TANC

Transmission Agency of Northern California

2010 NEAR-TERM AND LONG-TERM POST-TRANSIENT POWERFLOW AND TRANSIENT STABILITY STUDIES FOR THE CALIFORNIA-OREGON TRANSMISSION PROJECT

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EXECUTIVE SUMMARY

The Transmission Agency of Northern California (TANC), a joint exercise of powers agency formed under the laws of the State of California, was established in 1984 for the primary purpose of studying, developing, owning, and operating transmission facilities which can be utilized by the TANC Members to access resources and increase the load serving capability of the TANC Member electric systems. As discussed in greater detail in Section 1, TANC is the largest participant in and the Project Manager for the 500-kV California-Oregon Transmission Project (COTP). The purpose of this report is to present the results of technical studies which demonstrate how TANC's transmission facilities meet the requirements of the North American Electric Reliability Corporation (NERC) Transmission Planning Reliability Standards (NERC Standards) TPL-001-0, TPL-002-0, TPL-003-0, and TPL-004-0. This report is the fourth such document prepared by TANC[1] and reflects TANC's commitment to undertake such assessments on an annual basis.

TANC performed technical studies to assess the performance of the 500-kV system in Northern California for Category A, Category B, and Category C contingency conditions with powerflow cases which modeled near-term on-peak and off-peak loads and long-term on-peak loads. In addition, TANC performed transient stability studies of a Category D contingency on the near-term and long-term on-peak load powerflow cases. In all of the cases studied, the 500-kV network in northern California was highly stressed and was operating outside of the parameters associated with existing operating nomograms. The near-term (2014-2015 time frame) on-peak and off-peak cases were selected for these studies to assess system performance with rated flows over the three California-Oregon Intertie (COI) 500-kV lines (which include the COTP). The long-term (2020) on-peak case was used to assess how increases in loads would impact the performance of the system. Additional information on the base cases used in the studies and the criteria applied during the studies is presented in Section 2.

Specifically, this report summarizes the results of:

- Post-transient powerflow studies which assessed the performance of the system for the 2015 summer off-peak and the 2015 and 2020 summer on-peak conditions. These studies investigated system performance for Category A conditions and for the Category B and C contingencies listed in Appendix B[2].

[1] TANC's annual assessment for 2009 was submitted to the WECC in January of 2010.
[2] The contingencies listed in Appendix B are those simulated by the California Operating Studies Subcommittee (OSS) in its seasonal operating studies.

- Reactive margin studies were performed to determine the reactive margins at critical buses for the Category B and C contingencies listed in Appendix B. These studies were performed on the 2015 and 2020 summer peak cases.
- Transient stability studies were performed to assess system stability for the Category B, C, and D contingencies listed in Appendix B. These studies were performed on the 2015 and 2020 summer peak cases.

It is likely that additional transmission facilities would be required in northern California to facilitate meeting the goals and mandates of the State of California regarding the development of renewable resources and the reduction of greenhouse gas emissions. The potential benefits and impacts of such facilities are not reflected in this report. TANC continues to coordinate and participate with other parties in discussions and joint studies (e.g., California Transmission Planning Group (CTPG) and the Sierra Subregional Planning Group (SSPG)) to identify the additional transmission facilities that would be located in northern California. The CTPG conducts statewide planning studies and issues reports from time to time which can be found on its web site. Reports on studies performed by the SSPG can be found on the WestConnect website. Information regarding any potential facilities that might be developed by TANC will be reflected, as appropriate, in future Study Reports filed by TANC.

Summary of Findings

The results of the above studies (which are discussed in greater detail in subsequent sections of this report) are summarized as follows:

<u>Post-Transient Power Flow Studies (Section 3)</u>

The post-transient power flow studies show that:

- For Category A conditions:
  - There would be no overloads in the cases modeling 2015 and 2020 on-peak load conditions or 2015 off-peak load conditions.
- For Category B conditions:
  - There would be no overloaded facilities rated 115-kV or higher in the northern California area in the 2015 on-peak case.
  - The CPV Station-Cortina 230-kV line is overloaded by about 3% in the 2020 on-peak case. As shown in Table 3-3 several options for mitigating this overload have been identified in the California Independent Operator's (CAISO) ***2010 CAISO Transmission Plan***.

  - The East Nicolaus–Rio Oso 115-kV line experiences an overload of 9% in the 2015 off-peak load case. This overload could be mitigated by reconductoring the 115-kV lines per the CAISO's transmission plan.
- For Category C conditions:
  - There would be no overloaded 500-kV transmission lines in the northern California area if the pertinent short-term emergency ratings were applied or if the planned upgrades to the pertinent 500-kV facilities were modeled as discussed in Table 3-4.
  - The Olinda 500/230-kV transformer would be overloaded by 7% in the 2015 off-peak load case. This overload could be mitigated by applying Special Protection Systems (SPS) needed for the new Hatchet Ridge generation interconnection (as discussed in the 2010 CAISO transmission plan) and by curtailing wind generation in Solano County.
  - The Round Mountain 500/230-kV transformer would be overloaded (by as much as 10% of its normal rating) in the 2015 off-peak load case (which does not model an emergency rating for this transformer). This overload would not exist if an emergency rating (such as that modeled in the 2020 on-peak case) was established for this transformer.
  - The Table Mountain 500/230-kV transformer would be overloaded (by as much as 7% of its normal rating) in the 2020 peak load case. This overload also occurs in the 2015 on-peak and off-peak cases. This overload would likely be mitigated by establishing an emergency rating for the transformer as recommended in the CAISO's transmission plan.
  - The CPV Station-Cortina 230-kV line is overloaded by about 3% in the 2020 on-peak case. As discussed in Table 3-4 several options for mitigating this overload have been identified in the CAISO's 2010 Transmission Plan.
  - In the 2015 off-peak case, the Cottonwood–Olinda #1&2 230-kV lines are overloaded by 5%. This overload could be mitigated by upgrading the limiting equipment at the Cottonwood Substation.
  - The Pease-East Marysville Junction 115-kV line is overloaded by about 4% in the 2020 on-peak case. As discussed in Table 3-4 reconductoring lines connected to the Pease Substation as discussed in the CAISO's 2010 Transmission Plan would mitigate this overload.

Reactive Margin Studies (Section 4)

The reactive margin studies simulating Category B and C contingencies on the 2015 and 2020 summer peak load cases show that reactive margins at the 500-kV buses in northern California would be well in excess of those required by the reliability criteria.

Transient Stability Studies (Section 5)

The transient stability studies simulating Category B and C contingencies on the 2015 and 2020 summer peak load cases show that:

- The system is stable and that all oscillations are damped for all of the contingencies evaluated, and
- All system voltage and transient frequency dips meet the Western Electricity Coordinating Council (WECC) Disturbance Performance Criteria.

The transient stability studies simulating the critical Category D contingency (loss of all three COI 500-kV lines) on the near-term and long-term, peak load cases show that:

- The system in northern California is stable and damped and all voltage and transient frequency dips in northern California meet the WECC Disturbance Performance Criteria.
- With respect to the balance of the WECC system, there are approximately twenty to thirty buses that experience voltage dip violations exceeding the 30% Category C criteria (there is no voltage dip criteria for Category D conditions). In addition, “out-of-step” conditions exist for a significant number of generators. It is noted that the NERC Standards for Category D contingencies do not require that the system achieve a new, stable operating point.

SECTION 1 - TANC TRANSMISSION FACILITIES

California-Oregon Transmission Project (COTP)

The 500-kV California-Oregon Transmission Project (COTP) is a 340-mile long, jointly owned facility that extends from the Captain Jack Substation in southern Oregon to the Tracy Substation in Central California. TANC is the majority owner of the COTP and serves as the Project Manager for the other owners of the COTP. The Western Area Power Administration (WAPA) is responsible for the operations and maintenance functions of the COTP.

The COTP was planned and is operated as part of the three 500-kV line system that interconnects southern Oregon with central California, which is known as the California-Oregon Intertie (COI). The other COI lines (known as the Pacific AC Intertie or PACI) are the Malin-Round Mountain #1 500-kV line (owned by WAPA) and the Malin-Round Mountain #2 500-kV line (owned by Pacific Gas & Electric (PG&E) and PacifiCorp). The COTP is located within the WAPA Sub-Balancing Authority Area which is within the Sacramento Municipal Utility District (SMUD) Balancing Authority Area. The two PACI lines are located within the Balancing Authority Area of the California Independent System Operator (CAISO).

Previous studies have shown that the operating transfer capability (OTC) of the COI is influenced by the amount of power transfer over the Pacific DC Intertie (PDCI) and the amount of hydroelectric generation on-line in northern California. Operating nomograms depicting the above interrelationships are developed on a seasonal basis by the California Operating Studies Subcommittee (OSS). Table 1-1 summarizes information contained in the 2010 summer peak AC/DC operating nomogram.

TABLE 1-1
2010 SUMMER PEAK AC/DC OPERATING NOMOGRAM

Allowable COI Flows (MW)	PDCI Flows (MW)	Northern California Hydro (%)
4,800	3,100	60%
4,625	3,100	80%
4,200	3,100	100%

Potential Future Transmission Projects

TANC continues to coordinate and participate with other parties in discussions and joint studies to identify the additional transmission facilities in northern California necessary to meet State goals and mandates. In addition, TANC is a member of the CTPG and participates in the CTPG studies. The CTPG conducts regional planning studies and issues reports from time to time which can be found on its web site. Information regarding any such TANC facilities identified will be reflected, as appropriate, in future Study Reports filed by TANC.

SECTION 2 - BASE CASES USED AND CRITERIA APPLIED IN THE STUDIES

Because of the significant amount of previous study work done by TANC, PG&E, and WAPA using a 2015 summer peak case, it was used for the "near-term" on-peak studies discussed in this report. In addition, TANC utilized a 2015 off-peak base case obtained from WAPA to assess near-term off-peak conditions and a 2020 heavy summer approved 20hs1a1 base case (approved by the WECC in June 2010) to assess long-term (10-year) on-peak load conditions. All three of these cases model projected firm transfers over the COI facilities as well as additional power transfers to stress the COI facilities.

2015 Summer Peak Case

The 2015 heavy summer case had been prepared by WAPA for near-term studies and modified by TANC to stress the system in northern California by:

- Increasing northern California hydro generation to about 90% of installed capacity. It is noted that these COI flow and northern California hydro levels are greater than those allowed by the 2010 summer peak nomogram and, as such, represent highly stressed system conditions.
- Decreasing generation in the southern California and increasing generation in northern California to increase Path 26 N-S transfers to 3,600 MW.

2015 Summer Off-Peak Case

The 2015 off-peak load case used in these studies was based on a base case used by WAPA for their studies. This case was modified by TANC to increase northern California hydro generation to about 61% of installed capacity.

2020 Summer Peak Case

The WECC 2020 heavy summer case which had been approved by the WECC in June 2010 was modified by TANC to:

- Increase northern California hydro generation to about 87% of installed capacity.
- Add 230 MW of queued wind generation (in Solano County) that has interconnection agreements in place with the CAISO.
- Increase COI transfers to 4,800 MW. It is noted that these COI flow and northern California hydro levels are greater than those allowed by the 2010 summer peak AC/DC nomogram and, as such, represent highly stressed system conditions.
- Increase the ratings of the Hatchet Ridge – Round Mountain 230-kV lines.
- Increase the load demand in the PG&E area to approximately 31,800 MW (which is the "1-in-10"year load forecast) as reflected in the recent CTPG 2020 case studies.

- Decrease generation in southern California and increase generation in northern California to increase Path 26 N-S transfers to about 3,600 MW.

Key parameters modeled in the three base cases discussed above are summarized in Table 2-1.

TABLE 2-1
KEY PARAMETERS IN BASE CASES USED FOR STUDIES

	2015 Summer Peak Case	2015 Off-Peak Case	2020 Summer Peak Case
Major Path Flows (MW)			
California-Oregon Intertie (North-to-South)	4,800	(3,676)	4.807
Pacific DC Intertie (North-to-South)	3,000	(1,856)	3,100
Path 26 (North-to-South)	3,613	(1,439)	3,605
Path 15 (North-to-South)	1,439	(5,395)	827
Northern California Load (MW)[3]	28,678	14,302	31,761
Northern California Hydroelectric Generation (MW/% of Installed)[4]	3,682/90%	2,507/61%	3,561/87%

Reactive Power Resources

The above base cases model all of the reactive power resources that were reported by the WECC members when the most recent WECC base cases were developed.

Protection Systems

There are several existing Remedial Action Schemes (RAS)/SPS that are in place and that are used to mitigate impacts of outages on the 500-kV system in northern California. These RAS/SPS, which were modeled in these studies, include:

- Dropping generation in the Pacific Northwest for outages of the Pacific DC Intertie (PDCI), the Malin-Round Mountain #1 and #2 500-kV lines, the Round Mountain-Table Mountain #1 and #2 500-kV lines, the Table Mountain-Tesla and Table Mountain-Vaca Dixon 500-kV lines, and the Table Mountain-Tesla and Vaca Dixon-Tesla 500-kV lines.
- Dropping pump loads in the PG&E and the SCE areas for outages of the Malin-

[3] Includes loads for PG&E, SMUD and other publicly-owned utilities in northern California, self-generation loads, and losses. For the 2015 case, peak loads are for 1-in-5 conditions. For the 2020 case, peak loads are for 1-in-10 conditions for northern California and 1-in-2 conditions elsewhere. Large pumping loads, which are modeled as negative generation, are not included.
[4] Based on a total installed capacity of 4,110 MW.

Round Mountain #1 and #2 500-kV lines, the Round Mountain-Table Mountain #1 and #2 500-kV lines, the Table Mountain-Tesla and Table Mountain-Vaca Dixon 500-kV lines, and the Table Mountain-Tesla and Vaca Dixon-Tesla 500-kV lines.

Control Devices

Control devices modeled in these studies reflect the input of the WECC members when the respective cases used in the studies were developed. Such control devices (that are pertinent to the operation of the 500-kV system in northern California) include:

- Switchable shunt capacitors and reactors at the Malin, Olinda, Tracy, and Table Mountain 500-kV buses.
- Bypassable series capacitors on the Olinda-Maxwell, Table Mountain-Tesla, and Table Mountain-Vaca Dixon 500-kV lines.

Study Criteria

TANC applied the NERC Standards and the WECC reactive margin criteria and study methodology and study guidelines to assess the performance of the 500-kV system in northern California. Information regarding the standards, criteria, and methodologies applied in these studies is presented in Appendix A.

Switching Sequences Used in Studies

The Category B and C contingencies simulated in these studies are listed in Appendix B; the switching sequences used to simulate these contingencies are based on those presented in the most recent OSS Handbook. The Category D contingency simulated in these studies is also listed in Appendix B; the switching sequence used to simulate this contingency was obtained based on the information from the most recent OSS Handbook. As appropriate, the switching sequences used in these studies reflect the use of the RAS/SPS that are in place to mitigate the known impacts of specific contingencies.

SECTION 3 - POST-TRANSIENT POWER FLOW STUDIES

Post-transient power flow studies were conducted to evaluate system performance following outages of the applicable 500-kV transmission facilities, the PDCI, and of two units at three nuclear plants (Diablo Canyon, San Onofre, and Palo Verde). The post-transient performance was evaluated based on the NERC Standards and WECC Criteria discussed in Appendix A. The governor power flow EPCL program written for the General Electric Positive Sequence Load Flow (PSLF) Power System Simulation Program was used to simulate the outages studied.

Study Overview

Post-transient power flow studies were conducted for 2015 and 2020 summer on-peak load conditions and for 2015 summer off-peak load conditions. System load levels and critical path flows were as summarized in Table 2-1 above. As noted above, the COI flow, PDCI flow, and northern California hydro conditions modeled in the on-peak studies are outside of the current operating nomogram. The purpose of this study is not to determine the applicable nomograms but to assess the bulk transmission system performance under highly stressed conditions. If the system performance is acceptable under these extreme conditions, it would be acceptable under the less stressed conditions described by the applicable nomograms.

Updated Ratings

The owners of the COI 500-kV transmission lines apply emergency ratings for these facilities when assessing the impacts of 500-kV contingencies. The normal and emergency ratings for these facilities are summarized in Table 3-1. As shown in Table 3-1 the ratings of most of the PACI facilities are limited by the thermal limitations of line conductors. As a result, PG&E has developed and uses 10 minute, short-term emergency ratings for these lines in assessing the impacts of 500-kV contingencies. This practice meets the NERC Standards that require line loadings to be within the applicable normal and emergency thermal rating limits as determined and consistently applied by the facilities owners. Appendix C contains information on the PG&E approved short-term emergency ratings for 500-kV conductors. These emergency ratings were used in the assessment of all 500-kV contingencies.

TABLE 3-1
500-KV LINE RATINGS

500-kV Line	Ratings (Amps)		Limiting Element(s)
	Summer Normal	Summer Emergency	
PACI Facilities			
Malin-Round Mountain #1	2,700	3,020	Normal –series capacitors Emergency – line conductors
Malin-Round Mountain #2	2,442	2,828	Line conductors[5]
Round Mountain-Table Mountain #1	2,442	2,828	Line conductors
Round Mountain-Table Mountain #2	2,442	2,828	Line conductors
Table Mountain-Vaca Dixon	2,478	2,964	Line conductors
Table Mountain-Tesla	2,430	2,730	Line conductors
Vaca Dixon-Tesla	2,430	2,816	Line conductors
Tesla-Los Banos	2,478	2,964	Line conductors
Tesla-Tracy	2,478	2,964	Line conductors
Tracy-Los Banos	2,478	2,964	Line conductors
COTP Facilities			
Captain Jack-Olinda	2,667	4,099	Series capacitor ratings
Olinda-Maxwell	2,991	4,300	Series capacitor ratings
Maxwell-Tracy	2,991	4,300	Series capacitor ratings

Mitigation of Criteria Violations

If criteria violations were found, possible mitigation options were examined and are presented for each of the noted criteria violations. The proposed mitigation methods for PG&E-owned facilities are based on information contained within the CAISO's Transmission Plans issued in 2010 or earlier.

Study Results – Category A Conditions

There were no Category A overloads noted for the cases modeling 2015 summer peak load conditions, 2020 summer peak load conditions, or 2015 summer off-peak load conditions.

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[5] The normal and emergency ratings of the series capacitors at Malin are 1,800 amps and 2,700 amps, respectively.

Study Results – Category B Conditions

A total of eighteen Category B contingencies involving 500-kV lines and 500/230-kV transformers in northern California (refer to Appendix B) and a Category B contingency involving the PDCI were simulated on each of the base cases discussed in Section 2. Table 3-2 summarizes the post-contingency overloads noted in these studies; as summarized in Table 3-2:

- For summer peak load conditions:
  - For the 2015 summer peak case, there were no facilities rated 115-kV or higher in northern California that were overloaded for the Category B contingencies studied.
  - An outage of the Olinda-Tracy 500-kV line results in a 3% overload on the CPV Station-Cortina 230-kV line for the 2020 summer peak case. Options for mitigating the overload (per the CAISO Transmission Plan) include reconductoring this line, looping a second 230-kV line into Cortina, or reducing generation at the CPV Station.
- For summer off-peak load conditions:
  - An outage of the Table Mountain 500/230-kV transformer would result in overloads of up to 9% on the East Nicolaus-Rio Oso 115-kV line. This overload would not exist if various lines connected to Rio Oso Substation were reconductored as is discussed in the CAISO's transmission plan.

TABLE 3-2
POST-TRANSIENT POWERFLOW STUDIES - CATEGORY B OVERLOADS

Outage	Impacted Facility	Emergency Rating	Loading (%)	Owner	Mitigation
2015 Off-Peak Case					
Table Mt. 500/230-kV Transformer	East Nicolaus – Rio Oso 115-kV Line	417 Amps	109	PG&E	Reconductor and upgrade various lines connected to Rio Oso Substation per the CAISO's 2010 transmission plan
2020 Summer Peak Case					
Olinda – Tracy 500-kV Line	CPV Station-Cortina 230-kV Line	954 Amps	103	PG&E	Potential mitigation options per the CAISO 2010 transmission plan include reconductoring this line, looping a second 230-kV line into Cortina, or reducing generation at the CPV Station.

