while other contributions are zero or close to zero

SMIB Participation Factors



- From the block diagram for **PIDGOV**, the state “**Governor PI**” is right after the point where R_{perm} contributes to the feedback loop
- The positive eigenvalue is indeed due to the governor
- Note that this discussion is the same regardless of whether you use the **Gen_50513_1** case or the full **WestExample**



SMIB Eigenvalues Example



- Also, you can easily make certain models for a particular generator inactive to see how it impacts the SMIB eigenvalues
- This can help you narrow down some of the other sources of positive eigenvalues
- Recall that bus 57236 currently has the largest maximum eigenvalue with 3.5259
- Run Validation and AutoCorrection; then, for bus 57236, make everything inactive except the machine, GENROU
- Re-Initialize and do the analysis again

Disabling all generator models except GENROU makes SMIB Eigenvalues negative

	Number of Bus	Name of Bus	ID	Area Name of Gen	Machine	Exciter	Governor	Stabilizer	Calculated	Number of Eigenvalues	Number of Zero Eigenvalues	Max Eigenvalue	Min Eigenvalue	Eigenvalue
2676	57210	SYNC_G49	G4	ALBERTA	GENROU	EXST1_GE	IEEEG1	WSCCST	YES	23	11	-0.6667	-31.6306	0.0000 + j0
2677	57233	SYNC_UE4	11	ALBERTA	GENROU	EXAC1	IEEEG1	PSS2A	YES	36	12	0.1000	-61.7009	0.0000 + j0
2678	57236	MUSKEG4	1	ALBERTA	GENROU	(ESAC7B)	(GGOV1)	(PSS2A)	YES	6	0	-0.1223	-35.4468	-0.1223 + j0
2679	57249	LNLKCG2	G1	ALBERTA	GENROU	REXS	GGOV1	PSS2A	YES	45	17	-0.0212	-179.0357	0.0000 + j0
2680	57259	HORUP8	1B	ALBERTA					YES	0	0	0.0000	0.0000	

- This generator now has only negative eigenvalues
- Can we narrow down which model is contributing to this small-signal instability?

SMIB Eigenvalues Example



- Re-enable the ESAC7B exciter; Re-Initialize and re-run the analysis

Disabling GGOV1 and PSS2A makes the generator's SMIB Eigenvalues negative

	Number of Bus	Name of Bus	ID	Area Name of Gen	Machine	Exciter	Governor	Stabilizer	Calculated	Number of Eigenvalues	Number of Zero Eigenvalues	Max Eigenvalue	Min Eigenvalue
2676	57210	SYNC_G49	G4	ALBERTA	GENROU	EXST1_GE	IEEEG1	WSCCST	YES	23	11	-0.6667	-31.63
2677	57233	SYNC_UE4	11	ALBERTA	GENROU	EXAC1	IEEEG1	PSS2A	YES	36	12	0.1000	-61.70
2678	57236	MUSKEG4	1	ALBERTA	GENROU	ESAC7B	(GGOV1)	(PSS2A)	YES	12	2	-0.3855	-47.87
2679	57249	LNLKCG2	G1	ALBERTA	GENROU	REXS	GGOV1	PSS2A	YES	45	17	-0.0212	-179.03
2680	57259	HORUP8	1B	ALBERTA					YES	0	0	0.0000	0.00

- This generator still has only negative eigenvalues, so we know its positive eigenvalue was associated with its governor or stabilizer

Disabling only PSS2A still makes the generator's SMIB Eigenvalues negative

	Number of Bus	Name of Bus	ID	Area Name of Gen	Machine	Exciter	Governor	Stabilizer	Calculated	Number of Eigenvalues	Number of Zero Eigenvalues	Max Eigenvalue	Min Eigenvalue
2676	57210	SYNC_G49	G4	ALBERTA	GENROU	EXST1_GE	IEEEG1	WSCCST	YES	23	11	-0.6667	-31.6306
2677	57233	SYNC_UE4	11	ALBERTA	GENROU	EXAC1	IEEEG1	PSS2A	YES	36	12	0.1000	-61.7009
2678	57236	MUSKEG4	1	ALBERTA	GENROU	ESAC7B	GGOV1	(PSS2A)	YES	22	4	-0.2442	-47.8768
2679	57249	LNLKCG2	G1	ALBERTA	GENROU	REXS	GGOV1	PSS2A	YES	45	17	-0.0212	-179.0357
2680	57259	HORUP8	1B	ALBERTA					YES	0	0	0.0000	0.0000

