Signal Hill dynamic stability modeling notes and assumptions

Models

Dynamic stability studies were conducted using GE PSLF 1.42_06.

1. The dynamic models used for the wind farm were the wind turbine models for the GE 1.5 and 3.6 MW Wind Turbine Generators. These models consist of the "gewtg" generator/converter model, the "exwtge" excitation (converter) control model, and the "wndtge" wind turbine control model.
2. Default values for the "gewtg" model were used. The machines were assumed to have Low Voltage Ride-Through (LVRT) capability.
3. Default values for the "exwtge" model were used:
    a. The wind farm was assumed to have a centralized "WindVAR" controller.
    b. The voltage controller was assumed to be closed-loop.
    c. The regulated bus was assumed to the be 34.5 kV collector bus.
    d. The machine was set to regulate VARS as opposed to power factor.
4. Default values for the "wndtge" model were used. A single-mass model was used.

Procedure

Stability results were evaluated based on the WECC Planning Standards criteria for transient stability. For a single-contingency event, transient voltage dip may not exceed 30% at any bus, 25% at load buses, and may not exceed 20% for more than 20 cycles at load buses. Frequency variations may not be below 59.6 Hz for more than 6 cycles at load buses.

The following faults were studied to determine the effect of the Project on transient stability:

1. 3-phase fault at the Lamar 230 kV bus, cleared after 4 cycles by tripping the Boone-Lamar 230 kV line, circuit 2.
2. 3-phase fault at the Boone 230 kV bus, cleared after 6 cycles by tripping the Boone-Lamar 230 kV line, circuit 2.
3. 3-phase fault at the Lamar 115 kV bus, cleared after 6 cycles by tripping the Lamar 230-115 kV transformer.
4. 3-phase fault at the Colorado Green 230 kV bus, cleared after 4 cycles by tripping the Lamar-Colorado Green 230 kV line.
5. 3-phase fault at the Signal Hill 230 kV bus, cleared after 6 cycles by tripping the Signal Hill-Lamar 230 kV line.
6. 3-phase fault at the Midway 230 kV bus, cleared after 6 cycles by tripping the Boone-Midway 230 kV line, circuit 2.
7. 3-phase fault at the Comanche Station 230 kV bus, cleared after 6 cycles by tripping the Comanche Unit 1 generator and station load.
8. Single-line-to-ground fault at the Boone 230 kV bus, with a delayed clearing time of 20 cycles by tripping the Boone-Lamar 230 kV line, circuit 2.

9. Single-line-to-ground fault at the Comanche Station 230 kV bus, with a delayed clearing time of 20 cycles by tripping the Comanche Unit 1 generator and station load.
10. Single-line-to-ground fault at the Midway 230 kV bus, with a delayed clearing time of 20 cycles by tripping the Boone-Midway 230 kV line, circuit 2.
11. Single-line-to-ground fault at the Lamar 230 kV bus, with a delayed clearing time of 20 cycles by tripping the Boone-Lamar 230 kV line, circuit 2.

Results

The system was monitored for transient stability violations for each of the fault scenarios. Table 2 summarizes the results of the study. The wind generation tripped offline on undervoltage conditions for the 3-phase faults located on the Lamar and Boone 230 kV buses (Fault 1 and Fault 2). The generation tripped because the voltage at the collector bus dipped to less than 0.3 per-unit voltage.

Voltage and frequency dip violations were observed at Lamar at distribution level voltages for several of the fault cases. These are due to the tripping of the nearby Colorado Green wind turbines, and in the Project cases, the tripping of the Project's wind turbines.

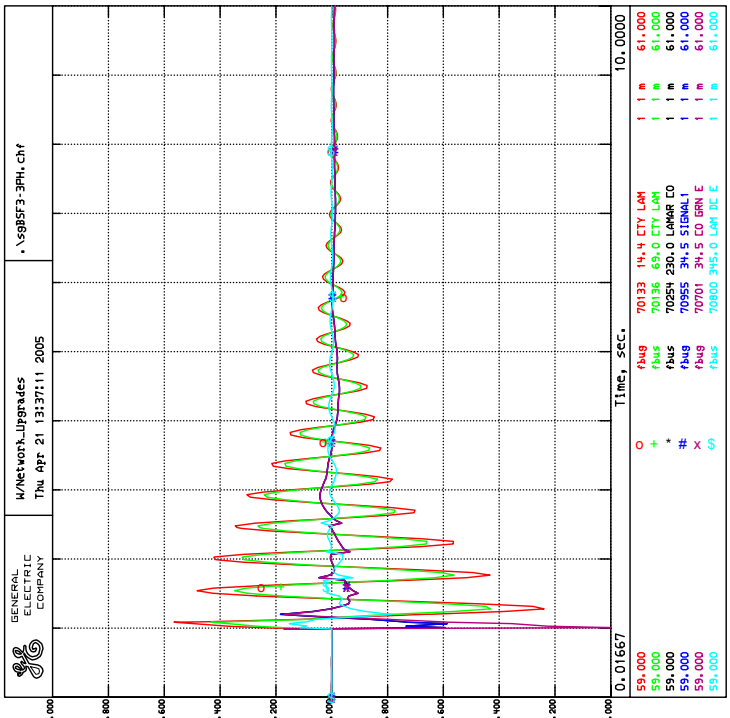
Table 1 - Transient Stability Results – Base Case