Study Results - Category C Conditions

A total of thirteen Category C contingencies (ten involving 500-kV transmission lines in northern California and three contingencies involving an outage of two large nuclear generating units (refer to Appendix B)) were simulated on each of the three base cases discussed in Section 2. As summarized in Table 3-3, the Category C post-contingency overloads noted in these studies are as follows:

- An outage of the Malin-Round Mountain #1 500-kV line and the Round Mountain-Table Mountain #2 500-kV line (due to a breaker failure at Round Mountain) would result in an overload of 7% on the Round Mountain-Table Mountain #1 500-kV line (which has a summer emergency rating of 2,828 amps) for 2015 summer peak case. In the 2020 case this overload does not occur. The overload could be mitigated by applying PG&E's approved short-term emergency rating for this line (3,280 amps).
- An outage of the Table Mountain-Tesla and Table Mountain-Vaca Dixon 500-kV lines results in overloads on the Table Mountain 500/230-kV transformer of 2% for the 2015 summer peak and the 2015 summer off-peak cases. This transformer is overloaded in the 2020 summer peak case by 7%. The CAISO transmission plan recommends that an emergency rating be established for this transformer which would likely mitigate the noted overloads.
- An outage of the Malin-Round Mountain #1 and #2 500-kV lines results in a 5% overload on the Cottonwood–Olinda #1&2 230 kV lines and in a 7% overload on the Olinda 500/230-kV transformer in the 2015 summer off-peak case. The 230-kV line overloads could be mitigated by upgrading the limiting equipment at the Cottonwood Substation. The overload on the Olinda transformer could be mitigated by applying SPS needed for the new Hatchet Ridge generation interconnection (as discussed in the 2010 CAISO transmission plan) and by curtailing wind generation in Solano County.
- An outage of the Round Mountain-Table Mountain #1 and #2 500-kV lines results in a 10% overload on the Round Mountain 500/230-kV transformer in the 2015 summer off-peak case. This overload would not exist if an emergency rating (such as that modeled in the 2020 on-peak case) was modeled for this transformer in the 2015 case.
- An outage of the Tesla-Table Mountain and Tesla–Vaca Dixon 500-kV lines results in a 2% overload on the Table Mountain 500/230-kV transformer for the 2015 off-peak case. The CAISO transmission plan recommends that an emergency rating, which would likely mitigate the noted overloads, be established for this transformer.
- In the 2020 peak case, an outage of Round Mountain – Malin #1 and Round Mountain – Table Mountain #1 500-kV lines causes a 1% overload of the Malin – Round Mountain #2 500-kV line which has an emergency rating of 2,700 amps. The limiting element is the Malin series capacitors which are planned to be upgraded in the 2011-2012 timeframe.

- An outage of the Round Mountain – Table Mountain #1&2 500-kV lines results in a 3% overload on the CPV Station-Cortina 230-kV line for the 2020 summer peak case. Options for mitigating the overload (per the 2010 CAISO Transmission Plan) include reconductoring this line, looping a second 230-kV line into Cortina, or reducing generation at the CPV Station.
- An outage of the Table Mountain–Vaca Dixon and Table Mountain–Tesla 500-kV lines results in a 2% overload on the CPV Station-Cortina 230-kV line for the 2020 summer peak case. Options for mitigating the overload (per the 2010 CAISO Transmission Plan) include reconductoring this line, looping a second 230-kV line into Cortina, or reducing generation at the CPV Station.
- In the 2020 peak case, an outage of the Tesla – Table Mountain and Tesla – Tracy 500-kV lines results in overloading the Pease – East Marysville 115-kV line by 4%. This overload can be mitigated by various reconductoring projects which are proposed for the Pease Substation and described in the 2010 CAISO transmission plan.
- An outage of the Table Mountain-Vaca Dixon and Table Mountain-Tesla 500-kV lines results in overloads on the Table Mountain 500/230-kV transformer of 7% for the 2020 summer peak case. The CAISO transmission plan recommends that an emergency rating be established for this transformer which would likely mitigate the noted overloads.

TABLE 3-3
POST-TRANSIENT POWERFLOW STUDIES - CATEGORY C OVERLOADS

500-kV Line Outage	Impacted Facility	Emergency Rating	Loading (%)	Owner	Mitigation
2015 Summer Peak Case					
Malin-Round Mountain #1 and Round Mountain-Table Mountain #2 500-kV Lines	Round Mountain-Table Mountain #1 500-kV Line	2,828 Amps	107	PG&E	Apply short-term emergency rating of 3,280 Amps
Table Mountain-Vaca Dixon and Table Mountain-Tesla 500-kV Lines	Table Mountain 500/230-kV Transformer	1,122 MVA	102	PG&E	Establish emergency rating for transformer per CAISO transmission plan
2015 Off-Peak Case					
Malin-Round Mountain #1 and #2 500-kV Lines	Cottonwood – Olinda #1 230-kV	926 Amps	105	WAPA	Upgrade terminal equipment at Cottonwood Substation [6]
	Cottonwood – Olinda #2 230-kV	926 Amps	105	WAPA	
	Olinda 500/230-kV Transformer	1,041 MVA	107	WAPA	Apply SPS needed for the Hatchet Ridge generation interconnection and curtail wind generation in Solano County
Round Mountain-Table Mountain #1 and #2 500-kV Lines	Round Mountain 500/230-kV Transformer	1,122 MVA	110	PG&E	Establish emergency rating for transformer (as is modeled in 2020 summer peak case)
Tesla – Table Mountain and Tesla Vaca Dixon 500-kV Lines	Table Mountain 500/230-kV Transformer	1,122 MVA	102	PG&E	See above
2020 Summer Peak Case					
Round Mountain-Malin #1 and Round Mountain-Table Mountain #2 500-kV Lines	Malin-Round Mountain #2 500-kV Line	2,700 Amps	101	PG&E	Limiting element is the series capacitors at Malin which are planned to be upgraded in the 2011-2012 timeframe

[6] WAPA is working with PG&E to accomplish these upgrades.

TABLE 3-3
POST-TRANSIENT POWERFLOW STUDIES - CATEGORY C OVERLOADS

500-kV Line Outage	Impacted Facility	Emergency Rating	Loading (%)	Owner	Mitigation
Table Mountain – Vaca Dixon and Table Mountain-Tesla 500-kV Lines	CPV Station-Cortina 230-kV Line	954 Amps	102	PG&E	Refer to Table 3-3
Tesla – Table Mountain and Tesla – Tracy 500-kV Lines	Pease – E.Mry J1 115-kV	507 Amps	104	PG&E	Reconductor per the CAISO 2010 Transmission Plan
Table Mountain – Vaca Dixon and Table Mountain – Tesla 500-kV Lines	Table Mountain #1 500/230-kV Transformer	1,122 MVA	107	PG&E	See above

SECTION 4 - REACTIVE MARGIN STUDIES

Reactive margin studies were performed on the 2015 and 2020 summer on-peak base cases. As discussed in Appendix A, the system must maintain a positive reactive power margin while the COI transfers are increased by 5% for Category B outages and increased by 2.5% for Category C outages. Positive reactive margin with rated COI flows is all that is required for outages involving two nuclear units at the Palo Verde, San Onofre, or Diablo Canyon nuclear plants.

These studies showed that:

- Positive reactive margins would exist for all Category B and C contingencies simulated.
- For Category B contingencies (in which COI flows were increased by 5%):
    - The lowest reactive margin (1,462 MVAR at the Malin 500-kV bus) for the 2015 summer on-peak case occurred for the Captain Jack-Olinda 500-kV line outage (refer to Table 4-1).
    - The lowest reactive margin in the 2020 summer on-peak case (330 MVAR at the Malin 500-kV bus) occurred for the Pacific DC Intertie 500-kV line outage (refer to Table 4-4)
- For Category C line contingencies (in which COI transfers were increased by 2.5%):
    - In the 2015 summer on-peak case, the lowest reactive margin (1,579 MVAR at the Captain Jack 500-kV bus) occurred for an outage of Round Mountain-Malin #1 500-kV and Round Mountain-Table Mountain #2 500-kV Lines (refer to Table 4-2).
    - In the 2020 summer on-peak case, the lowest reactive margin (684 MVAR at the Tracy 500-kV bus) occurred for an outage of Tesla-Table Mountain 500-kV and Tesla-Tracy 500-kV Lines (refer to Table 4-5).
- For Category C contingencies involving two nuclear generation units:
    - In the 2015 summer on-peak case, the lowest reactive margin (1,277 MVAR at Captain Jack) occurred after an outage of two units at Diablo Canyon (refer to Table 4-3).
    - In the 2020 summer on-peak case, the lowest reactive margin (382 MVAR at Round Mountain) occurred after an outage of two units at Diablo Canyon (refer to Table 4-6).

TABLE 4-1 CATEGORY B NORTHERN CALIFORNIA REACTIVE MARGINS 2015 SUMMER PEAK CASES (COI Transfers Increased by 5%)		
Outage	**Minimum Margin (MVAR)**	**Bus w/ Minimum Margin**
Captain Jack-Olinda 500-kV Line	1,462	Malin
Malin-Captain Jack 500-kV Line	2,142	Captain Jack
Malin-Round Mountain 500-kV Line	2,242	Malin
Olinda-Tracy 500-kV Line	1,792	Captain Jack
Round Mountain-Table Mountain 500-kV Line	1,660	Captain Jack
Table Mountain-Tesla 500-kV Line	1,915	Captain Jack
Table Mountain-Vaca Dixon 500-kV Line	1,810	Captain Jack
Tracy-Los Banos 500-kV Line	2,372	Captain Jack
Tesla-Los Banos 500-kV Line	2,351	Captain Jack
Tracy-Tesla 500-kV Line	2,205	Captain Jack
Vaca Dixon-Tesla 500-kV Line	1,723	Vaca Dixon
Olinda 500/230-kV Transformer	2,167	Captain Jack
Table Mountain 500/230-kV Transformer	2,146	Captain Jack
Round Mountain 500/230-kV Transformer	2,035	Captain Jack
Tracy 500/230-kV Transformer	2,160	Captain Jack
Tesla 500/230-kV Transformer	2,157	Captain Jack
Vaca Dixon 500/230-kV Transformer	2,144	Captain Jack
Los Banos 500/230-kV Transformer	2,168	Captain Jack
PDCI Bipole Outage	2,065	Captain Jack

TABLE 4-2 CATEGORY C NORTHERN CALIFORNIA REACTIVE MARGINS 2015 SUMMER PEAK CASES (COI Transfers Increased by 2.5%)		
Outage	**Minimum Margin (MVAR)**	**Bus w/ Minimum Margin**
Malin-Round Mountain #1 and #2 500-kV Lines	2,567	Captain Jack
Round Mountain-Table Mountain #1 and #2 500-kV Lines	2,468	Round Mountain
Round Mountain-Malin #1 500-kV and Round Mountain-Table Mountain #2 500-kV Lines	1,579	Captain Jack
Table Mountain-Vaca Dixon 500-kV and Table Mountain-Tesla 500-kV Lines	2,194	Table Mountain
Tracy-Tesla 500-kV and Tracy-Los Banos 500-kV Lines	2,102	Tracy
Tesla-Table Mountain 500-kV and Tesla-Tracy 500-kV Lines	1,805	Captain Jack
Table Mountain-Round Mountain and Table Mountain-Vaca Dixon 500-kV	1,762	Malin
Table Mountain-Vaca Dixon 500-kV and Vaca Dixon 500/230-kV Transformer	2,147	Captain Jack
Tesla-Table Mountain 500-kV and Tesla-Vaca Dixon 500-kV Lines	1,852	Vaca Dixon
Los Banos-Tesla 500-kV and Los Banos-Tracy 500-kV Lines	2,219	Captain Jack

TABLE 4-3 TWO UNIT OUTAGES - NORTHERN CALIFORNIA REACTIVE MARGINS 2015 SUMMER PEAK CASES		
Outage	**Minimum Margin (MVAR)**	**Bus w/ Minimum Margin**
Diablo Canyon 2-Unit Trip	1,277	Captain Jack
Palo Verde 2-Unit Trip	1,402	Captain Jack
San Onofre 2-Unit Trip	1,781	Captain Jack

TABLE 4-4
CATEGORY B NORTHERN CALIFORNIA REACTIVE MARGINS
2020 SUMMER PEAK CASES
(COI Transfers Increased by 5%)

Outage	Minimum Margin (MVAR)	Bus w/ Minimum Margin
Captain Jack-Olinda 500-kV Line	671	Malin
Malin-Captain Jack 500-kV Line	1,292	Malin
Malin-Round Mountain 500-kV Line	1,373	Malin
Olinda-Tracy 500-kV Line	854	Table Mountain
Round Mountain-Table Mountain 500-kV Line	715	Malin
Table Mountain-Tesla 500-kV Line	989	Malin
Table Mountain-Vaca Dixon 500-kV Line	890	Malin
Tracy-Los Banos 500-kV Line	1,433	Malin
Tesla-Los Banos 500-kV Line	1,431	Malin
Tracy-Tesla 500-kV Line	1,272	Malin
Vaca Dixon-Tesla 500-kV Line	1,104	Malin
Olinda 500/230-kV Transformer	1,224	Malin
Table Mountain 500/230-kV Transformer	1,292	Captain Jack
Round Mountain 500/230-kV Transformer	1,182	Malin
Tracy 500/230-kV Transformer	1,281	Malin
Tesla 500/230-kV Transformer	1,242	Malin
Vaca Dixon 500/230-kV Transformer	1,277	Malin
Los Banos 500/230-kV Transformer	1,294	Malin
PDCI Bipole Outage	330	Malin

TABLE 4-5 CATEGORY C NORTHERN CALIFORNIA REACTIVE MARGINS 2020 SUMMER PEAK CASES (COI Transfers Increased by 2.5%)		
Outage	**Minimum Margin (MVAR)**	**Bus w/ Minimum Margin**
Malin-Round Mountain #1 and #2 500-kV Lines	1,998	Malin
Round Mountain-Table Mountain #1 and #2 500-kV Lines	1,795	Olinda
Round Mountain-Malin #1 500-kV and Round Mountain-Table Mountain #2 500-kV Lines	695	Captain Jack
Table Mountain-Vaca Dixon 500-kV and Table Mountain-Tesla 500-kV Lines	2,063	Table Mountain
Tracy-Tesla 500-kV and Tracy-Los Banos 500-kV Lines	1,439	Olinda
Tesla-Table Mountain 500-kV and Tesla-Tracy 500-kV Lines	684	Tracy
Tesla-Table Mountain 500-kV and Tesla-Vaca Dixon 500-kV Lines	2,000	Vaca Dixon
Table Mountain-Round Mountain 500-kV and Table Mountain-Vaca Dixon 500-kV Lines	745	Captain jack
Table Mountain-Vaca Dixon 500-kV and Vaca Dixon 500/230-kV Transformer	1,274	Malin
Los Banos-Tesla 500-kV and Los Banos-Tracy 500-kV Lines	1,219	Malin

TABLE 4-6 TWO UNIT OUTAGES - NORTHERN CALIFORNIA REACTIVE MARGINS 2020 SUMMER PEAK CASES		
Outage	**Minimum Margin (MVAR)**	**Bus w/ Minimum Margin**
Diablo Canyon 2-Unit Trip	382	Captain Jack
Palo Verde 2-Unit Trip	475	Malin
San Onofre 2-Unit Trip	451	Captain Jack

SECTION 5 - TRANSIENT STABILITY STUDIES

Transient stability studies were conducted on the 2015 and 2020 summer on-peak cases to evaluate the system performance following the Category B, C, and D contingencies listed in Appendix B. The transient performance was evaluated based on the NERC Standards and WECC Criteria summarized in Appendix A.

The transient stability studies assessing the impacts of Category B and C contingencies on the 2015 and 2020 summer on-peak load cases show that the WECC system is stable and damped for all contingencies and that all voltage and transient frequency dips meet the WECC Criteria discussed in Appendix A. Appendix D contains plots for the following outages:

- PDCI Bi-pole outage
- Malin-Round Mt. #1 and #2 500-kV Double Line Outage
- Palo Verde Units #1 and #2 Trip

The Category D outage involving all three COI lines initiates operation of the NE/SE separation scheme and results in the operation of RAS/SPS which involve tripping pump loads and other loads in northern California and tripping generation in the Pacific Northwest. The operation of the NE/SE Separation Scheme results in the WECC area being split into two "islands". The "southern island" includes the systems in California, southern Nevada, Arizona, and New Mexico; the "northern island" includes the balance of the WECC system.

The transient stability studies simulating this Category D contingency on the near-term and long-term, on-peak load cases show that:

- Underfrequency load shedding occurs throughout the "southern island" of the WECC system.
- With respect to the system in northern California:
  - It is stable and damped.
  - All voltage dips meet the WECC Disturbance Performance Criteria.
  - All frequency dips meet the WECC Disturbance Performance Criteria, with the low frequencies of approximately 59.2 Hz.
  - The Helms Pumped Storage Project (and several large pumping loads) trip due to frequencies dipping below 59.5 Hz.
- With respect to the balance of the WECC system:
  - Approximately twenty to thirty buses experience voltage dip violations exceeding the 30% Category C criteria (there is no voltage dip criteria for

Category D conditions).

- A large number of generators go "out-of-step"; a majority of these units are located in the "northern island" of the WECC system. However, it is noted that the NERC Standards for Category D contingencies do not require that the system achieve a new, stable operating point.

Appendix E contains plots of the voltage and frequency at various northern California buses for this Category D contingency for the near-term peak load case.

APPENDIX A
NERC/WECC RELIABILITY STANDARDS

TANC utilizes the NERC/WECC Reliability Standards, the WECC reactive margin criteria and study methodology, and study guidelines unique to the 500-kV transmission network in northern California to assess the performance of the TANC-owned facilities.

NERC/WECC Reliability Standards

The NERC/WECC Reliability Standards require that transmission system performance assessments be conducted on an annual basis, and that future study years and critical system conditions be studied as deemed appropriate by the responsible entity. The fundamental purpose of the interconnected transmission system is to move power from resources to load. The transmission system:

- Must be planned, designed, constructed, and operated such that it is capable of reliably performing this function over a wide range of system conditions.
- Must be capable of withstanding both common contingencies and the less probable extreme contingencies.
- Is planned so that it should be able to operate within thermal, voltage, and stability limits during normal and emergency conditions.

The NERC Transmission Planning Reliability Standards (NERC Standards) define the measures needed to maintain reliability of the interconnected bulk electric systems using the following two terms:

- Adequacy - The ability of the electric systems to supply the aggregate electrical demand and energy requirements of customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements.
- Security - The ability of the electric system to withstand a sudden disturbance such as the unanticipated loss of one or more system elements.

The NERC Standards for System Adequacy and Security (summarized in Table A-1) address these concepts and require that system performance assessments shall indicate that the system limits are met for all planned facilities in service (Category A), loss of a single element (Category B), loss of two or more elements (Category C), and extreme events resulting in two or more elements removed or cascading out of service (Category D). Extreme contingencies measure the robustness of the transmission system and are to be reviewed for reliability and evaluated for risks and consequences.