- If we disable only the stabilizer, we again find that this generator has only negative eigenvalues
- This indicates that we should more carefully consider the PSS2A model and its parameters

SMIB Eigenvalues Example



- However, now disable only the exciter ESAC7B and re-enable the other models
- Leave both GGOV1 and PSS2A active and Re-Initialize and run the analysis again
- Interestingly, the Max Eigenvalue for bus 57236 now changes to zero

Disabling ESAC7B makes the generator's SMIB Max Eigenvalue equal zero

	Number of Bus	Name of Bus	ID	Area Name of Gen	Machine	Exciter	Governor	Stabilizer	Calculated	Number of Eigenvalues	Number of Zero Eigenvalues	Max Eigenvalue	Min Eigenvalue
2676	57210	SYNC_G49	G4	ALBERTA	GENROU	EXST1_GE	IEEEG1	WSCCST	YES	23	11	-0.6667	-31.6306 0
2677	57233	SYNC_UE4	11	ALBERTA	GENROU	EXAC1	IEEEG1	PSS2A	YES	36	12	0.1000	-61.7009 0
2678	57236	MUSKEG4	1	ALBERTA	GENROU	(ESAC7B)	GGOV1	PSS2A	YES	35	8	0.0000	-35.4468 0
2679	57249	LNLKCG2	G1	ALBERTA	GENROU	REXS	GGOV1	PSS2A	YES	45	17	-0.0212	-179.0357 0
2680	57259	HORUP8	1B	ALBERTA					YES	0	0	0.0000	0.0000

- Open the SMIB Dialog
- You will see that there are quite a few zero eigenvalues
- These zero eigenvalues are caused by the ignored states- an ignored state will have a participation factor of one for one of the zero eigenvalues
- This is true for a lot (but not all) of the zero eigenvalues in the case

SMIB Eigenvalues Example



- Let's look at the participation factors for the maximum eigenvalue of Bus 57236
- Re-enable all of the models for Bus 57236 if you disabled them
- Click "Re-Initialize" and "Run SMIB Eigen Analysis"
- Then, right-click and "Show SMIB Dialog" for Bus 57236
- Open the Eigenvalues tab and sort by "Real Part"
- There are actually two positive eigenvalues for this generator which are complex conjugates
- The state "Stabilizer Transducer 2" has a relatively large participation factor, but it is not the largest (scroll over and look at the other states, especially some of the machine states)
- In this example, the cause of the instability does not seem as obvious to identify

SMIB Eigenvalues Example



- Let's save out the 2-bus equivalent for the bus 57236
- Save it as **Gen_57236_1.pwb** (this should be the default name that appears in the save dialog) Save two-bus equivalent for this bus

SMIB Eigenvalues

Run SMIB Eigen Analysis Re-Initialize Eigenvalue Analysis Last Run: 6/8/2010 2:08:48 PM