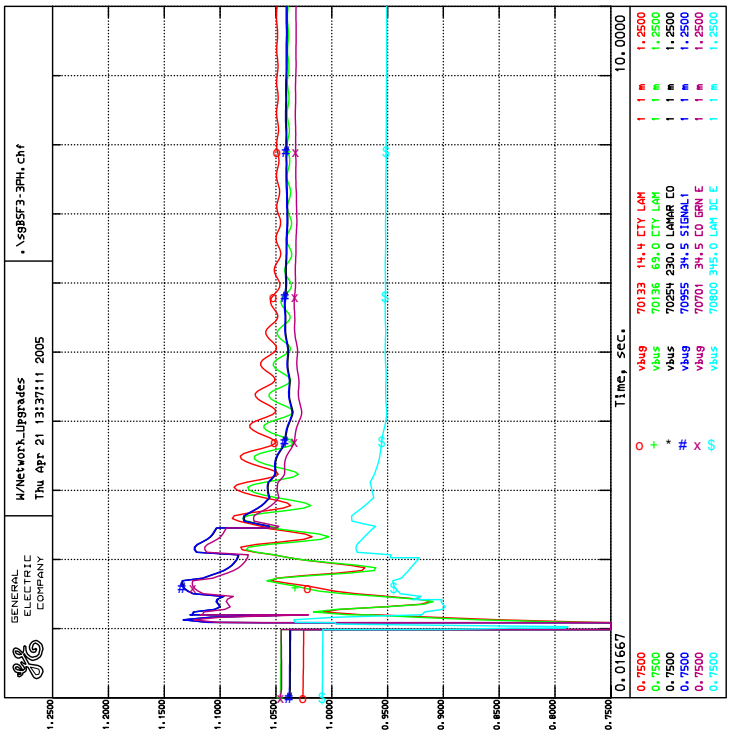
	Fault Location	Action	Result
6	3PH at Midway 230 kV bus; 6 cycles	Trip Boone-Midway 230 kV line, circuit 2	System Stable, Colorado Green Wind Tripped
7	3PH at Comanche Station 230 kV bus; 6 cycles	Trip Comanche Unit 1	System Stable, Colorado Green Wind Tripped
8	SLG at Boone 230 kV bus; 20 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable, Colorado Green Wind Tripped
11	SLG at Lamar 230 kV bus; 20 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable

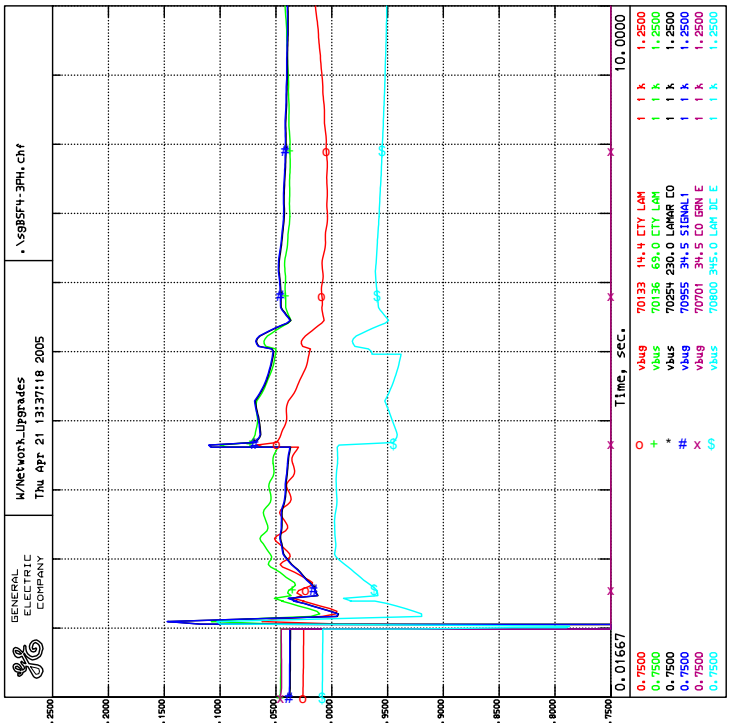
Table 2 - Transient Stability Results – Base Case with Network Upgrades (Signal Hill Generation Off) <dpb updated table on 4.26.5>