TABLE A-1 TRANSMISSION SYSTEM STANDARDS – NORMAL AND EMERGENCY CONDITIONS				
Category	**Contingencies**	**System Limits or Impacts**		
	Initiating Event(s) and Contingency Element(s)	**System Stable and both Thermal and Voltage Limits within Applicable Rating[a]**	**Loss of Demand or Curtailed Firm Transfers**	**Cascading Outages**
A. No Contingencies.	All Facilities in Service	Yes	No	No
B. Event resulting in the loss of a single element.	Single Line Ground (SLG) or 3 Phase (3Ø Fault, with Normal Clearing: 1. Generator 2. Transmission Circuit 3. Transformer Loss of an Element without a Fault	Yes	No[b]	No
	Single Pole Block, Normal Clearing[e]: 4. Single Pole (dc) Line	Yes	No[b]	No
C. Event(s) resulting in the loss of two or more multiple elements.	SLG Fault, with Normal Clearing[e]: 1. Bus Section 2. Breaker (failure or internal Fault)	Yes	Planned/ Controlled[c]	No
	SLG or 3Ø Fault, with Normal Clearing[e], Manual system Adjustments, followed by another SLG or 3Ø Fault, with Normal Clearing [e]: 3. Category B (B1, B2, B3 or B4) contingency, manual system adjustments, followed by another Category B (B1, B2, B3, or B4) contingency	Yes	Planned/ Controlled[c]	No
	Bipolar block, with Normal Clearing[e]: 4. Bipolar (dc) Line Fault (non 3Ø), with Normal Clearing[e]: 5. Any two circuits of a multiple circuit towerline[f]	Yes	Planned/ Controlled[c]	No
	SLG Fault, with Delayed Clearing[e] (stuck breaker or protection system failure): 6. Generator 7. Transformer 8. Transmission Circuit 9. Bus Section	Yes	Planned/ Controlled[c]	No
D[d]. Extreme event resulting in two or more (multiple) elements removed or Cascading out of service.	3Ø Fault, with Delayed Clearing[e] (stuck breaker or protection system failure): 1. Generator 2. Transmission Circuit 3. Transformer 4. Bus Section	Evaluate for risks and consequences. • May involve substantial loss of customer Demand and generation in a widespread area or areas. • Portions or all of the interconnected systems may or may not achieve a new, stable operating point. • Evaluation of these events may require joint studies with neighboring systems.		
	3Ø Fault, with Normal Clearing[e]: 5. Breaker (failure or internal Fault)			

D[d].	6. Loss of towerline with three or more circuits 7. All transmission lines on a common right-of-way 8. Loss of a substation (one voltage level plus transformers) 9. Loss of switching station (one voltage level plus transformers) 10. Loss of all generating units at a station 11. Loss of a large Load or major Load center 12. Failure of a fully redundant Special Protection System(or remedial action scheme) to operate when required 13. Operation, partial operation, or misoperation of a fully redundant Special Protection System (or Remedial Action Scheme) in response to an event or abnormal system condition for which it was not intended to operate 14. Impact of severe power swings or oscillations from Disturbances in another Regional Reliability Organization.	

a) Applicable rating refers to the applicable Normal and Emergency facility thermal rating or system voltage limit as determined and consistently applied by the system or facility owner. Applicable Ratings may include Emergency ratings applicable for short durations as required to permit operating steps necessary to maintain system control. All Ratings must be established consistent with applicable NERC Reliability Standards addressing Facility Ratings.

b) Planned or controlled interruption of electric supply to radial customers or some local Network customers, connected to or supplied by the Faulted element or by the affected area, may occur in certain areas without impacting the overall reliability of the interconnected transmission systems. To prepare for the next contingency, system adjustments are permitted, including curtailments of contracted Firm (non-recallable reserved) electric power Transfers.

c) Depending on system design and expected system impacts, the controlled interruption of electric supply to customers (load shedding), the planned removal from service of certain generators, and/or the curtailment of contracted Firm (non-callable reserved) electric power Transfers may be necessary to maintain the overall reliability of the interconnected transmission systems.

d) A number of extreme contingencies that are listed under Category D and judged to be critical by the transmission planning entity(ies) will be selected for evaluation. It is not expected that all possible facility outages under each listed contingency of Category D will be evaluated.

e) Normal clearing is when the protection system operates as designed and the Fault is cleared in the time normally expected with proper functioning of the installed protection systems. Delayed clearing of a Fault is due to failure of any protection system component such as a relay, circuit breakers, or current transformer, and not because of an intentional design delay.

f) System assessments may exclude these events where multiple circuit towers are used over short distances (e.g., station entrance, river crossings) in accordance with Regional exemption criteria.

The annual assessments should also include the effects of existing and planned protection schemes, backup or redundant protection schemes, and control devices to ensure that protection systems and control devices are sufficient to meet the system performance criteria as defined in Categories C and D of Table A-1. The transmission system must be capable of meeting Category C and D requirements while accommodating the planned outage of any bulk electric equipment (including protection systems or their components) at all demand levels for which planned outages are performed.

WECC Disturbance Performance and Reactive Margin Criteria

The NERC Standards discussed above do not specifically address the criteria or study methodology required to ensure reliability for the more severe contingencies involving transient stability or voltage collapse. As a result, WECC has developed criteria and a methodology for conducting transient and voltage stability studies. The WECC criteria and methodology are aligned with the NERC disturbance categories and specify limits for voltage, frequency, damping, and real/reactive power margins. These supplementary WECC criteria are summarized in Table A-2.

TABLE A-2
WECC RELIABILITY CRITERIA

Performance Level	Disturbance	Transient Voltage Dip Criteria	Transient Frequency Dip Criteria	Post Transient Voltage Deviation
B	N-1 (Single Contingency)	Max V Dip at Load Buses-25% Max Duration of V Dip > 20% - 20 cycles	Duration of Frequency Below 59.6 Hz - 6 cycles	Not to exceed 5%
C	N-2 (Double Contingency)	Max V Dip – 30% Max Duration of V Dip > 20% - 40 cycles	Duration of Frequency Below 59.4 Hz - 6 cycles	Not to exceed 10%

Each contingency studied as part of the transient stability studies was simulated for 20 seconds in order to demonstrate that it complies with the above criteria. The transient stability studies also utilized, as appropriate, the Fast AC Reactive Insertion (FACRI) scheme which, depending on system conditions after the outage, may insert the Olinda and Malin shunt capacitors as well as the Fort Rock series capacitors. Other criteria applied in the transient stability studies were as follows:

- All machines in the system shall remain in synchronism as demonstrated by their relative rotor angles.

- System stability is evaluated based on the damping of the relative rotor angles and the damping of the voltage magnitude swings.
- Transient voltage dips and frequency dips must meet the WECC Reliability Criteria shown in Table A-2.

Voltage stability criteria and real/reactive power margins address the period after transient stability oscillations have damped out and before manual actions to adjust generation or interchange schedules can be implemented. This is typically in the period between 20 seconds to 3 minutes after a disturbance. An area susceptible to voltage collapse can be identified by a power flow contingency analysis. Cases that exhibit large voltage deviations or fail to converge to a solution are typically at or near a voltage unstable operating point. Note that voltage collapse typically occurs after the VAR capability of the region is depleted.

There are two types of analysis typically conducted to address voltage collapse. These include Power-Voltage (PV) and Reactive-Voltage Power (QV). Both PV and QV analysis should be assessed to determine the reactive margin. Either method may be used for a general voltage stability evaluation, but more detailed studies should demonstrate adequate voltage stability margin for both PV and QV analysis. Sole reliance on either PV or QV analysis is not sufficient to assess voltage stability and the proximity to voltage collapse. The system must be planned and operated to maintain minimum levels of margin to account for uncertainties in data, equipment performance, and differences in the transmission network conditions. In addition, PV and QV analysis can be used to determine the required amounts of undervoltage load shedding and to address the proper combination of static and dynamic reactive power support.

PV Analysis

PV analysis is a study technique that relates voltage at a point in the transmission network to either of the following:

- A load within a defined region, or
- A power transfer across a transmission interface.

The benefit of this methodology is that it provides an indication of the proximity to voltage collapse throughout a range of load levels or power transfers on an interface path. With this technique, the load or transmission interface power transfers are increased and the critical voltage points are recorded at each load level. As the load or power transfers into a region are increased, the voltage profile of the region will become lower until an incremental increase in the load or power transfer causes the voltage to increase rather than decrease. When this occurs, the point of voltage collapse is reached.

The WECC sets the methodology for performing PV analysis. Based on the WECC methodology, the maximum load or transfer limit operating point should be the lower of the following:

- 5.0% below the load or interface path flow at the voltage collapse point on the PV curve for Category B disturbances (N-1).
- 2.5% below the load or interface path flow at the voltage collapse point on the PV curve for Category C disturbances (N-2).
- At or below the load or interface path flow at the voltage collapse point on the PV curve for Category D disturbances.

QV Analysis

QV analysis is a study technique that relates VAR margin at a point in the transmission network to the voltage at that point in the network. The benefit of this methodology is that it provides an indication of the proximity to voltage collapse due to a shortage of VAR resources at a specific point in the system. With this technique, a fictitious VAR device is modeled at a critical point in the transmission system. The voltage of this device is set to a desired value, and the VAR output required to maintain this voltage is recorded. As the voltage is decreased, the VAR device must produce more VARs to maintain the desired voltage. The point of voltage collapse is reached when an incremental decrease in voltage also causes a decrease in the VAR output of the device. The output of the VAR device represents the amount of reactive power deficiency at that point of the system. The VAR deficiency at any point in the system must be less than the margin determined from the WECC QV methodology.

The WECC sets the methodology for performing QV analysis. Based on the WECC methodology, the maximum VAR margin for a given load level or transfer limit should be greater than the following:

- The most reactive deficient bus must have adequate reactive power margin for the most severe Category B disturbance (N-1) to satisfy the following conditions;
  - A 5% increase beyond the maximum forecasted load, or
  - A 5% increase beyond the maximum allowable interface flows.

- A Category C disturbance (N-2) requires 50% of the reactive power margin requirement of a Category B disturbance (a 2.5% increase beyond the maximum load forecast load or interface flow).
- A Category D disturbance requires a reactive power margin greater than 0.

APPENDIX B
LIST OF CONTINGENCIES SIMULATED[7]

NERC Category B2 Contingencies

- Malin-Round Mountain 500-kV line
- Malin-Captain Jack 500-kV line
- Round Mountain-Table Mountain 500-kV line
- Table Mountain-Tesla 500-kV line
- Table Mountain-Vaca Dixon 500-kV line
- Vaca Dixon-Tesla 500-kV line
- Tracy-Los Banos 500-kV line
- Tracy-Tesla 500-kV line
- Tesla-Los Banos 500-kV line
- Captain Jack-Olinda 500-kV line
- Olinda-Tracy 500-kV line

NERC Category B3 Contingencies

- Round Mountain 500/230-kV transformer
- Table Mountain 500/230-kV transformer
- Olinda 500/230-kV transformer
- Tesla 500/230-kV #2 transformer
- Tracy 500/230-kV #1 transformer
- Vaca Dixon 500/230-kV #11 transformer

NERC Category B4 Contingencies – Bipolar DC Line Outage

- Pacific DC Intertie

NERC Category C3 Contingencies

- Malin-Round Mountain #1 and #2 500-kV lines
- Round Mountain–Table Mountain #1 and #2 500-kV lines
- Table Mountain-Tesla and Table Mountain–Vaca Dixon 500-kV lines
- Tesla–Los Banos and Tracy–Los Banos 500-kV lines

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[7] Various levels of RAS/SPS are applied for most of the Category B and C contingencies listed. These range from the use of shunt capacitor/shunt reactor switching for most Category B line outages to load and generator dropping for the PDCI outage and most Category C line outages. RAS/SPS applied for the Category D contingency includes load and generator dropping and application of the WECC NE/SE Separation Scheme.

- Table Mountain-Tesla and Vaca Dixon-Tesla 500-kV lines
- Tesla-Tracy and Tracy-Los Banos 500-kV lines

NERC Category C3 Contingencies

- Palo Verde units 1 and 2
- Diablo Canyon units 1 and 2
- San Onofre units 1 and 2

NERC Category C7 Contingencies

- Table Mountain–Vaca Dixon 500-kV line and Vaca Dixon #1 500/230-kV transformer

NERC Category C8 Contingencies

- Malin-Round Mountain #1 and Round Mountain–Table Mountain #2 500-kV lines
- Round Mountain-Table Mountain #1 and Table Mountain–Vaca Dixon 500-kV lines
- Table Mountain-Tesla and Tesla-Tracy 500-kV lines

NERC Category D Contingencies – 2015 On-Peak Case

- Malin-Round Mountain #1 and #2 500-kV lines and Captain Jack-Olinda 500-kV line

APPENDIX C

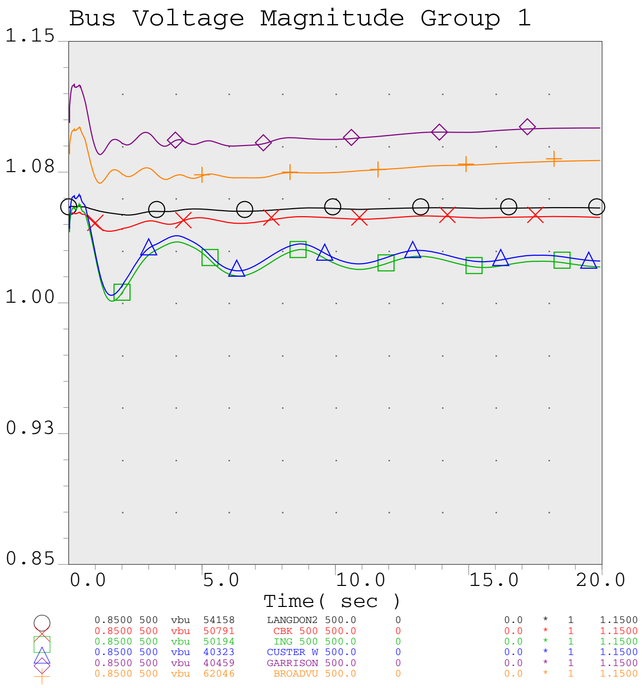
SHORT-TERM EMERGENCY RATINGS FOR PG&E 500-KV LINE CONDUCTORS[1]

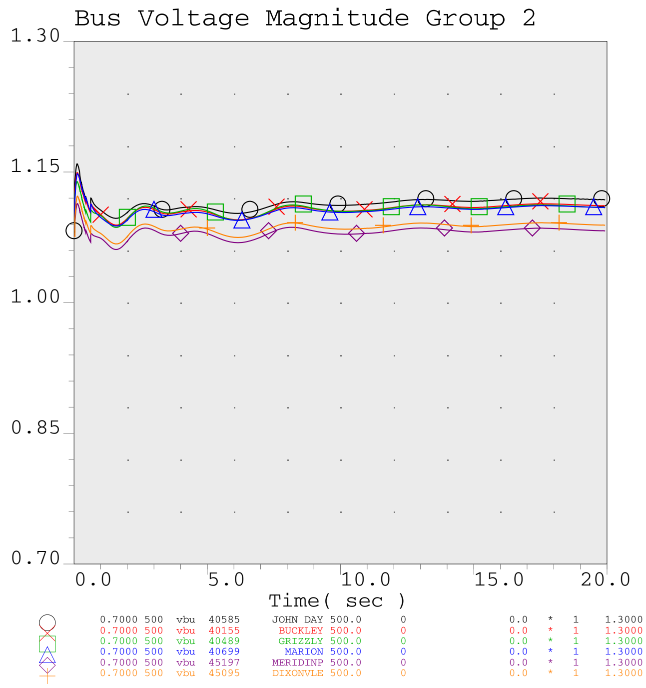
500-kV Line	Limiting Conductor (All Lines Utilize Two Conductors per Phase)	Existing Ratings		Proposed Short-term Emergency Rating					
		Summer Normal (SN) (Amps)	Summer Emergency (SE) (Amps)	Pre-outage Loading (Amps)	% of Existing SN	Max. Cond. Temp (^{0}C) [2]	Maximum Post-outage Loading [3] (Amps)	% of Existing SE	Max. Cond. Temp (^{0}C) [2]
Malin–Round Mt. #2	1852 kcmil ACSR	2,442	2,828	2,200	90	<80	3,280	116	<90
Round Mt.–Table Mt. #1	1852 kcmil ACSR	2,442	2,828	2,200	90	<80	3,280	116	<90
Round Mt.–Table Mt. #2	1852 kcmil ACSR	2,442	2,828	2,200	90	<80	3,280	116	<90
Table Mt.–Vaca Dixon	2300 kcmil AAC	2,478	2,964	2,478	100	<75	4,000	135	<93
Table Mt.–Tesla	2300 kcmil AAC	2,478	2,964	2,160	87	<75	3,556[4]	120	<85
Vaca Dixon–Tesla	1855 kcmil ACSR	2,430	2,816	2,230	92	<80	3,556	126	<90
Tesla-–Los Banos	2300 kcmil AAC	2,478	2,964	2,230	90	<75	3,556	120	<85
Tesla–Tracy	2300 kcmil AAC	2,478	2,964	2,230	90	<75	3,556	120	<85
Tracy–Los Banos	2300 kcmil AAC	2,478	2,964	2,230	90	<75	3,556	120	<85

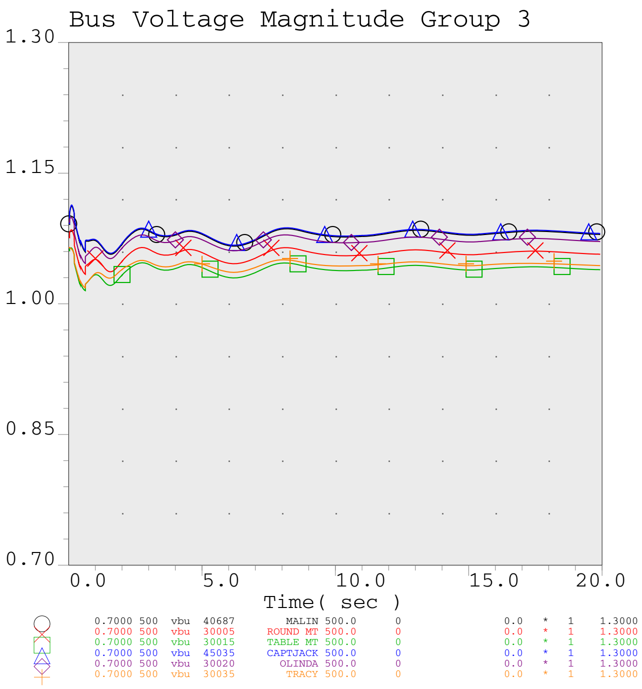
[1] The short-term emergency ratings were developed based on the Engineering Standard for Overhead Line Conductors for summer interior region (ambient temperature = 109.4°F, 2.0 ft/sec wind speed and with solar). PG&E T&D Engineering approved the short-term emergency ratings in December 2002.
[2] For pre-contingency conditions.
[3] The duration of the maximum post-outage loading is 10 minutes.
[4] As of September 2006, the short-term emergency rating of this line is limited by the bundled 2300 kcmil AAC conductors.

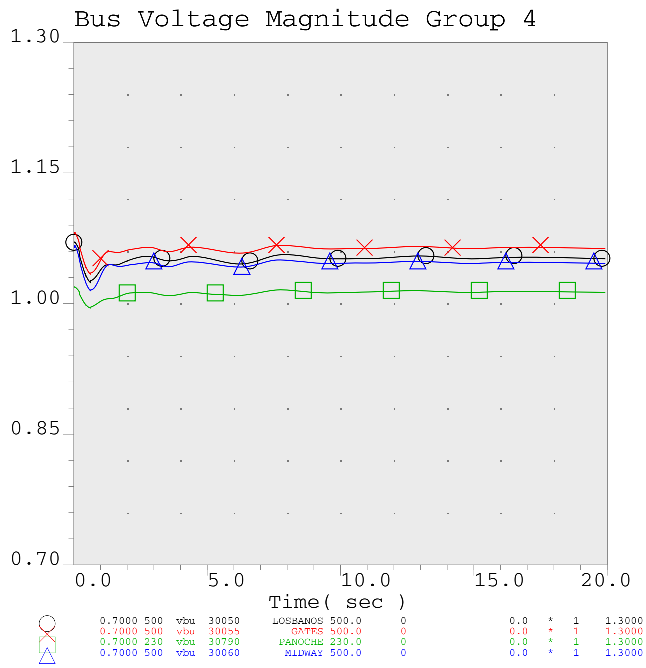
APPENDIX D
TRANSIENT STABILITY PLOTS
FOR CATEGORY B AND C CONTINGENCIES

2015 Summer Peak Case
Plots for Category B Outage
Involving the Pacific DC Intertie









WESTERN ELECTRICITY COORDINATING COUNCIL
2015 HEAVY SUMMER 2 A APPROVED BASE CASE
MAY 3, 2010
Loss of PDCI Bipole with North-to-South flow

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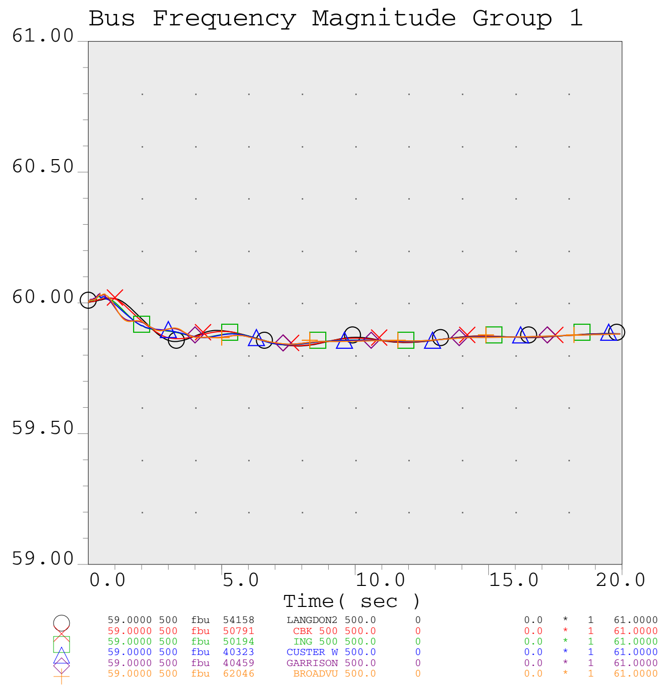