	Number of Bus	Name of Bus	ID	Area Name of Gen	Machine	Exciter	Governor	Stabilizer	Calculated	Number of Eigenvalues	Number of Zero Eigenvalues	Max Eigenval	Min Eigen
1	57236	MUSKEG4				ESAC7B	GGOV1	PSS2A	YES	41	12	3.5259	-4%
2	57836	MUSKEG6				ESAC7B	GGOV1	PSS2A	YES	41	10	3.5183	-4%
3	51444	BKL 1S1							YES	6	0	1.2363	-4%
4	24123	REDON7 G				EXDC1	IEEEG1	WSCCST	YES	23	5	0.8914	-3%
5	24124	REDON8 G				EXDC1	IEEEG1	WSCCST	YES	23	5	0.8862	-3%
6	31788	ROCK CK2				EXDC4	HYGOV		YES	11	0	0.7285	-3%
7	24161	ALAMT6 G				EXDC1	IEEEG1	WSCCST	YES	23	5	0.6959	-3%
8	66060	NAUGT G2				EXST2A	IEEEG1	IEEEEST	YES	24	8	0.6818	-3%
9	70568	RAWHIDEB				ESAC7B	GGOV1	PSS2A	YES	41	11	0.5446	-6%
10	70569	RAWHIDEC				ESAC7B	GGOV1	PSS2A	YES	41	13	0.5372	-6%
11	24123	REDON7 G				EXDC1	WSCCST		YES	17	4	0.5097	-2%
12	24124	REDON8 G				EXDC1	WSCCST		YES	17	4	0.5088	-2%
13	24161	ALAMT6 G				EXDC1	WSCCST		YES	17	4	0.4305	-2%
14	32171	HIGHWIND3				EXWTG1			YES	6	0	0.3408	-2%
15	46439	ROSS 42					PIDGOV	PSS2A	YES	31	8	0.1985	-3%
16	34329	STAR_GT2				EXAC8B	GAST_GE	PSS2A	YES	35	10	0.1350	-4%
17	34328	STAR_GT1				EXAC8B	GAST_GE	PSS2A	YES	35	10	0.1350	-4%
18	52141	COR-G1				EXDC4	GPWSCC		YES	14	1	0.0688	-7%
19	70069	CABCRKA				EXST1_GE	HYGOV	IEEEEST	YES	21	7	0.0410	-5%
20	51499	HAC 4G1							YES	6	0	0.0316	-4%
21	43557	SULIVAN							YES	6	0	0.0260	-6%
22	50513	PCN 13G1				EXST1_GE	PIDGOV	PSS2A	YES	36	11	0.0119	-9%
23	50515	PCN 13G3				EXST1_GE	PIDGOV	PSS2A	YES	36	12	0.0059	-5%
24	51214	SSH 4G1							YES	6	0	0.0029	-4%
25	51213	M3C 4G1							YES	6	0	0.0023	-4%
26	54062	SHERRITT							YES	0	0	0.0000	0
27	64120	TRACY G4	1	SIERRA	GENSAL	EXST4B	GGOV1	PSS2A	YES	39	10	0.0000	-3%
28	38951	TBC POT2	1	PG AND E	GENROU				YES	0	0	0.0000	0

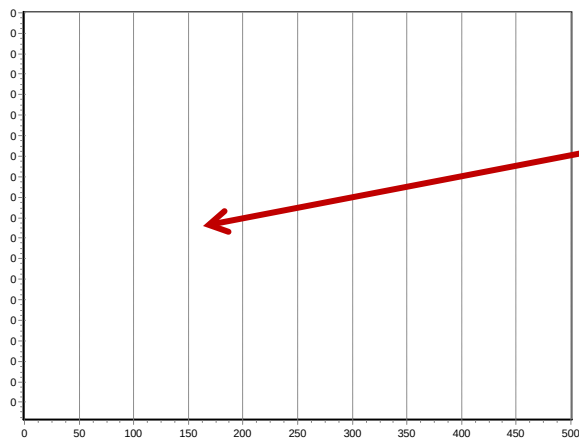
Context Menu for Row 1 (Bus 57236):

- Show SMIB Dialog
- Save Two Bus Equivalent**
- Show Dialog...
- Display/Column Options...
- Search for Text...
- Transient Generator records
- Set/Toggle/Columns
- Copy/Paste/Send
- Advanced Row Filter...
- Advanced Row Sort...
- Advanced Column Filter...
- Advanced Column Sort...
- f(x) Define Expression...
- Refresh Display
- Help (F1)
- Form Control

SMIB Eigenvalues Example

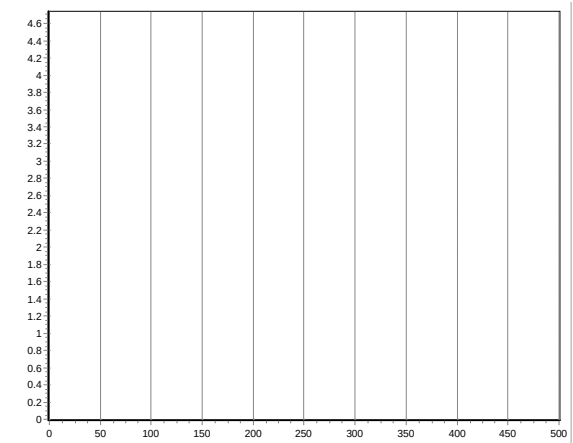


- Open **Gen_57236_1.pwb**
- It has two buses, the slack bus which is also the infinite bus, and bus 57236 with attached generator models
- Running the analysis for 500 seconds with no event does not cause numerical instability like in the earlier example
- More analysis is needed to determine what is causing the positive eigenvalues



Gen_57236_1, stabilizer states

The stabilizer is the only model with states that are not completely flat, as they should be in steady-state



Gen_57236_1, all other states