	Fault Location	Action	Result
1	3PH at Lamar 230 kV bus, 4 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable, Colorado Green Wind Tripped
2	3PH at Boone 230 kV bus, 6 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable, Colorado Green Wind Tripped Frequency Violation: 40.7 Hz for 11 cycles at CO GRN 34.5 <dpb note: need all RAS schemes that trip the CO GRN 230 kV line. Tripping fixes this problem.>
3	3PH at Lamar 115 kV bus; 6 cycles	Trip Lamar 230-115 kV transformer	System Stable, Colorado Green Wind Tripped • Overvoltage spike fixed at CO GRN 34.5 • Frequency violations fixed at CHENEY 69, FT HOLLY 69, HILLTOP 69, SPRNGFLD 69, SPRNGFLD 4.2, VILLAS 69, WALSH 69, T BUTTES 69
4	3PH at Colorado Green 230 kV bus; 4 cycles	Trip Lamar-Colorado Green 230 kV line	System Stable, Colorado Green Wind Tripped
5	3PH at Signal Hill 230 kV bus; 6 cycles	Trip Signal Hill-Lamar 230 kV line	System Stable, Colorado Green Wind Tripped • All overvoltage spikes fixed: CHENEY 69, CTY LAM 69, EADS 69, FT HOLLY 69, FT. LYON 69, GRANADA 69, HILLTOP 69, PROWERS 69, SPRNGFLD 69, SPRNGFLD 4.2, T BUTTES 69, VILAS 69, WALSH 69, WILOW CK 69, CO GRN 34.5 • All frequency violations fixed: CTY LAM 14.4
6	3PH at Midway 230 kV bus; 6 cycles	Trip Boone-Midway 230 kV line, circuit 2	System Stable, Colorado Green Wind Tripped • All frequency violations fixed: CTY LAM 14.4, CTY LAM 25, CTY LAM 4.2, HOLLY 25, HOLLY 4
7	3PH at Comanche Station 230 kV bus; 6 cycles	Trip Comanche Unit 1	System Stable, Colorado Green Wind Tripped • All frequency violations fixed: CTY LAM 14.4, CTY LAM 25, CTY LAM 4.2, HOLLY 25, HOLLY 4, CTY LAM 69, FT. LYON 69, PROWERS 69
8	SLG at Boone 230 kV bus; 20 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable
9	SLG at Comanche Station 230 kV bus; 20 cycles	Trip Comanche Unit 1	System Stable
10	SLG at Midway 230 kV bus; 20 cycles	Trip Boone-Midway 230 kV line, circuit 2	System Stable
11	SLG at Lamar 230 kV bus; 20 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable

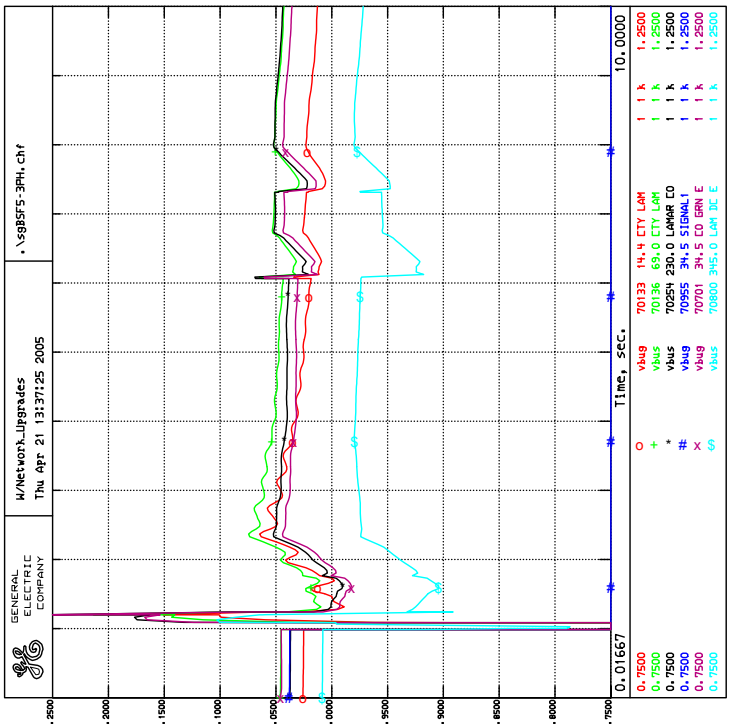
12	3PH at Boone 230 kV bus; 6 cycles	Trip Boone 230-115 kV transformer	System Stable, Colorado Green Wind Tripped Voltage and Frequency Violations: • Voltage dip > 25% at load buses: BOONE 69, FOWLER 69, HUERFANO 69, LAJUNTAW 69, LS ANMAS 69, 4.2, MANZANOL 69, ORDWAY 69, PHILLIPS 69, ROCKYFRD 69, SNEPESTA 69 • 43.0 Hz for 11 cycles at CHENEY 69, FT. HOLLY 69, HILLTOP 69, SPRNGFLD 69, 4.2, T BUTTES 69, VILAS 69, WALSH 69, WILOW CK 69 • 47.2 Hz for 11 cycles at CTY LAM 69,25, 14.4, 4.2, EADS 69, FT. LYON 69, GRANADA 69, HOLLY 25, 4.0, PROWERS 69, WILOW CK 69 Post-transient voltage deviation of > 5%: • 0.86 to 0.88 pu final voltage at FOWLER 69, LAJUNTAW 115, LS ANMAS 4.0, MANZANOL 69, ORDWAY 69 • 0.90 to 0.95 pu final voltage at APT MEM 115, APT PARK 115, BOONE 115, 69, CTY LAJ 69, 13.8, DOT 115, HUERFANO 69, LA SEPCA 69, LAJ IP 69, LAJUNTAW 69, LS ANMAS 69, NTHRIDGE 115, PHILLIPS 69, ROCKYFRD 69, SNEPESTA 69