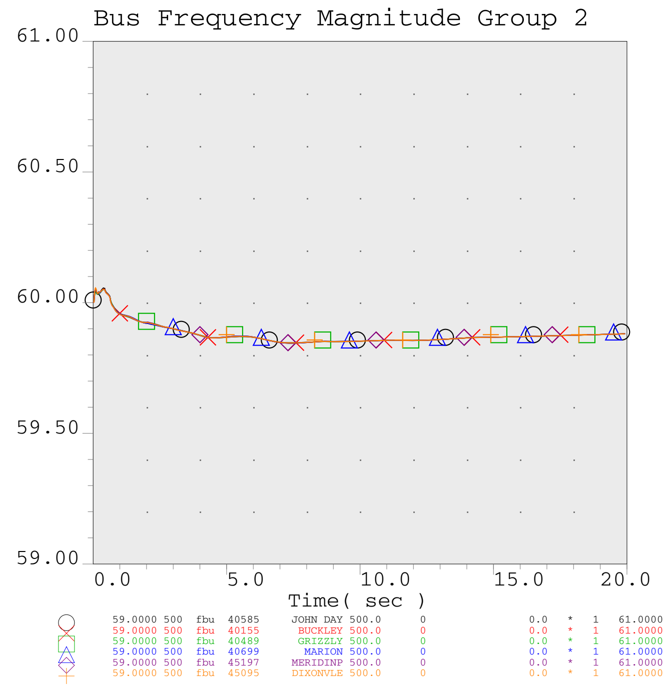

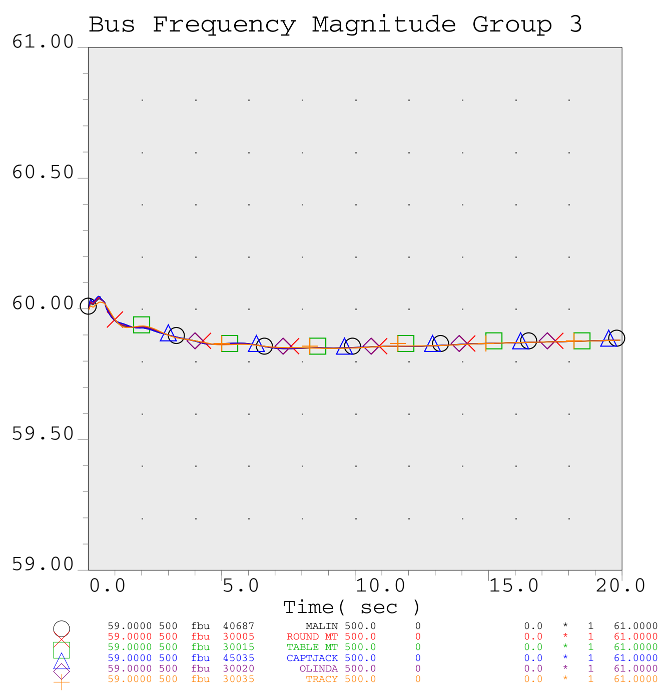

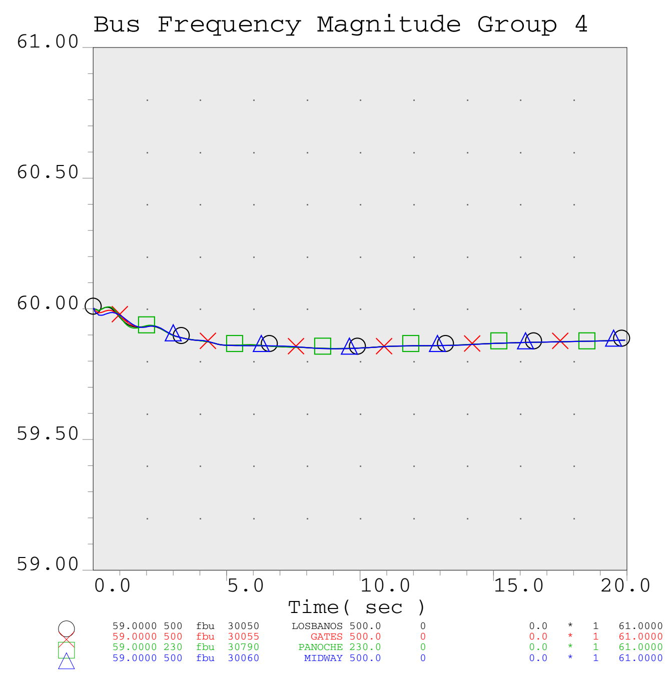

WESTERN ELECTRICITY COORDINATING COUNCIL
2015 HEAVY SUMMER 2 A APPROVED BASE CASE
MAY 3, 2010
Loss of PDCI Bipole with North-to-South flow

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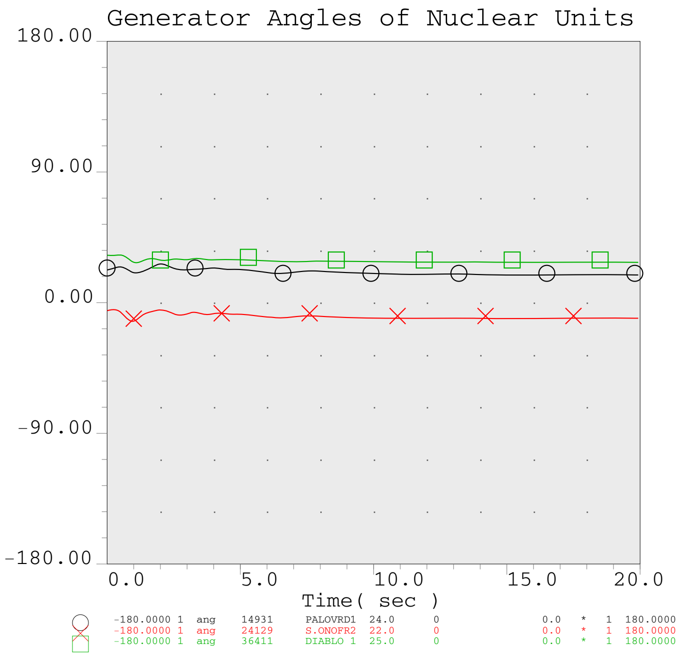

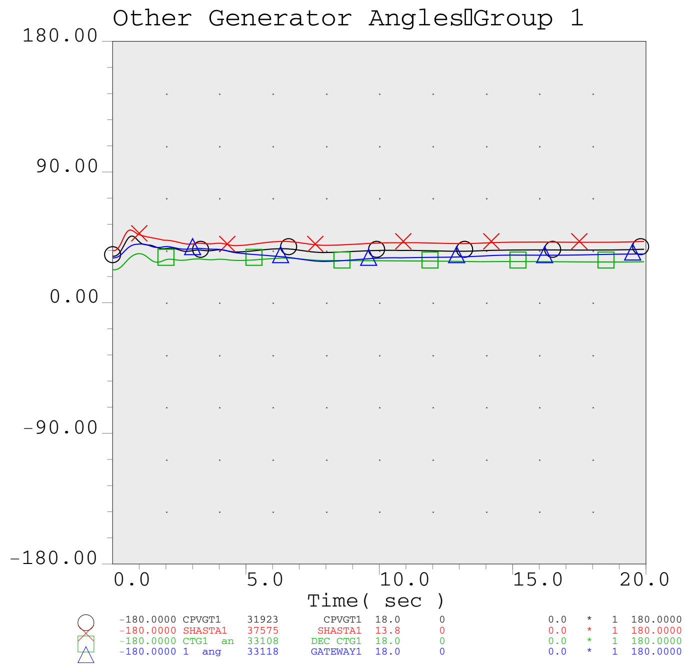

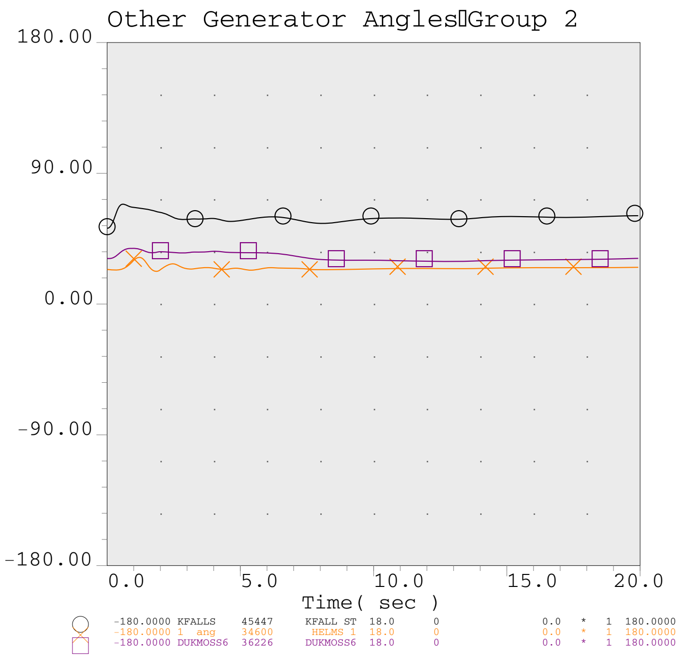

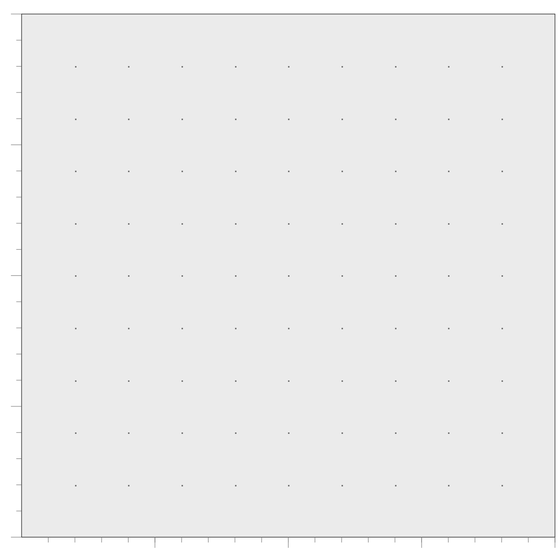

WESTERN ELECTRICITY COORDINATING COUNCIL
2015 HEAVY SUMMER 2 A APPROVED BASE CASE
MAY 3, 2010
Loss of PDCI Bipole with North-to-South flow

15hs2a_ten_year_ama_PDCI_ns-2700.chf

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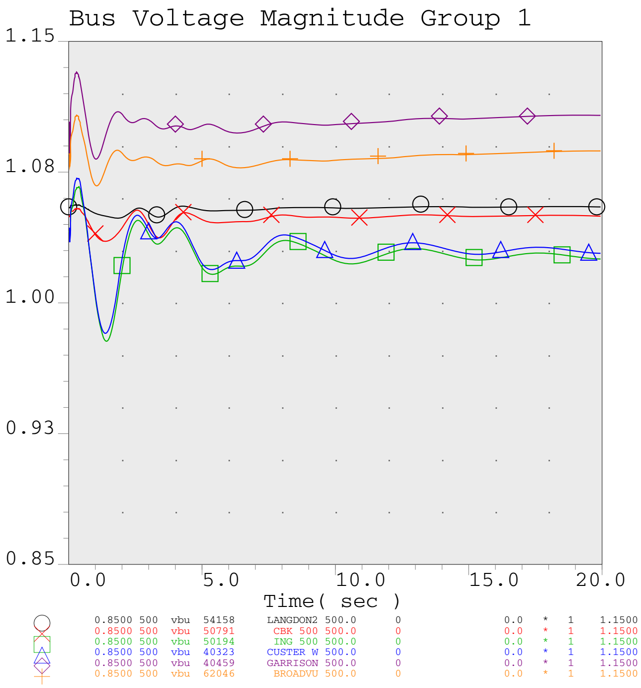
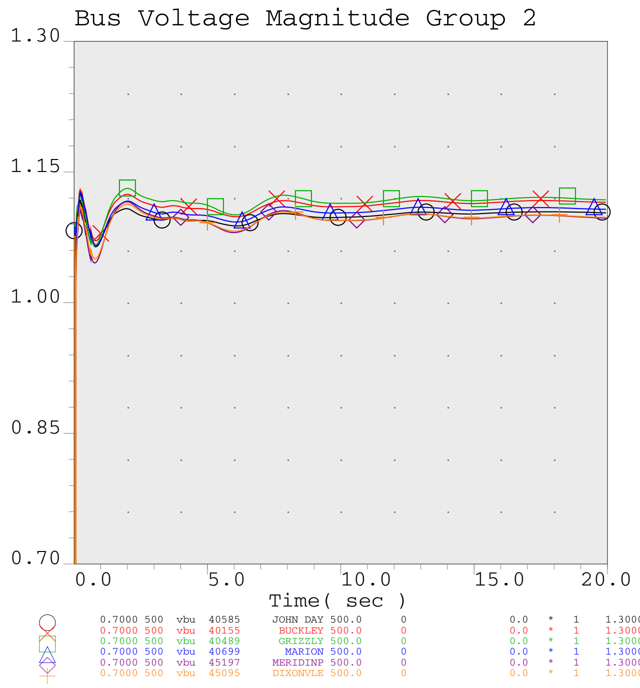
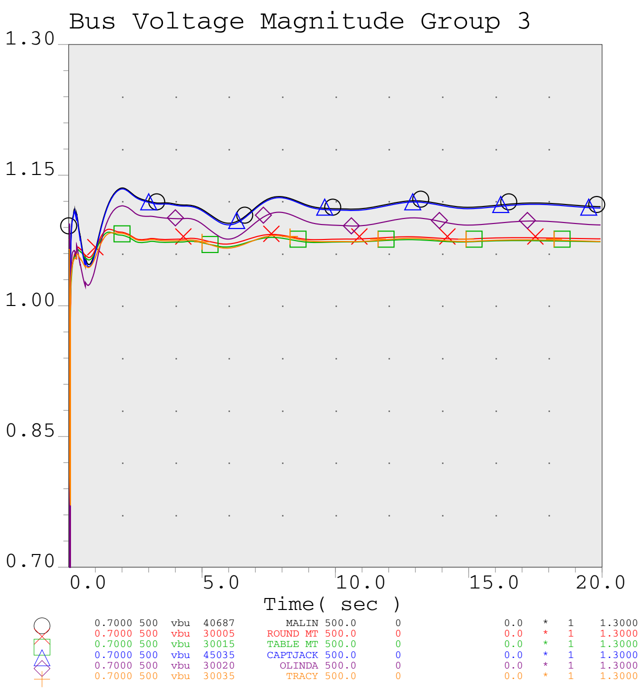
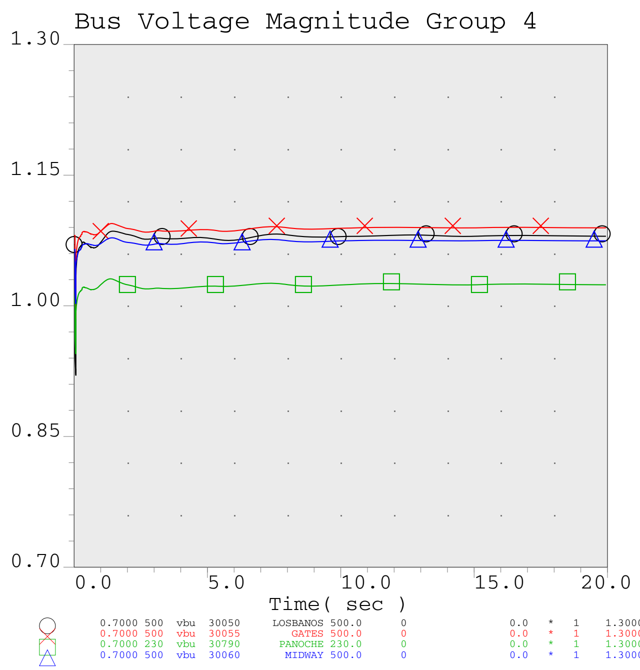
Thu Sep 30 02:17:06 2010

2015 Summer Peak Case
Plots for Category C Outage
Involving the Malin-Round Mountain #1 and #2 500-kV Lines



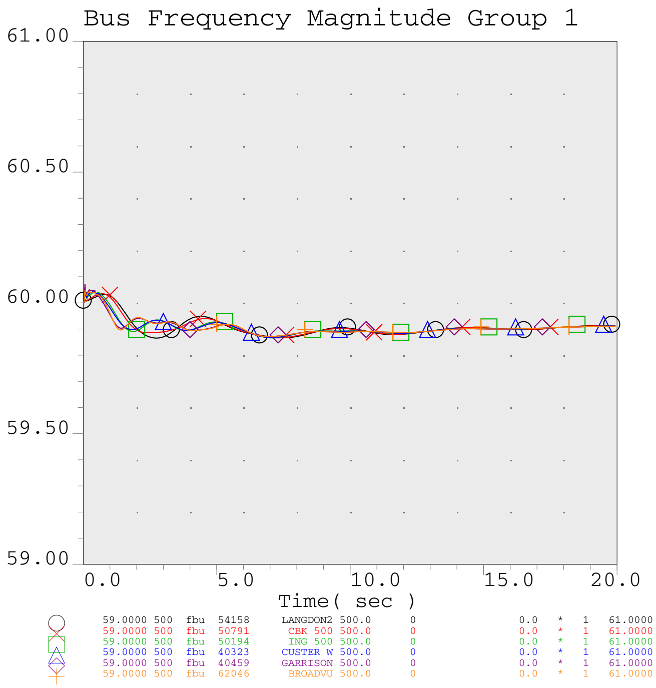


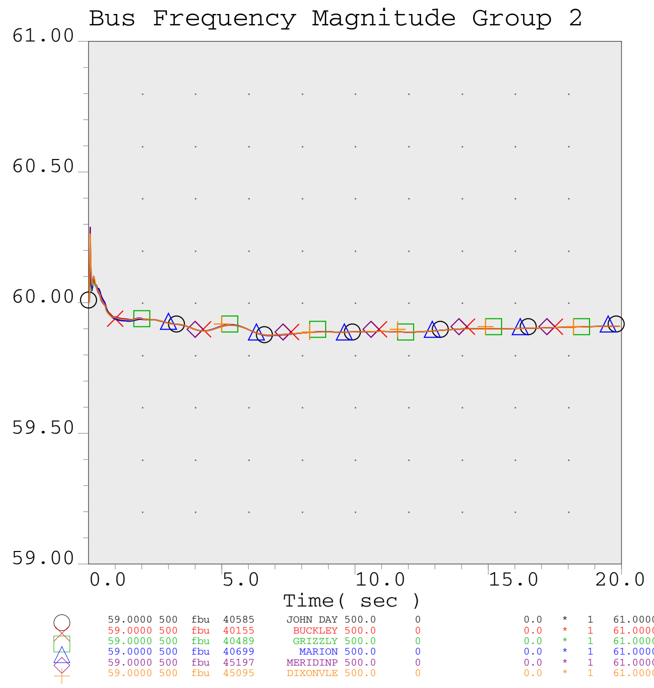


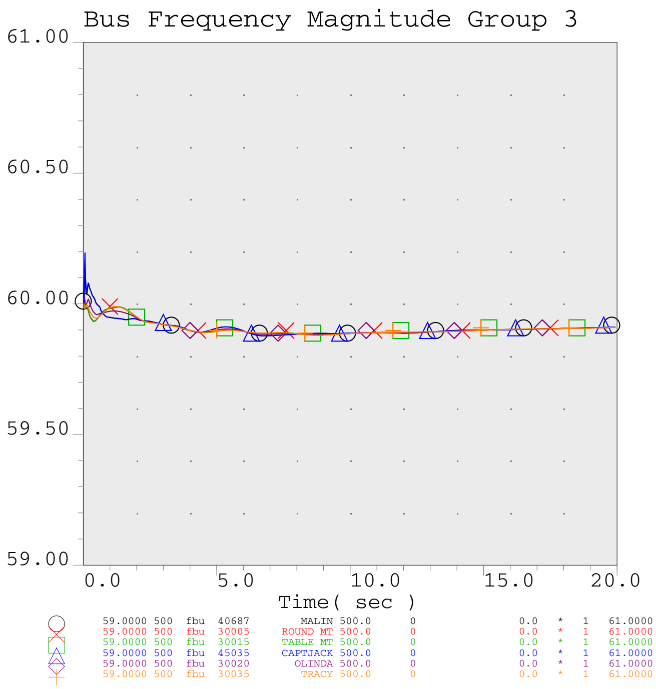


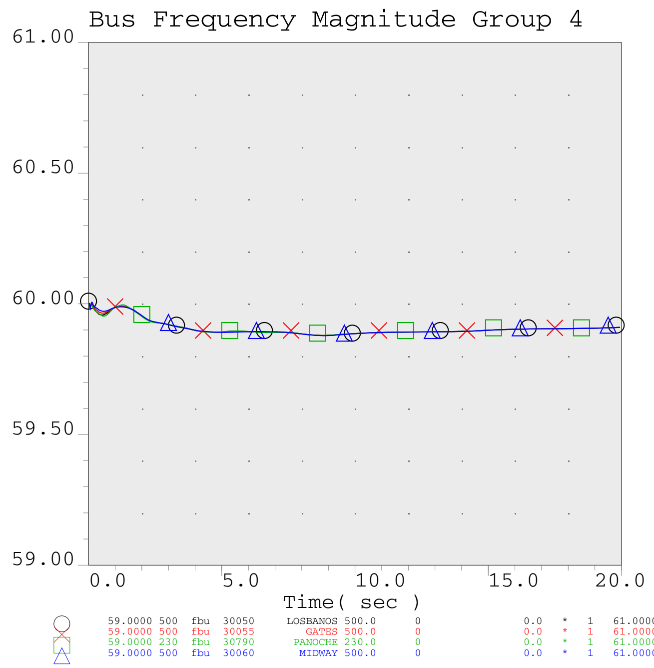
WESTERN ELECTRICITY COORDINATING COUNCIL
2015 HEAVY SUMMER 2 A APPROVED BASE CASE
MAY 3, 2010
Malin - Round Mountain #1 and #2 500 kV Double Line Outage