GENERAL ELECTRIC COMPANY
W/Network_Upgrades
Thu Apr 21 13:37:11 2005
.\SB5F3-3PH.chf
61.000
60.800
60.600
60.400
60.200
60.000
59.800
59.600
59.400
59.200
59.000
0.01667
Time, sec.
10.0000
59.000 O fbus 70133 14.4 CTY LAM 1 1 m 61.000
59.000 + fbus 70136 69.0 CTY LAM 1 1 m 61.000
59.000 * fbus 70254 230.0 LAMAR CO 1 1 m 61.000
59.000 # fbus 70955 34.5 SIGNAL1 1 1 m 61.000
59.000 x fbus 70701 34.5 CO GRN E 1 1 m 61.000
59.000 $ fbus 70800 345.0 LAM DC E 1 1 m 61.000
GI-2004-11 Signal Hill 69 MW
System Impact Study
Fault 3: 3PH Fault at LAMAR CO 115 kV Bus
Clearing: 6 cyc, Trip LAMAR CO 230-115 kV Xfmr


GENERAL ELECTRIC COMPANY
W/Network_Upgrades
Thu Apr 21 13:37:11 2005
.\SB5F3-3PH.chf
1.2500
1.2000
1.1500
1.1000
1.0500
1.0000
0.9500
0.9000
0.8500
0.8000
0.7500
0.01667
Time, sec.
10.0000
0.7500 O vbus 70133 14.4 CTY LAM 1 1 m 1.2500
0.7500 + vbus 70136 69.0 CTY LAM 1 1 m 1.2500
0.7500 * vbus 70254 230.0 LAMAR CO 1 1 m 1.2500
0.7500 # vbus 70955 34.5 SIGNAL1 1 1 m 1.2500
0.7500 x vbus 70701 34.5 CO GRN E 1 1 m 1.2500
0.7500 $ vbus 70800 345.0 LAM DC E 1 1 m 1.2500
GI-2004-11 Signal Hill 69 MW
System Impact Study
Fault 3: 3PH Fault at LAMAR CO 115 kV Bus
Clearing: 6 cyc, Trip LAMAR CO 230-115 kV Xfmr



GI-2004-11 Signal Hill 69 MW
System Impact Study
Fault 4: 3PH Fault at COLO GRN 230 kV Bus
Clearing: 4 cyc, Trip LAMAR CO-COLO GRN 230 kV Line



GI-2004-11 Signal Hill 69 MW
System Impact Study
Fault 5: 3PH Fault at SIGNALHL 230 kV Bus
Clearing: 6 cyc, Trip SIGNALHL-LAMAR CO 230 kV Line