	15hs2a_ten_year_ama_Mal-Rnd1-2_ns.chf	. Thu Sep 30 00:06:38 2010









WESTERN ELECTRICITY COORDINATING COUNCIL
2015 HEAVY SUMMER 2 A APPROVED BASE CASE
MAY 3, 2010
Malin - Round Mountain #1 and #2 500 kV Double Line Outage

15hs2a_ten_year_ama_Mal-Rnd1-2_ns.chf

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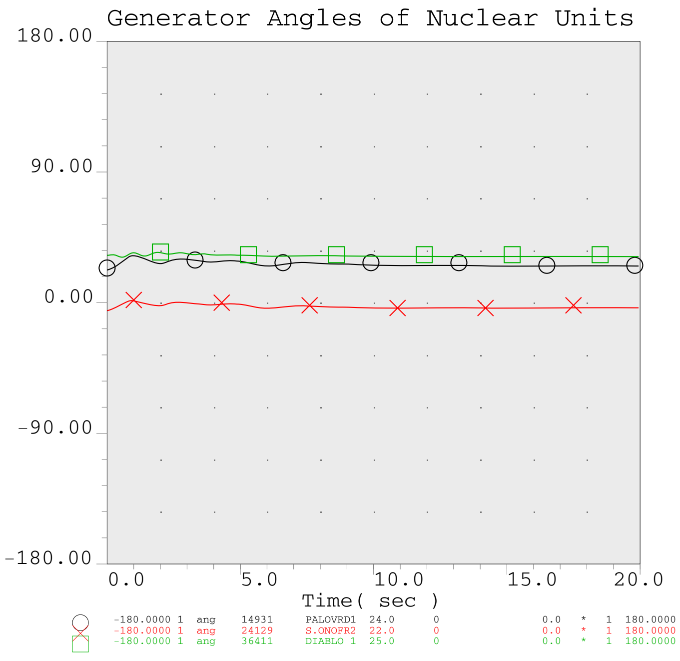
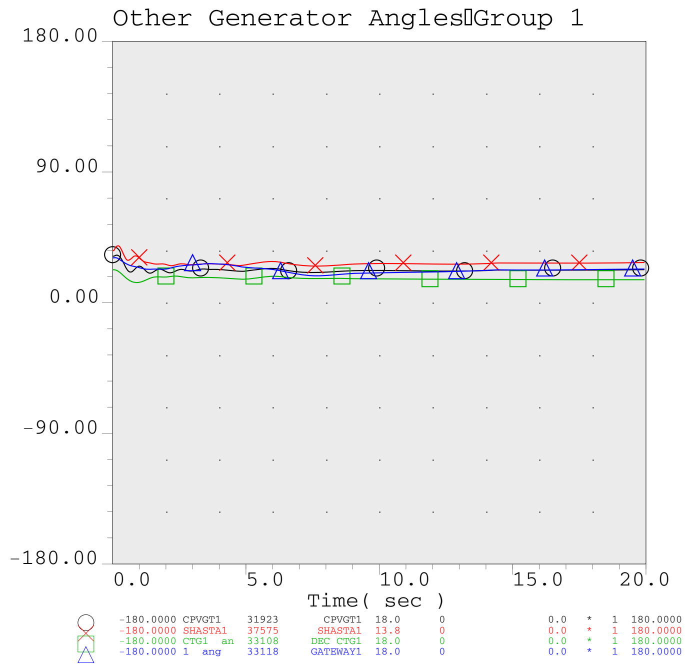
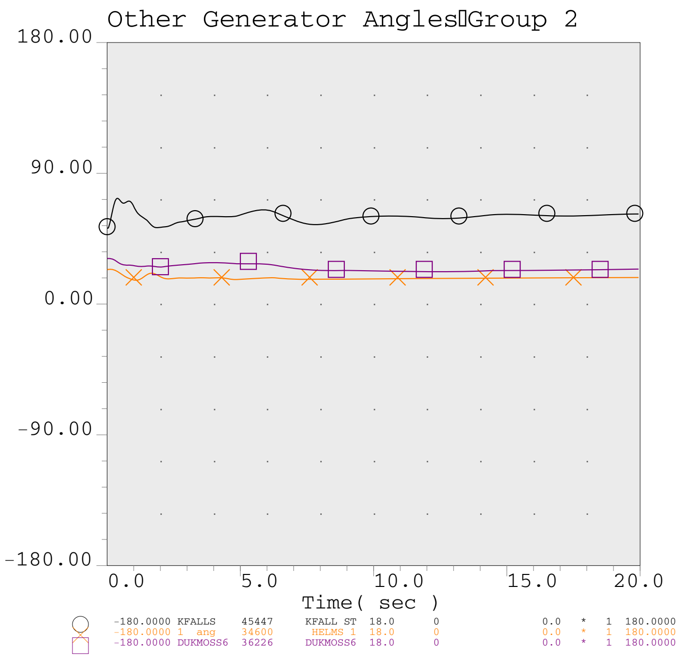
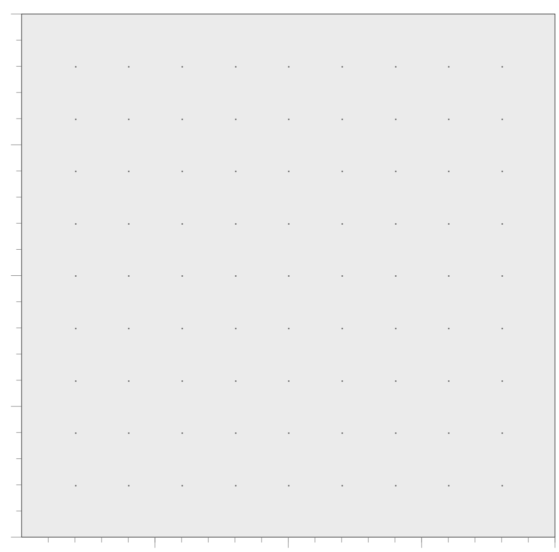
Thu Sep 30 00:06:38 2010







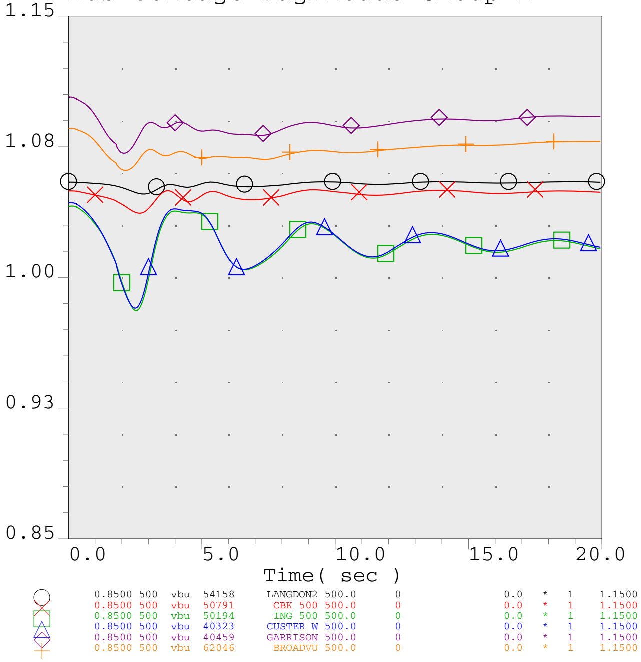


WESTERN ELECTRICITY COORDINATING COUNCIL
2015 HEAVY SUMMER 2 A APPROVED BASE CASE
MAY 3, 2010
Malin - Round Mountain #1 and #2 500 kV Double Line Outage

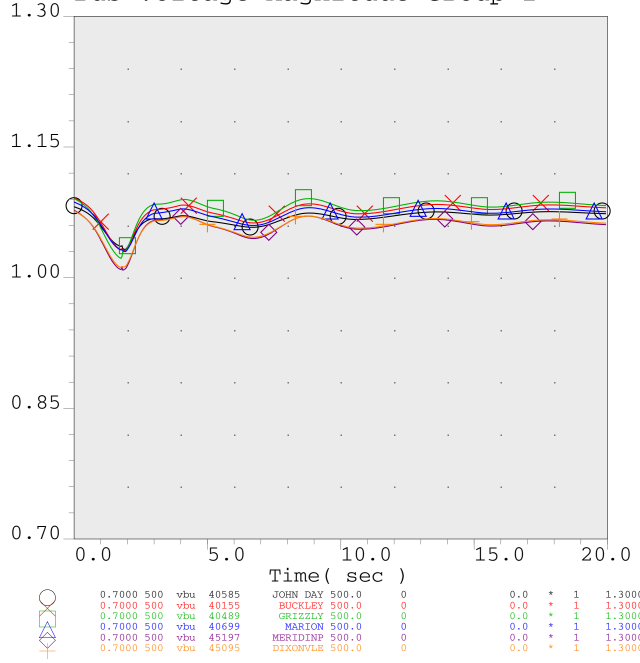
15hs2a_ten_year_ama_Mal-Rnd1-2_ns.chf	. Thu Sep 30 00:06:39 2010

2015 Summer Peak Case
Plots for Category C Tripping of the Palo Verde Units #2 and #3

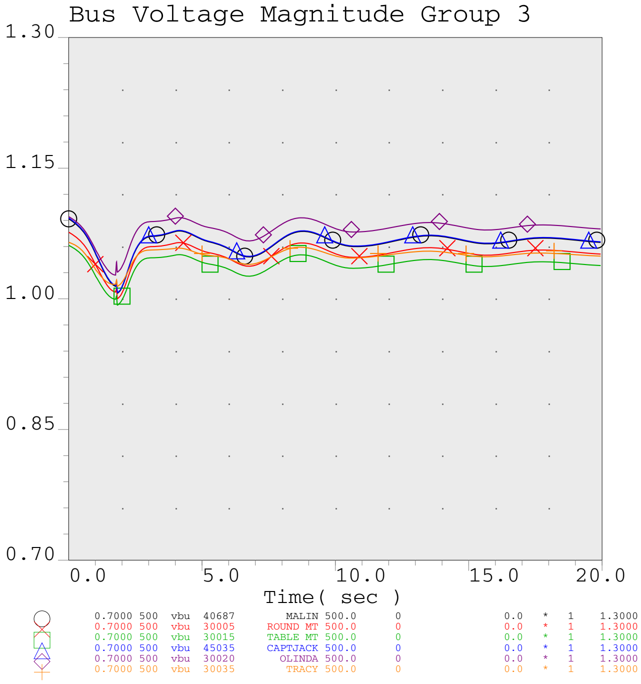
Bus Voltage Magnitude Group 1



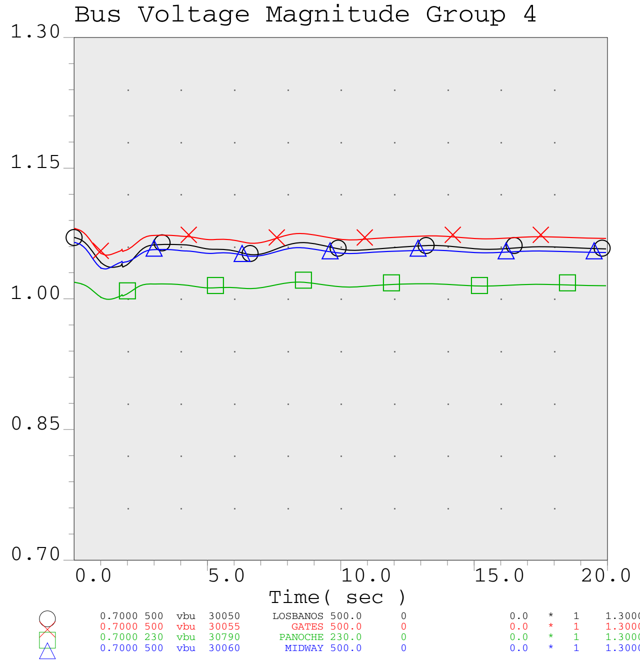
Bus Voltage Magnitude Group 2



Bus Voltage Magnitude Group 3



Bus Voltage Magnitude Group 4

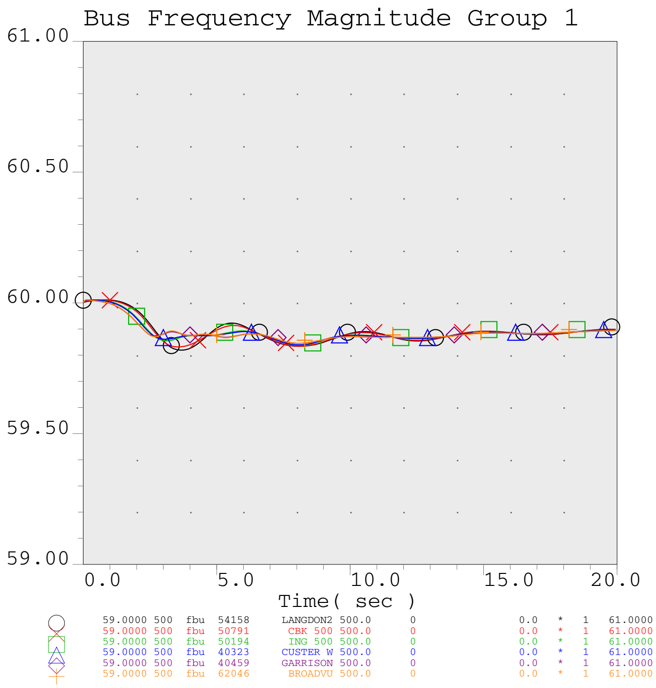


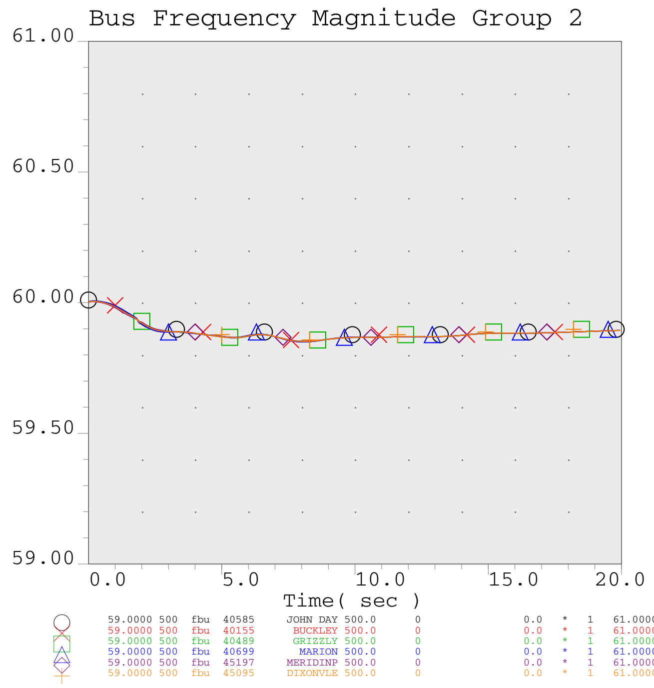
WESTERN ELECTRICITY COORDINATING COUNCIL
2015 HEAVY SUMMER 2 A APPROVED BASE CASE
MAY 3, 2010
Trip 2 Palo Verde Units

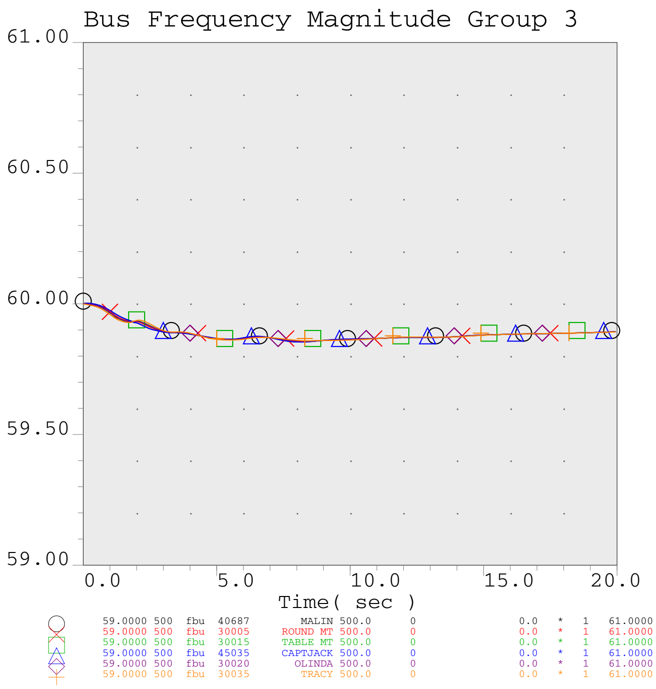
15hs2a_ten_year_ama_PV23_LD120.chf

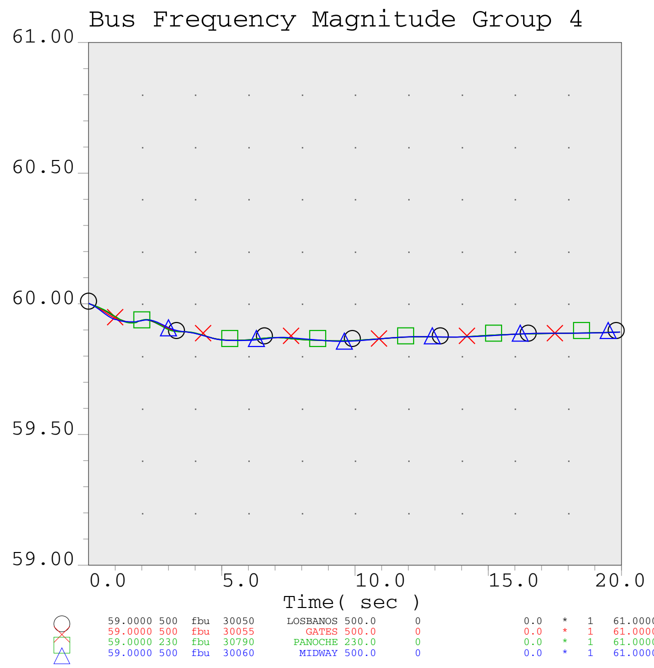
.

Thu Sep 30 02:36:50 2010



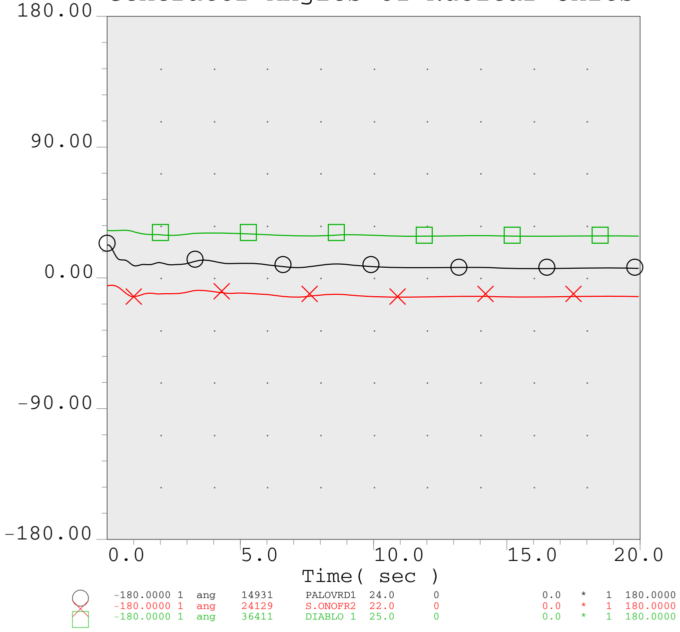




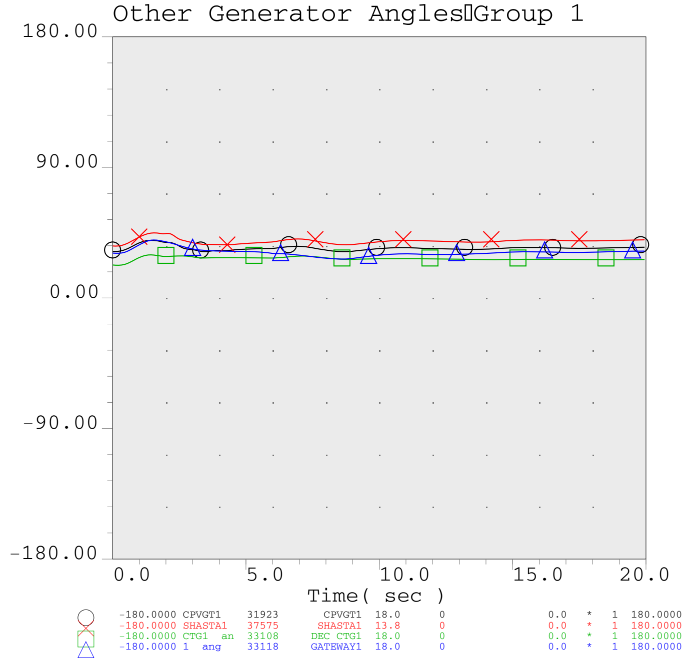


WESTERN ELECTRICITY COORDINATING COUNCIL
2015 HEAVY SUMMER 2 A APPROVED BASE CASE
MAY 3, 2010
Trip 2 Palo Verde Units

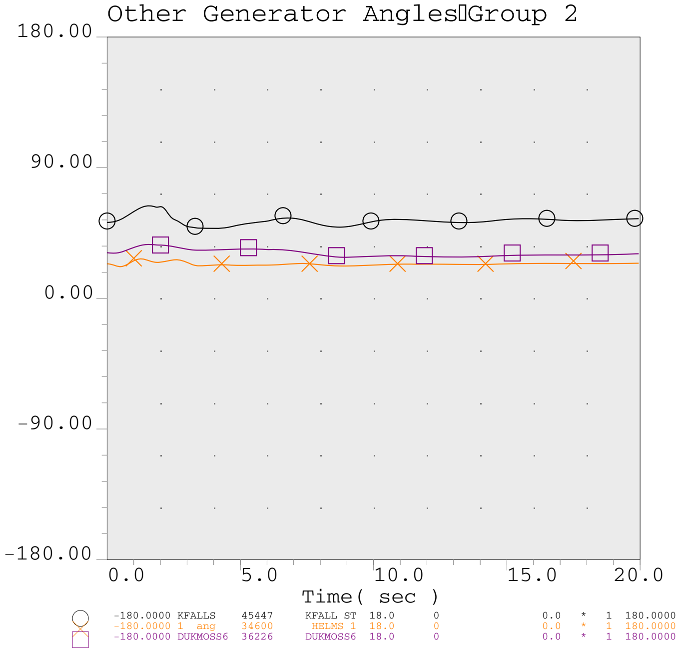
Generator Angles of Nuclear Units

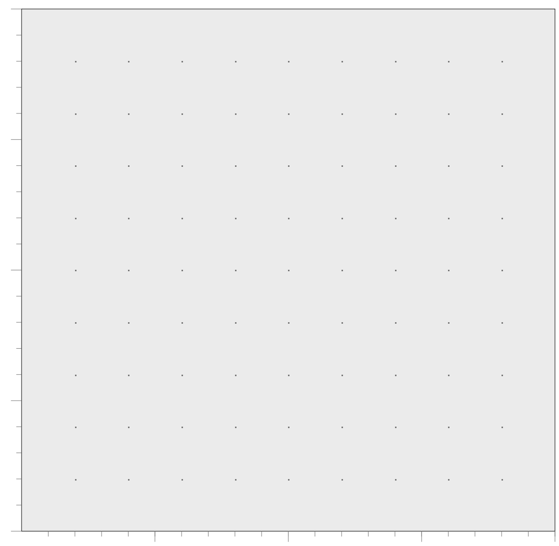


Other Generator Angles Group 1



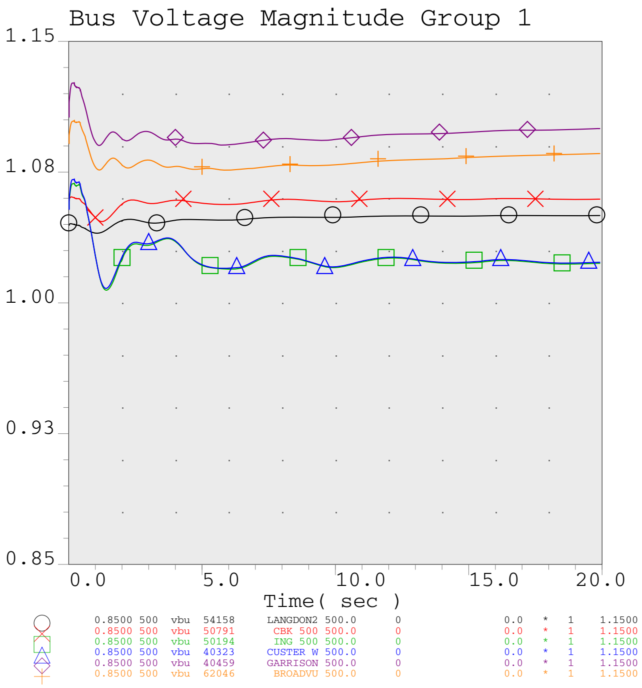
Other Generator Angles Group 2

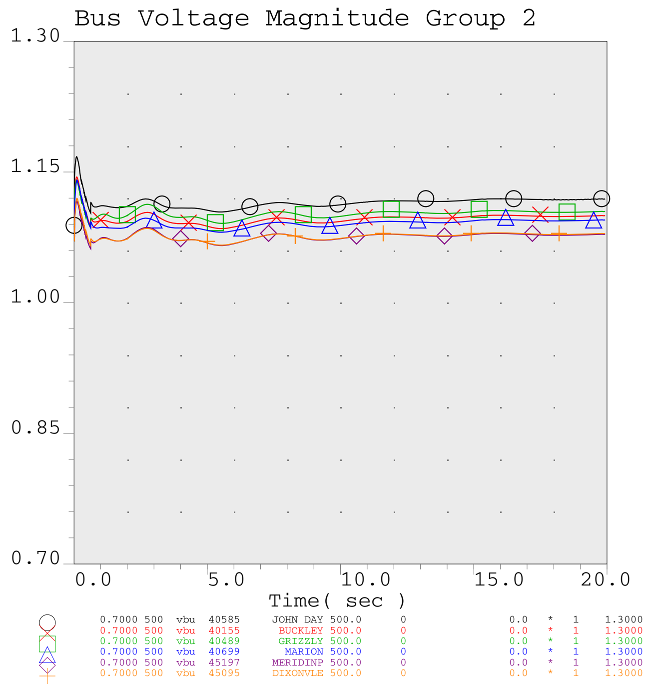


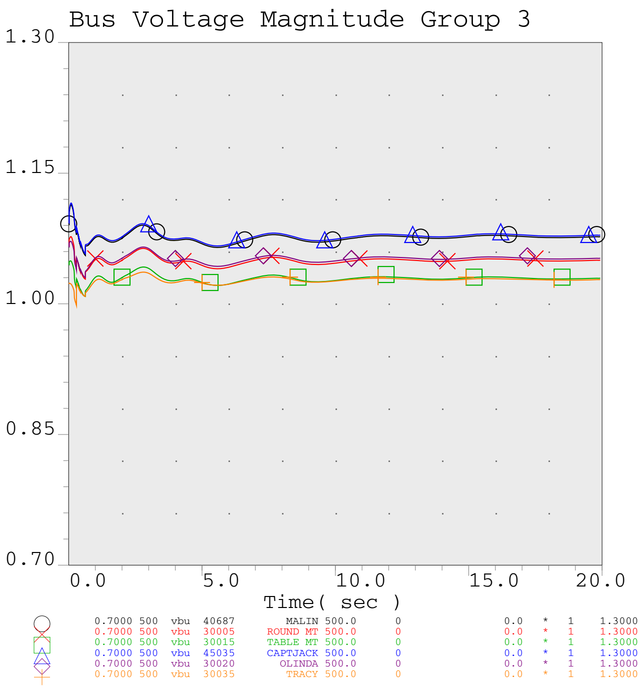


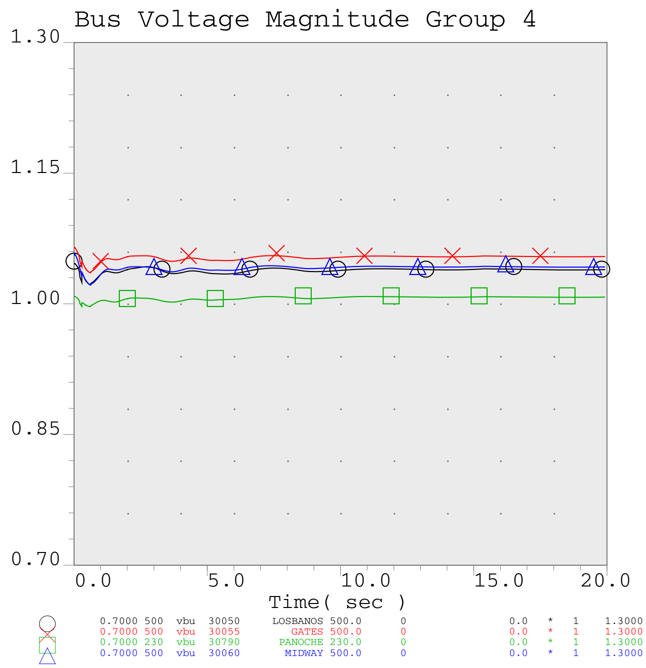
WESTERN ELECTRICITY COORDINATING COUNCIL
2015 HEAVY SUMMER 2 A APPROVED BASE CASE
MAY 3, 2010
Trip 2 Palo Verde Units

2020 Summer Peak Case
Plots for Category B Outage
Involving the Pacific DC Intertie







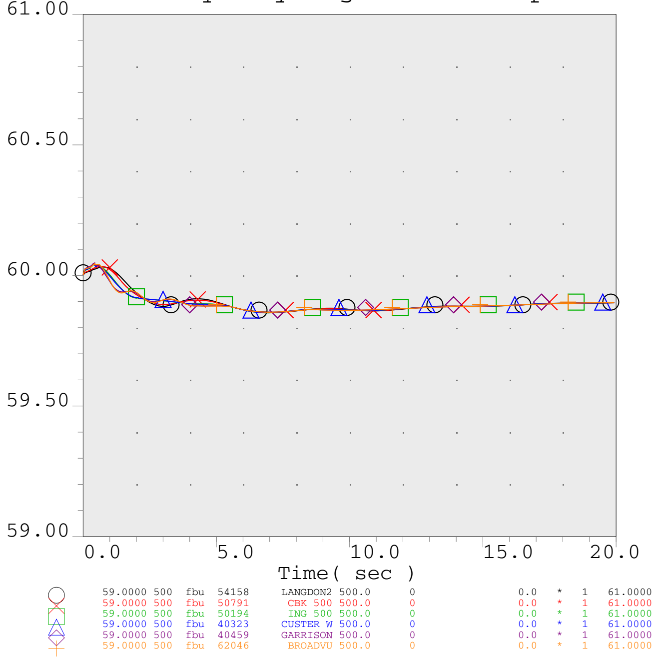


WESTERN ELECTRICITY COORDINATING COUNCIL
20HS1 APPROVED BASE CASE
JUNE 9,2010
BASE CASE
Loss of PDCI Bipole with North-to-South flow

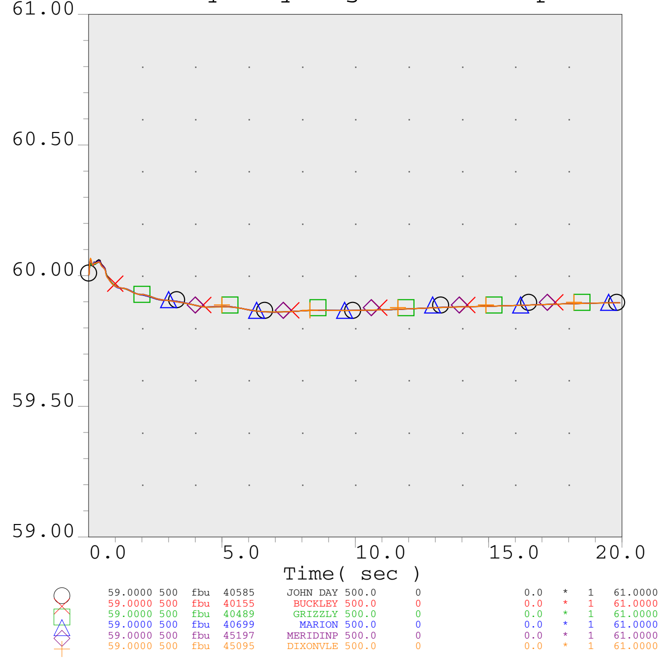
20hs1a_ten_year_v2_PDCI_ns-2700.chf .

Thu Sep 30 09:55:38 2010

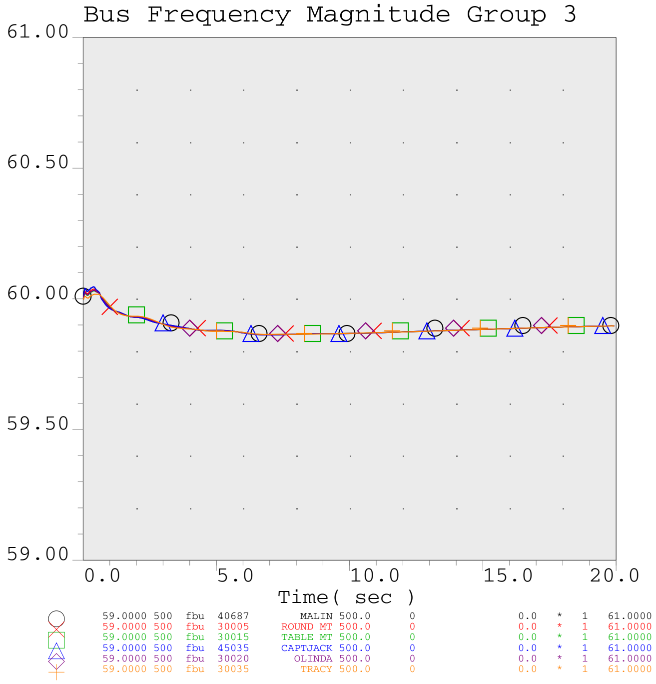
Bus Frequency Magnitude Group 1



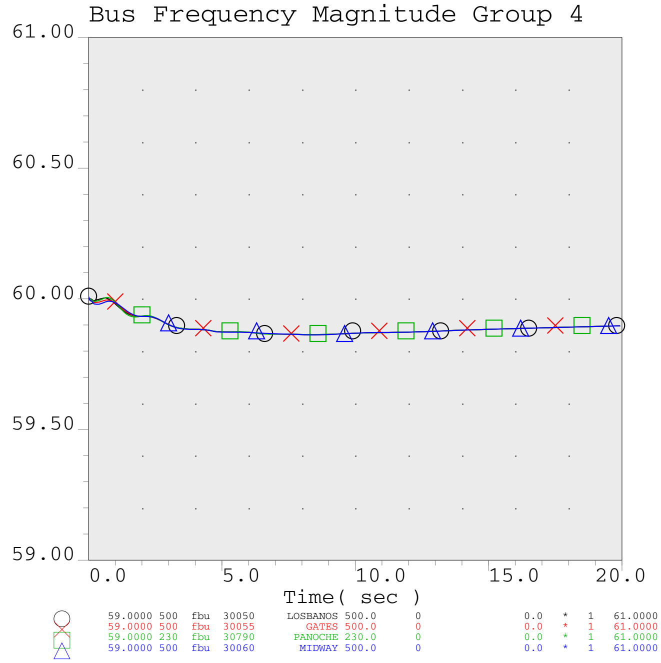
Bus Frequency Magnitude Group 2



Bus Frequency Magnitude Group 3



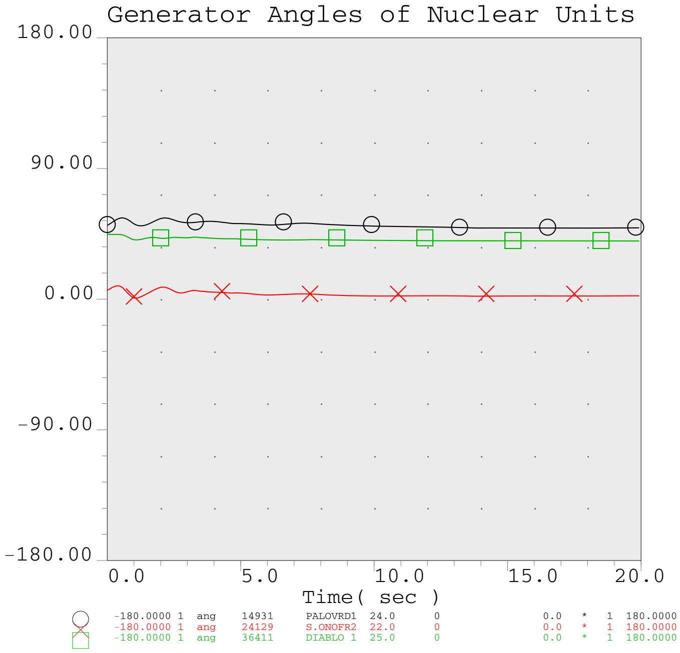
Bus Frequency Magnitude Group 4



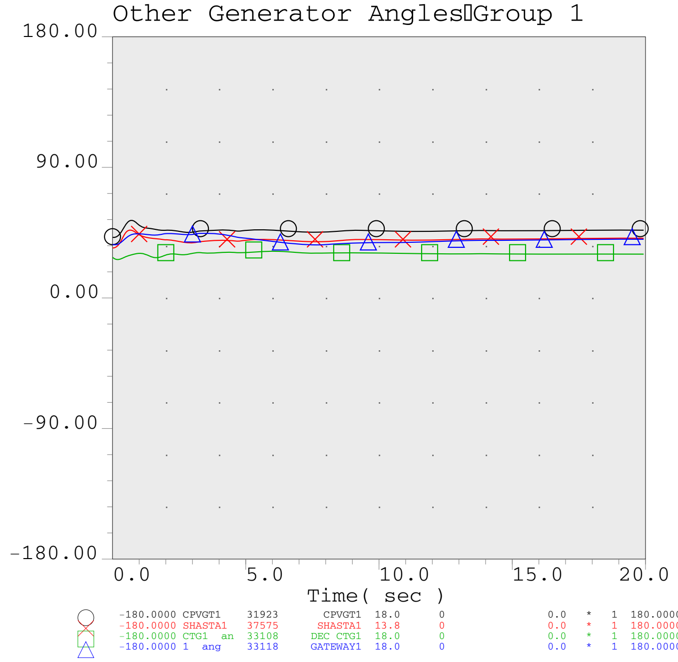
WESTERN ELECTRICITY COORDINATING COUNCIL
20HS1 APPROVED BASE CASE
JUNE 9,2010
BASE CASE
Loss of PDCI Bipole with North-to-South flow

	20hs1a_ten_year_v2_PDCI_ns-2700.chf	. Thu Sep 30 09:55:39 2010

Generator Angles of Nuclear Units



Other Generator Angles Group 1



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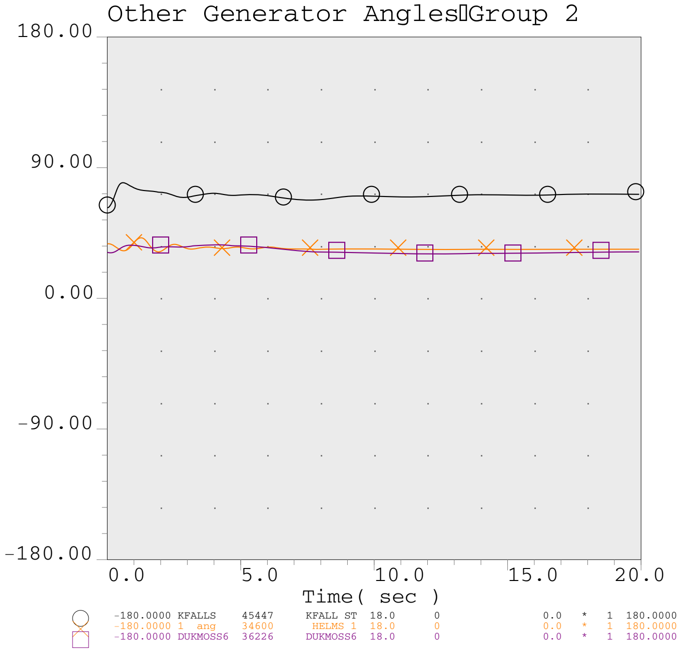