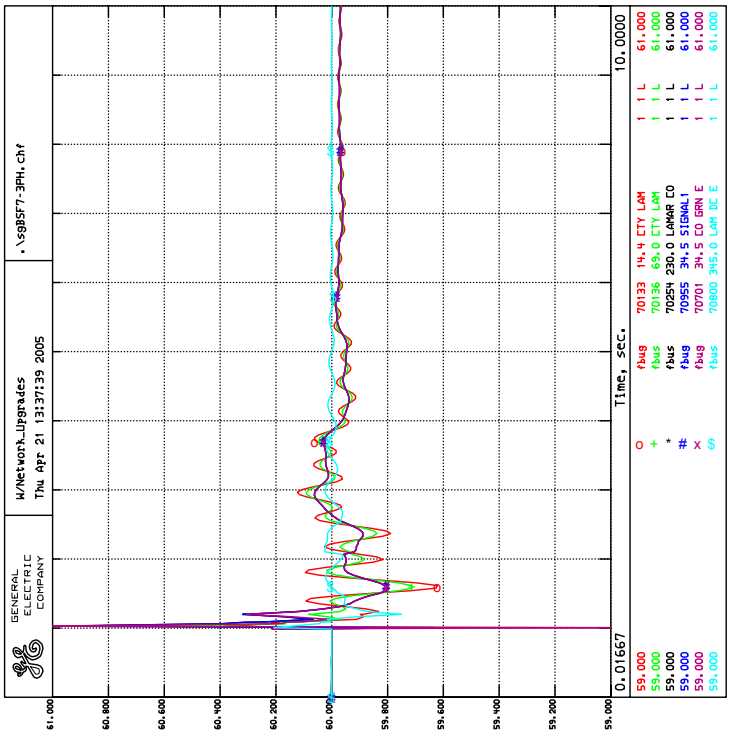

GENERAL ELECTRIC COMPANY
M/Network_Upgrades
Thu Apr 21 13:37:39 2005
.\SgBSF7-3PH.chf
61.000
60.800
60.600
60.400
60.200
60.000
59.800
59.600
59.400
59.200
59.000
0.01667
Time, sec.
10.0000
59.000 O #bus 70133 14.4 CTY LAM 1 1 L 61.000
59.000 + #bus 70136 69.0 CTY LAM 1 1 L 61.000
59.000 * #bus 70254 230.0 LAMAR CO 1 1 L 61.000
59.000 # #bus 70955 34.5 SIGNAL1 1 1 L 61.000
59.000 x #bus 70701 34.5 CO GRN E 1 1 L 61.000
59.000 #bus 70800 345.0 LAM DC E 1 1 L 61.000
GI-2004-11 Signal Hill 69 MW
System Impact Study
Fault 7: 3PH Fault at COMANCHE 230 kV Bus
Clearing: 6 cyc, Trip COMAN 1 Gen and Plant Load

Table 3 - Transient Stability Results – Case with 69 MW Signal Hill Wind and Network Upgrades <dpb updated table on 4.19.5>

	Fault Location	Action	Result
1	3PH at Lamar 230 kV bus, 4 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable, Colorado Green Wind Tripped
2	3PH at Boone 230 kV bus, 6 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable, Colorado Green Wind Tripped, Signal Hill Wind Tripped. New frequency violations: • 59.4 Hz for 6 cycles at CTY LAM 14.4
3	3PH at Lamar 115 kV bus; 6 cycles	Trip Lamar 230-115 kV transformer	System Stable, Colorado Green Wind Tripped New frequency violations: • 59.5 Hz for 7 cycles at CHEN TAP 69, CHENEY 69, FT HOLLY 69, HOLL TAP 69
4	3PH at Colorado Green 230 kV bus; 4 cycles	Trip Lamar-Colorado Green 230 kV line	System Stable, Colorado Green Wind Tripped
5	3PH at Signal Hill 230 kV bus; 6 cycles	Trip Signal Hill-Lamar 230 kV line	System Stable, Colorado Green Wind Tripped, Signal Hill Wind Tripped
6	3PH at Midway 230 kV bus; 6 cycles	Trip Boone-Midway 230 kV line, circuit 2	System Stable, Colorado Green Wind Tripped, Signal Hill Wind Tripped
7	3PH at Comanche Station 230 kV bus; 6 cycles	Trip Comanche Unit 1	System Stable, Colorado Green Wind Tripped, Signal Hill Wind Tripped New frequency violations: • 59.6 Hz for 7 cycles at PUEBLO 69[i]
8	SLG at Boone 230 kV bus; 20 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable
9	SLG at Comanche		
	SLG at Midway 230 kV bus; 20 cycles	Trip Boone-Midway 230 kV line, circuit 2	System Stable
11	SLG at Lamar 230 kV bus; 20 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable
12	3PH at Boone 230 kV bus; 6 cycles	Trip Boone 230-115 kV transformer	System Stable, Colorado Green Wind Tripped; Signal Hill Wind Tripped