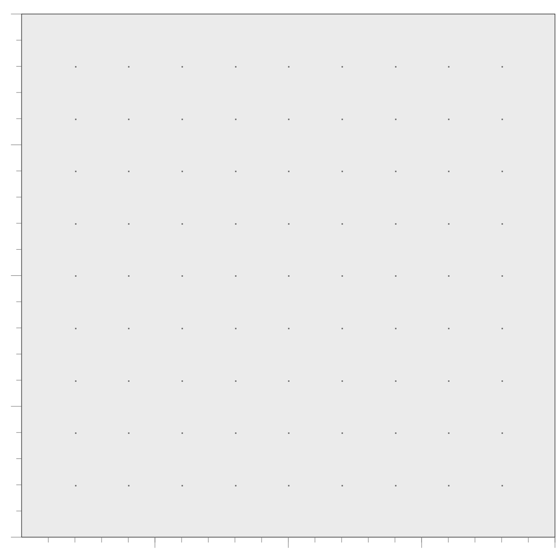

WESTERN ELECTRICITY COORDINATING COUNCIL
20HS1 APPROVED BASE CASE
JUNE 9,2010
BASE CASE
Loss of PDCI Bipole with North-to-South flow

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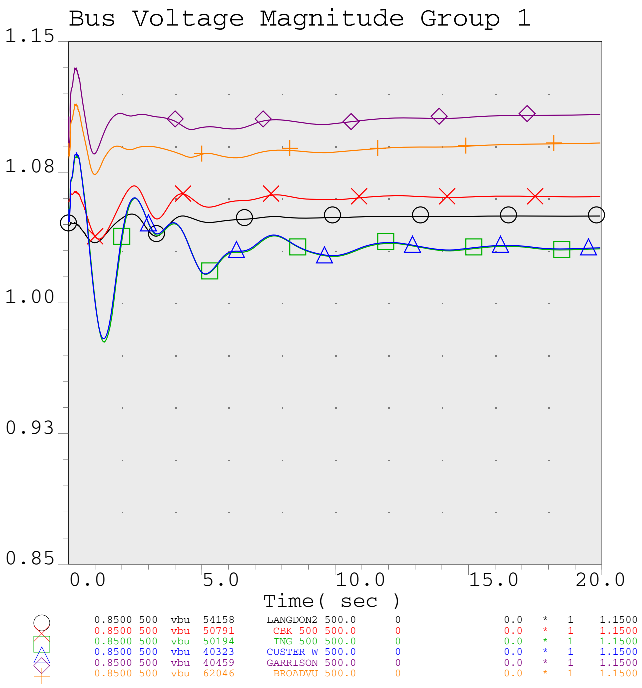
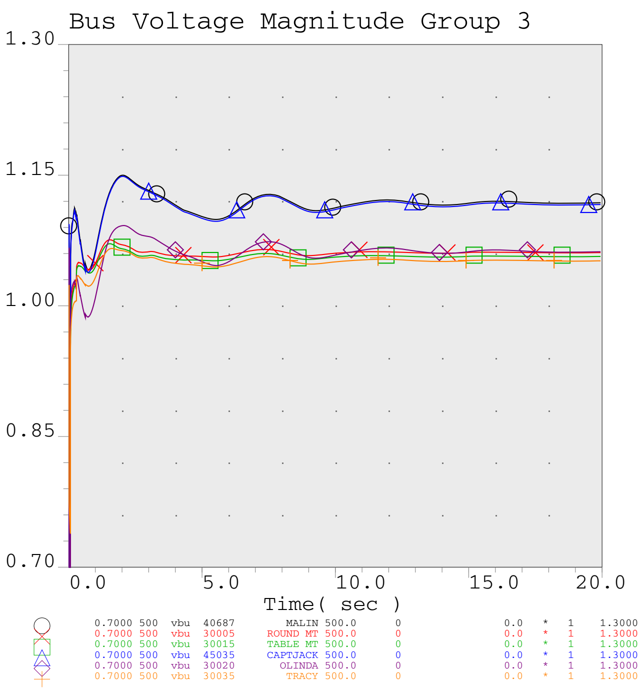
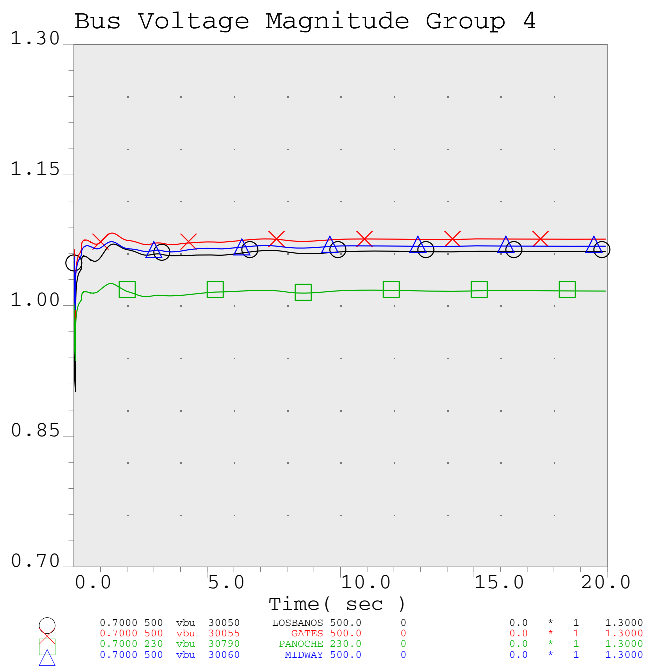
2020 Summer Peak Case
Plots for Category C Outage
Involving the Malin-Round Mountain #1 and #2 500-kV Lines







WESTERN ELECTRICITY COORDINATING COUNCIL
20HS1 APPROVED BASE CASE
JUNE 9,2010
BASE CASE
Malin - Round Mountain #1 and #2 500 kV Double Line Outage

20hs1a_ten_year_v2_Mal-Rnd1-2_ns.chf

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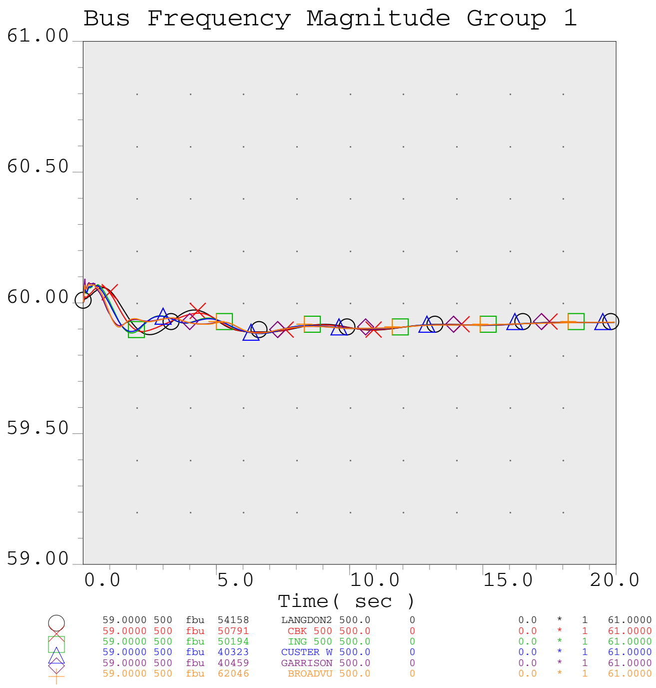
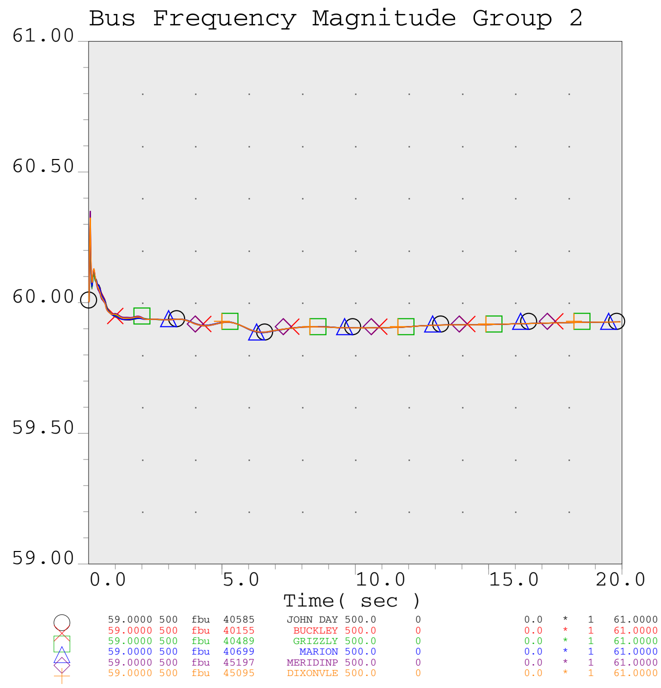
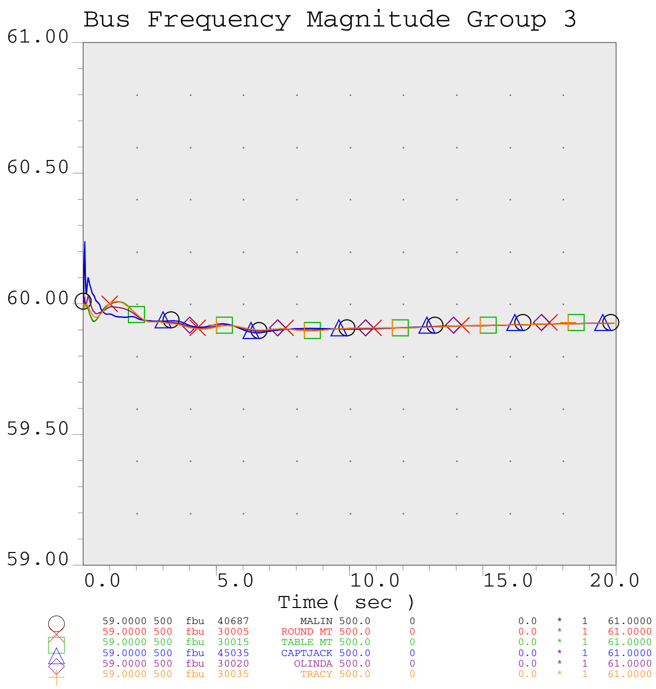
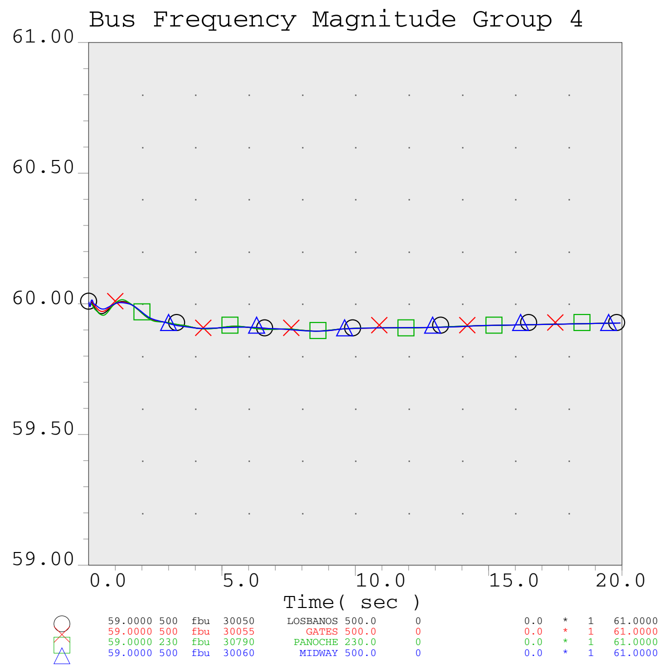
Thu Sep 30 07:54:06 2010









WESTERN ELECTRICITY COORDINATING COUNCIL
20HS1 APPROVED BASE CASE
JUNE 9,2010
BASE CASE
Malin - Round Mountain #1 and #2 500 kV Double Line Outage

20hs1a_ten_year_v2_Mal-Rnd1-2_ns.chf

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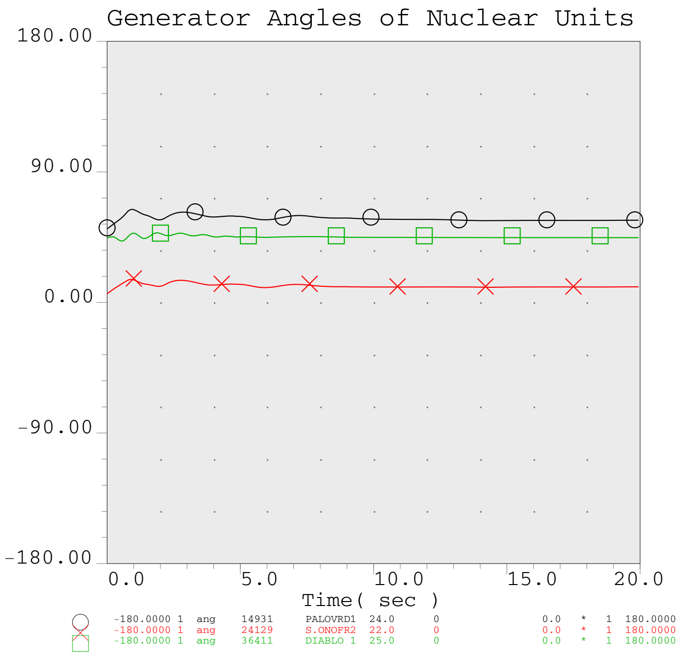
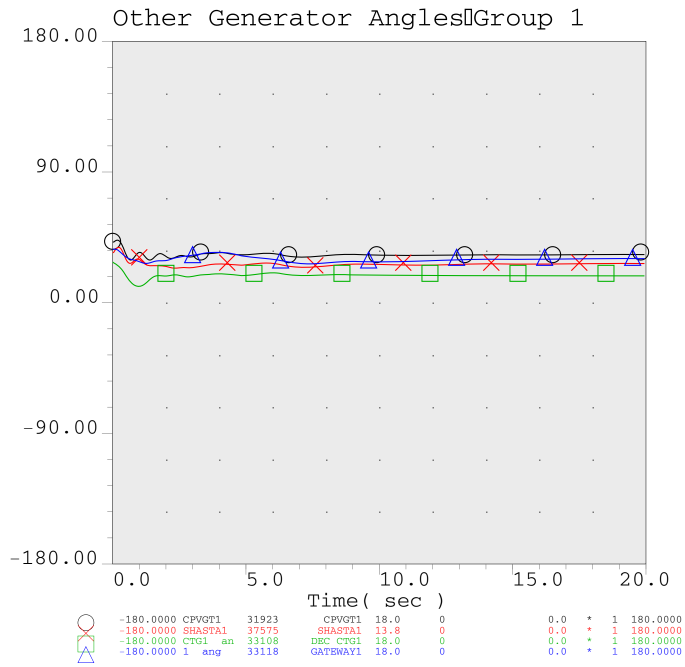
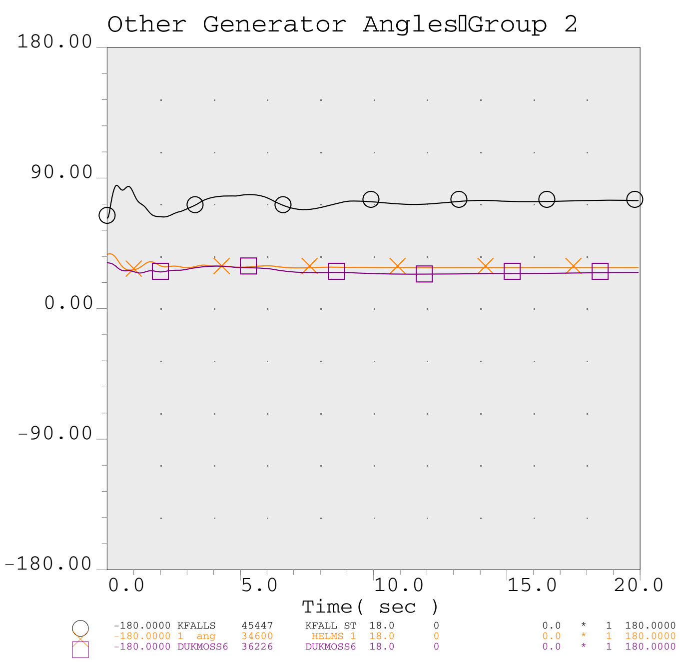
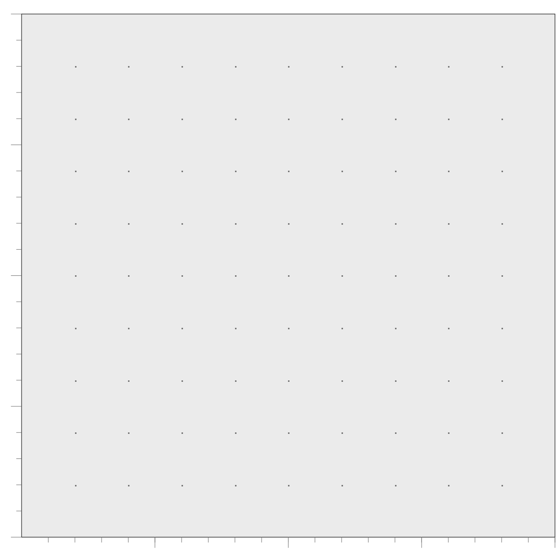
Thu Sep 30 07:54:06 2010





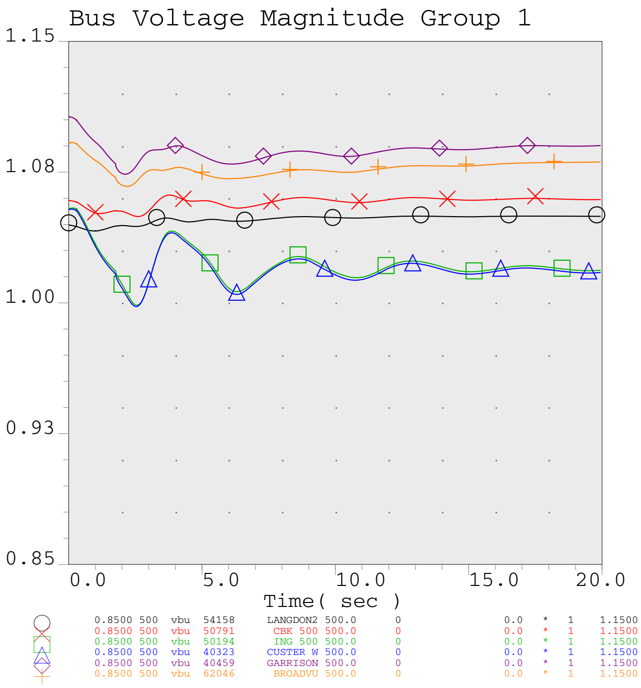


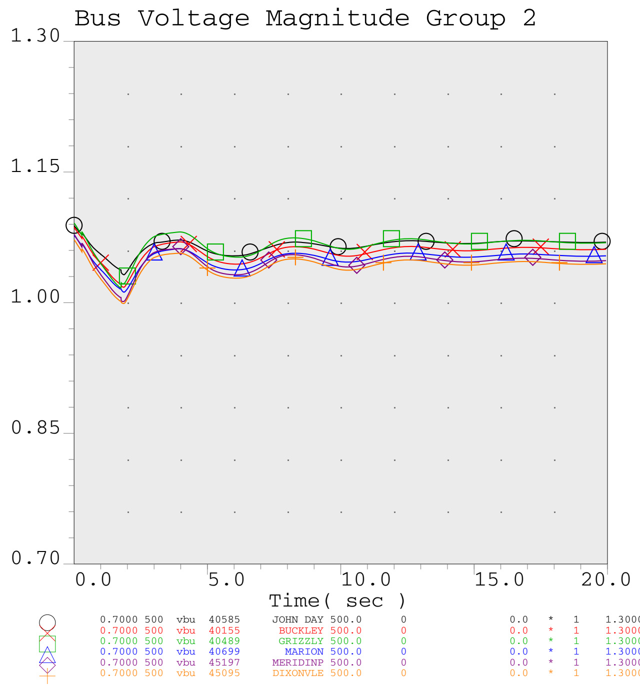


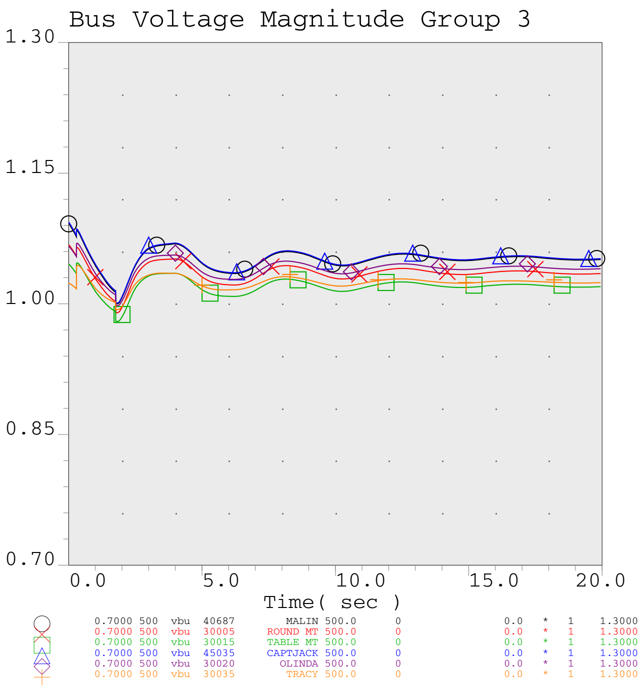
WESTERN ELECTRICITY COORDINATING COUNCIL
20HS1 APPROVED BASE CASE
JUNE 9,2010
BASE CASE
Malin - Round Mountain #1 and #2 500 kV Double Line Outage