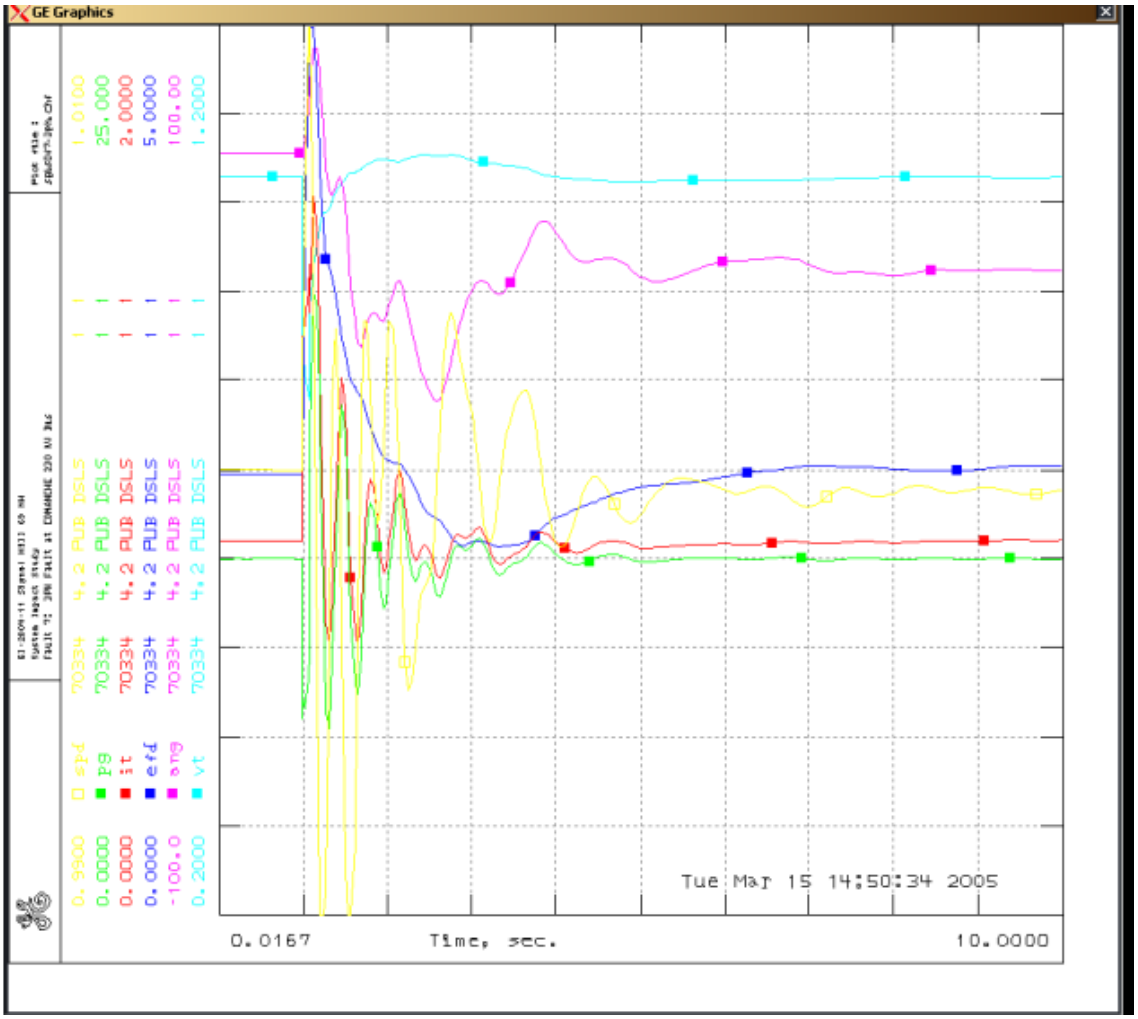
Table 4 - Transient Stability Results – Base Case with GI-2004-2 (Colorado Green Expansion)

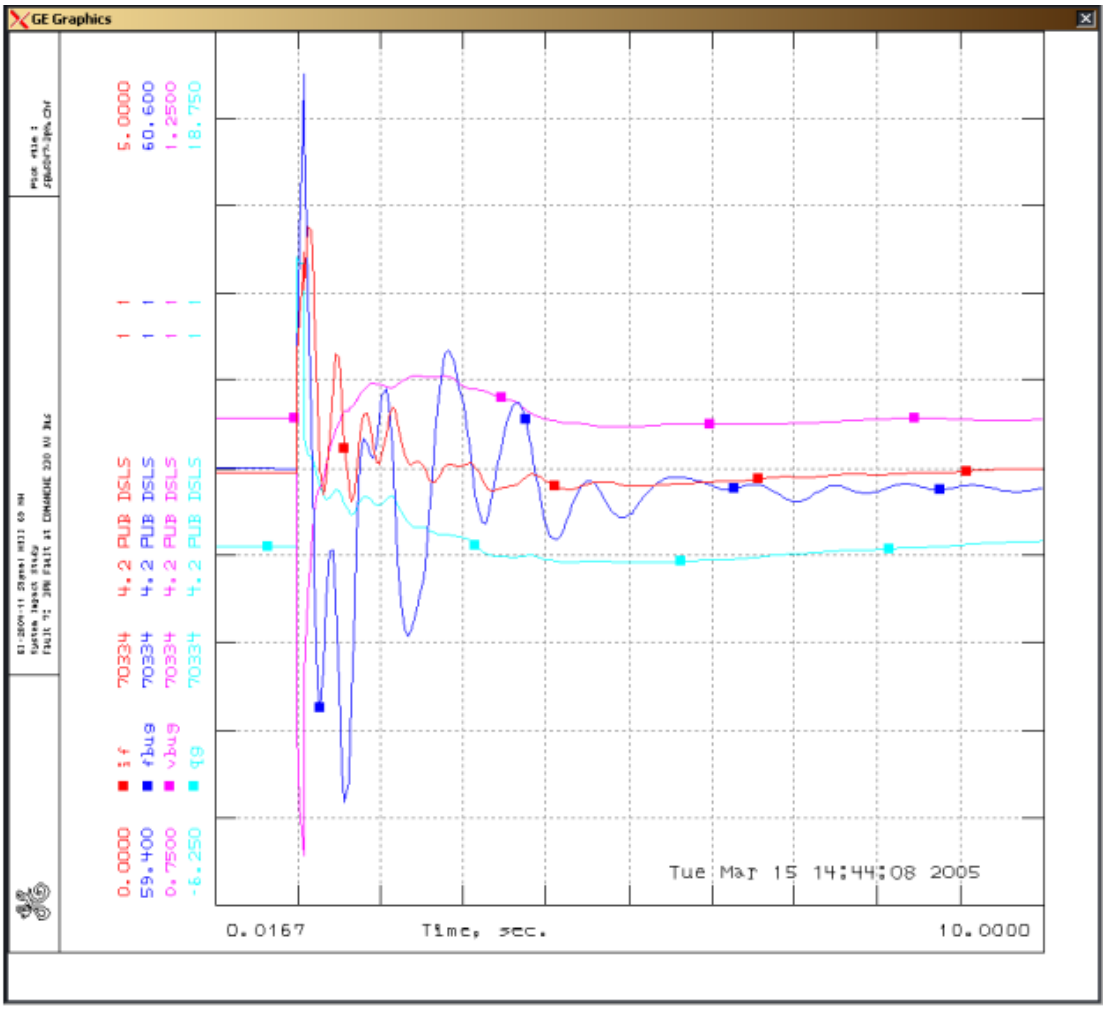
	Fault Location	Action	Result
1	3PH at Lamar 230 kV bus, 4 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable, Colorado Green Wind 1 & 2 Tripped
2	3PH at Boone 230 kV bus, 6 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable, Colorado Green Wind 1 & 2 Tripped
3	3PH at Lamar 115 kV bus; 6 cycles	Trip Lamar 230-115 kV transformer	System Stable, Colorado Green Wind 1 & 2 Tripped
4	3PH at Colorado Green 230 kV bus; 4 cycles	Trip Lamar-Colorado Green 230 kV line	System Stable, Colorado Green Wind 1 & 2 Tripped
5	3PH at Signal Hill 230 kV bus; 6 cycles	Trip Signal Hill-Lamar 230 kV line	System Stable, Colorado Green Wind 1 & 2 Tripped
6	3PH at Midway 230 kV bus; 6 cycles	Trip Boone-Midway 230 kV line, circuit 2	System Stable, Colorado Green Wind 1 & 2 Tripped
7	3PH at Comanche Station 230 kV bus; 6 cycles	Trip Comanche Unit 1	System Stable, Colorado Green Wind 1 & 2 Tripped
8	SLG at Boone 230 kV bus; 20 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable, Colorado Green Wind 1 & 2 Tripped
9	SLG at Comanche Station 230 kV bus; 20 cycles	Trip Comanche Unit 1	System Stable
10	SLG at Midway 230 kV bus; 20 cycles	Trip Boone-Midway 230 kV line, circuit 2	System Stable
11	SLG at Lamar 230 kV bus; 20 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable, Colorado Green Wind 1 & 2 Tripped

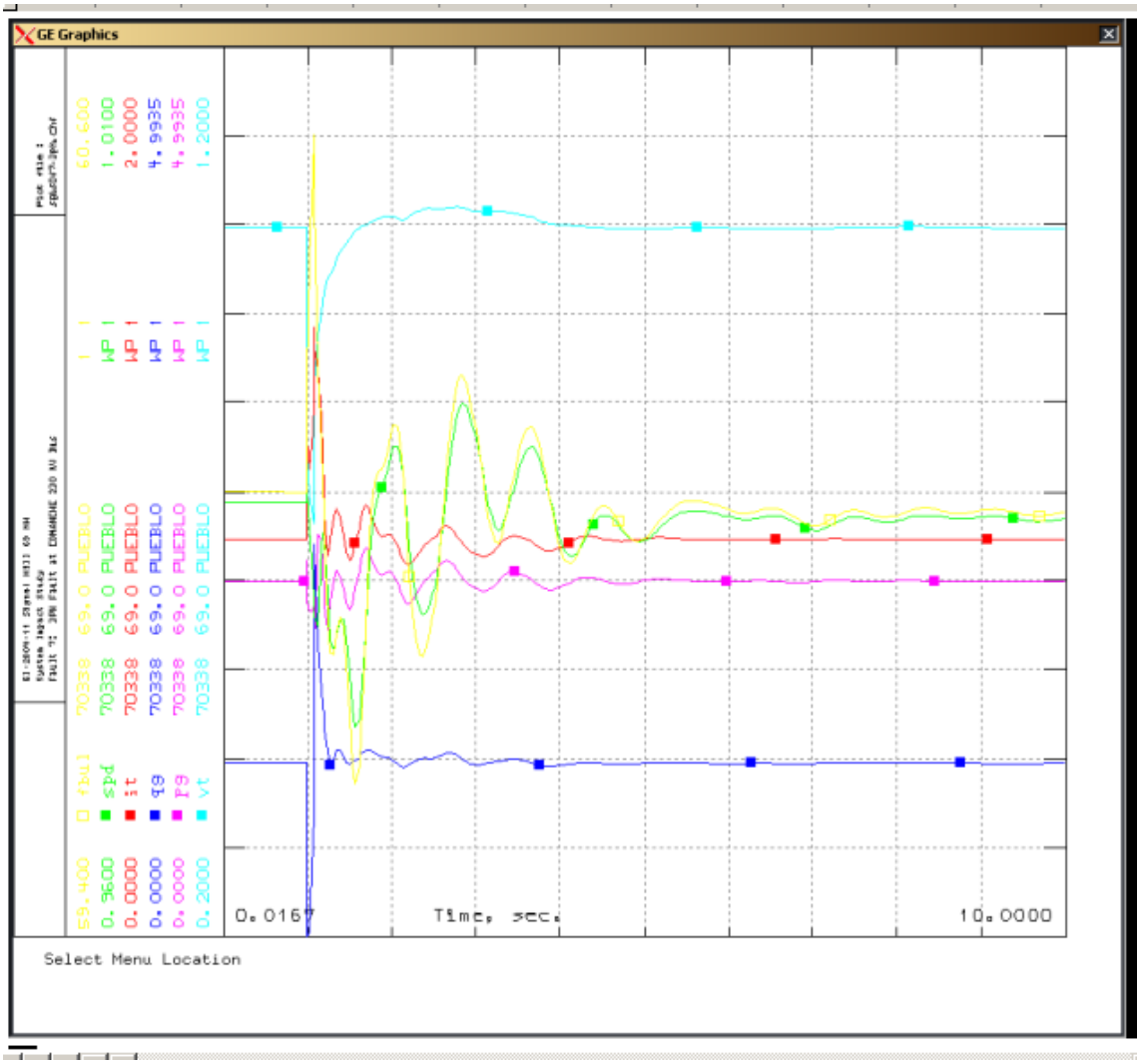
Table 5 - Transient Stability Results – Case with GI-2004-2 and 69 MW Signal Hill Wind

	Fault Location	Action	Result
1	3PH at Lamar 230 kV bus, 4 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable, Colorado Green Wind 1 & 2 Tripped, Signal Hill Wind Tripped
2	3PH at Boone 230 kV bus, 6 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable, Colorado Green Wind 1 & 2 Tripped, Signal Hill Wind Tripped
3	3PH at Lamar 115 kV bus; 6 cycles	Trip Lamar 230-115 kV transformer	System Stable, Colorado Green Wind 1 & 2 Tripped
4	3PH at Colorado Green 230 kV bus; 4 cycles	Trip Lamar-Colorado Green 230 kV line	System Stable, Colorado Green Wind 1 & 2 Tripped
5	3PH at Signal Hill 230 kV bus; 6 cycles	Trip Signal Hill-Lamar 230 kV line	System Stable, Colorado Green Wind 1 & 2 Tripped, Signal Hill Wind Tripped
6	3PH at Midway 230 kV bus; 6 cycles	Trip Boone-Midway 230 kV line, circuit 2	System Stable, Colorado Green Wind 1 & 2 Tripped, Signal Hill Wind Tripped • 59.5 Hz for 6 cycles at CTY LAM 14.4
7	3PH at Comanche Station 230 kV bus; 6 cycles	Trip Comanche Unit 1	System Stable, Colorado Green Wind 1 & 2 Tripped • 59.5 Hz for 7 cycles at CTY LAM 14.4
8	SLG at Boone 230 kV bus; 20 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable, Colorado Green Wind 1 & 2 Tripped, Signal Hill Wind Tripped • 59.5 Hz for 7 cycles at CTY LAM 14.4
9	SLG at Comanche Station 230 kV bus; 20 cycles	Trip Comanche Unit 1	System Stable
10	SLG at Midway 230 kV bus; 20 cycles	Trip Boone-Midway 230 kV line, circuit 2	System Stable
11	SLG at Lamar 230 kV bus; 20 cycles	Trip Boone-Lamar 230 kV line, circuit 2	System Stable, Colorado Green Wind 1 & 2 Tripped, Signal Hill Wind Tripped

[i] Frequency dip is likely due to under-damped model for generator 70334 “PUB DSLS”. May also be due to interactions between 70334 generator and 70338 load “HP.” See plots attached to this footnote.


GE Graphics
spd
Pg
it
eff
emg
vt
Tue Mar 15 14:50:34 2005
0.0167
Time, sec.
10.0000


GE Graphics
5.0000
60.600
1.2500
18.750
1 1
4.2 PUB DSLS
70334
if
fbug
vbug
qg
0.0000
59.400
0.7500
-6.250
Tue Mar 15 14:44:08 2005
0.0167
Time, sec.
10.0000


GE Graphics
60.600
1.0100
2.0000
4.9935
4.9935
1.2000
1
WP 1
WP 1
WP 1
WP 1
WP 1
69.0 PUEBLO
69.0 PUEBLO
69.0 PUEBLO
69.0 PUEBLO
69.0 PUEBLO
69.0 PUEBLO
70338
70338
70338
70338
70338
70338
fbll
spd
it
q9
p9
vt
59.400
0.9600
0.0000
0.0000
0.0000
0.2000
0.0167
Time, sec.
10.0000
Select Menu Location