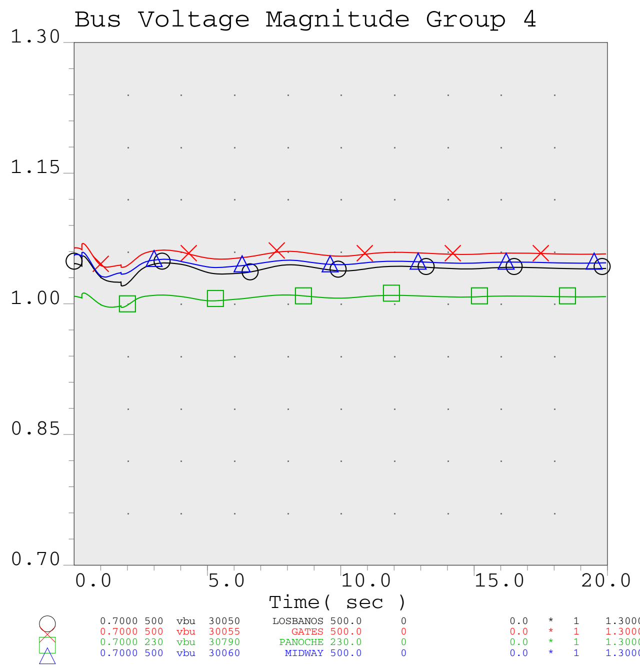
	20hs1a_ten_year_v2_Mal-Rnd1-2_ns.chf	. Thu Sep 30 07:54:06 2010

2020 Summer Peak Case
Plots for Category C Tripping of the Palo Verde Units #2 and #3









WESTERN ELECTRICITY COORDINATING COUNCIL
20HS1 APPROVED BASE CASE
JUNE 9,2010
BASE CASE
Trip 2 Palo Verde Units

20hs1a_ten_year_v2_PV23_LD120.chf

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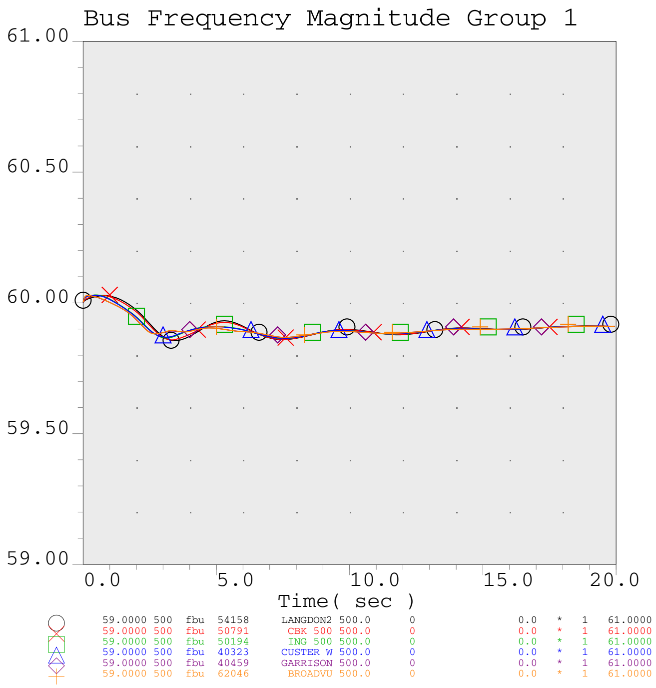
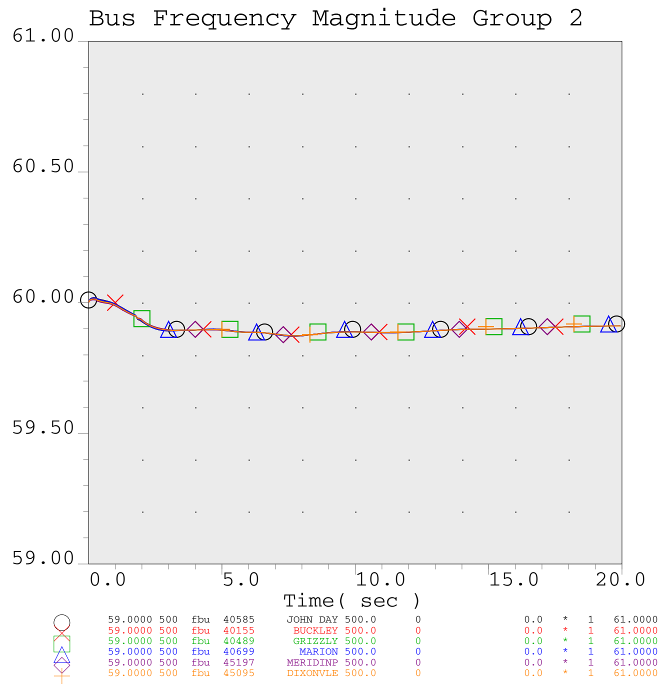
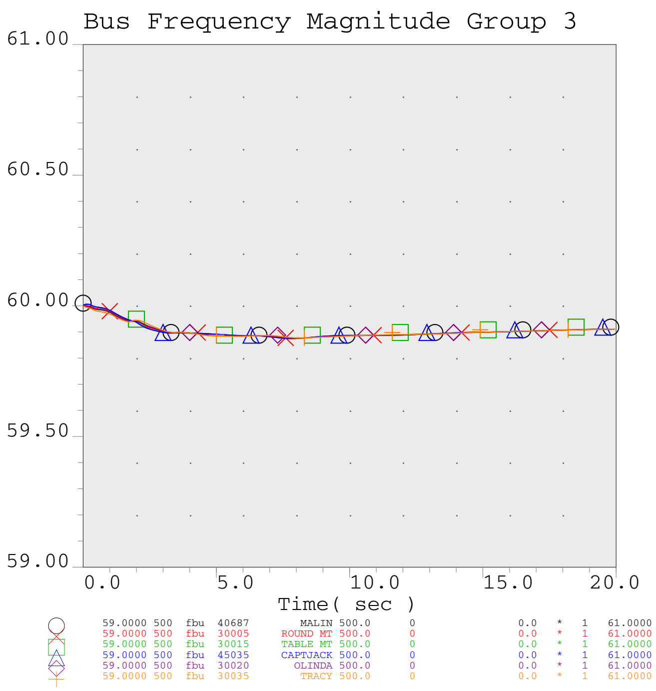
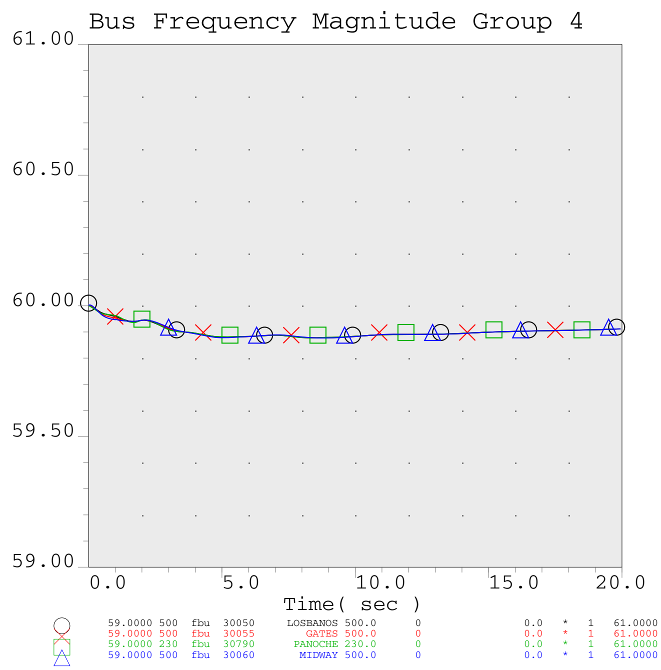
Thu Sep 30 10:12:44 2010









WESTERN ELECTRICITY COORDINATING COUNCIL
20HS1 APPROVED BASE CASE
JUNE 9,2010
BASE CASE
Trip 2 Palo Verde Units

20hs1a_ten_year_v2_PV23_LD120.chf

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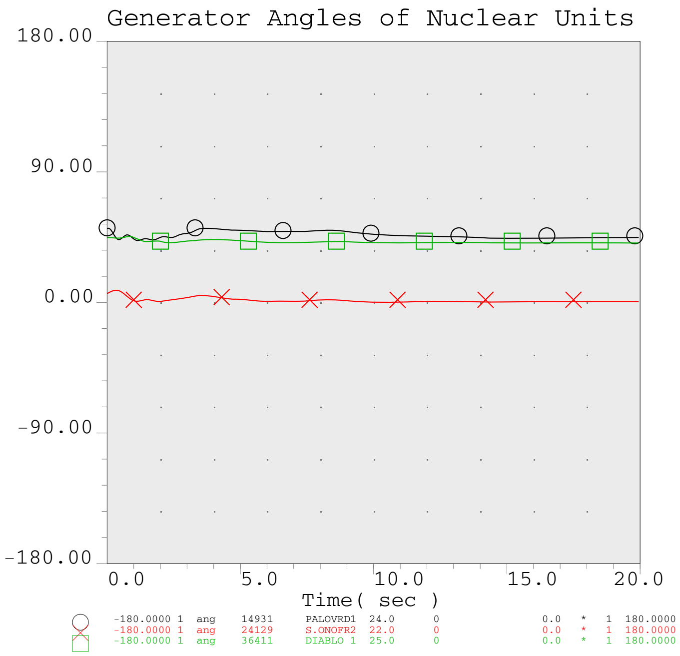
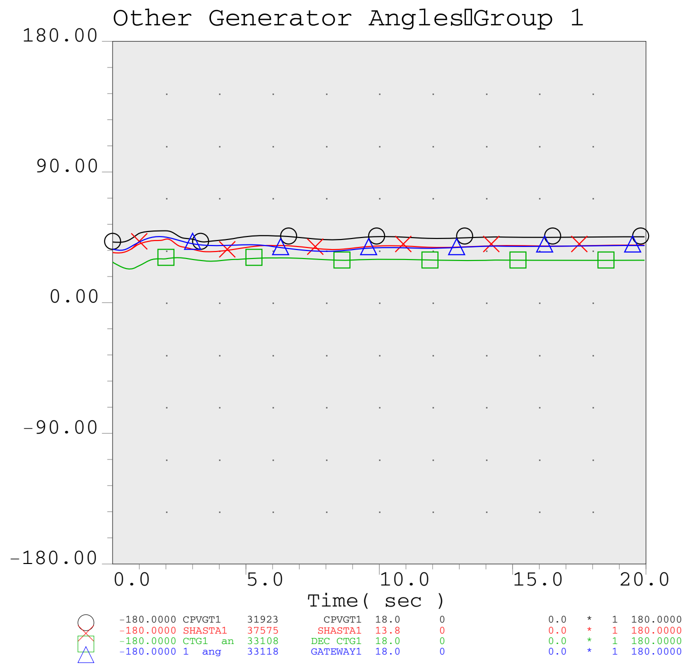
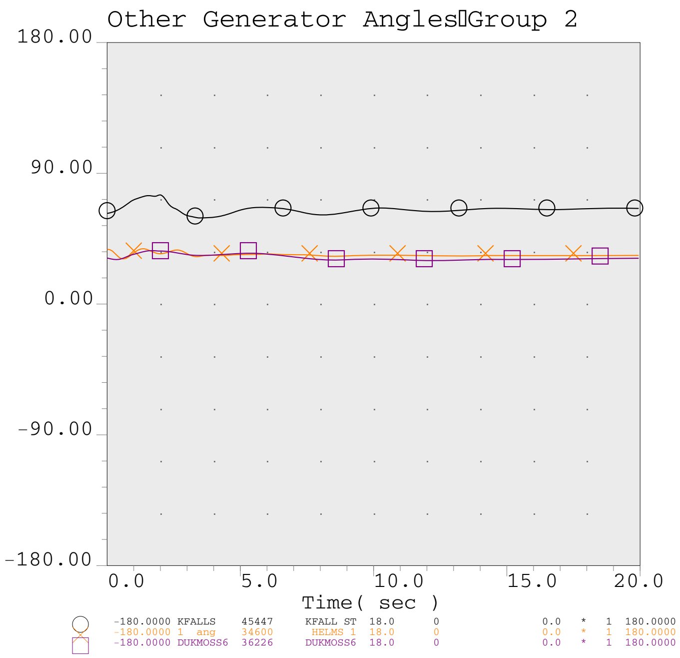
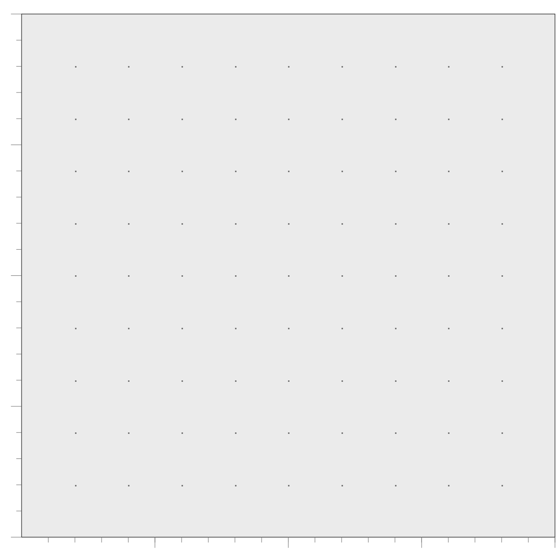
Thu Sep 30 10:12:45 2010









WESTERN ELECTRICITY COORDINATING COUNCIL
20HS1 APPROVED BASE CASE
JUNE 9,2010
BASE CASE
Trip 2 Palo Verde Units

20hs1a_ten_year_v2_PV23_LD120.chf

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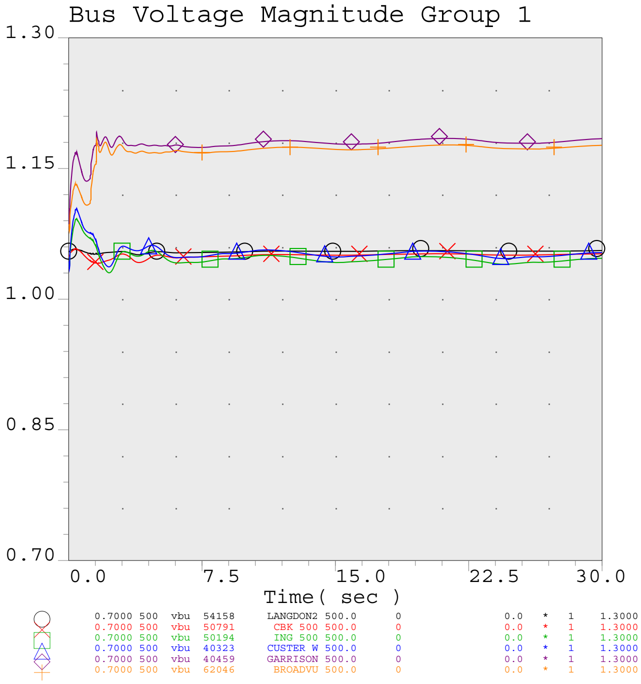
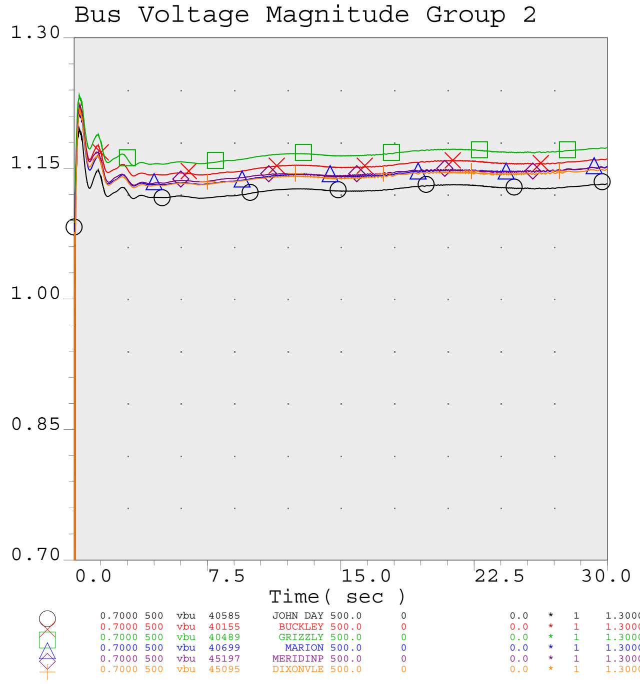
Thu Sep 30 10:12:45 2010

APPENDIX E
TRANSIENT STABILITY PLOTS
FOR CATEGORY D CONTINGENCY

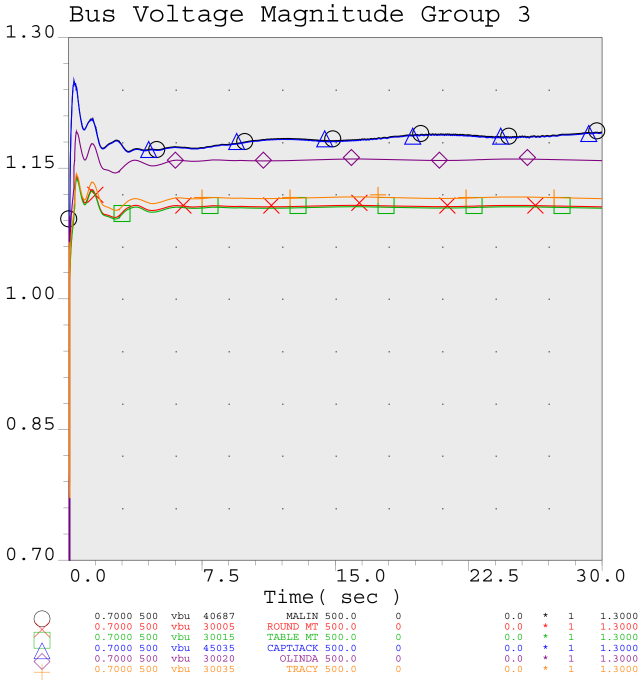
Bus Voltage Magnitude Group 1



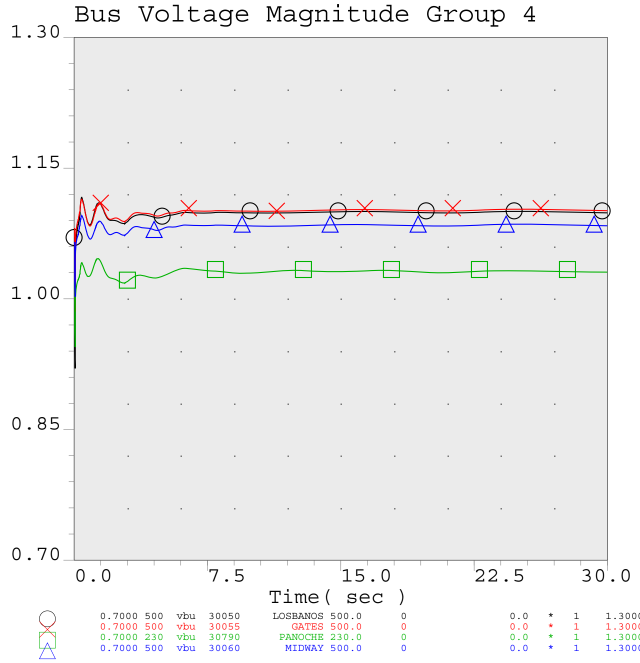
Bus Voltage Magnitude Group 2



Bus Voltage Magnitude Group 3



Bus Voltage Magnitude Group 4



WESTERN ELECTRICITY COORDINATING COUNCIL
2015 HEAVY SUMMER 2 A APPROVED BASE CASE
MAY 3, 2010
NE/SE Seperation: PG&E Load Drop Incl.(IRAS)

15hs2a_ten_year_ama_v2_NESE_Sep_lddrop_AMA.chf

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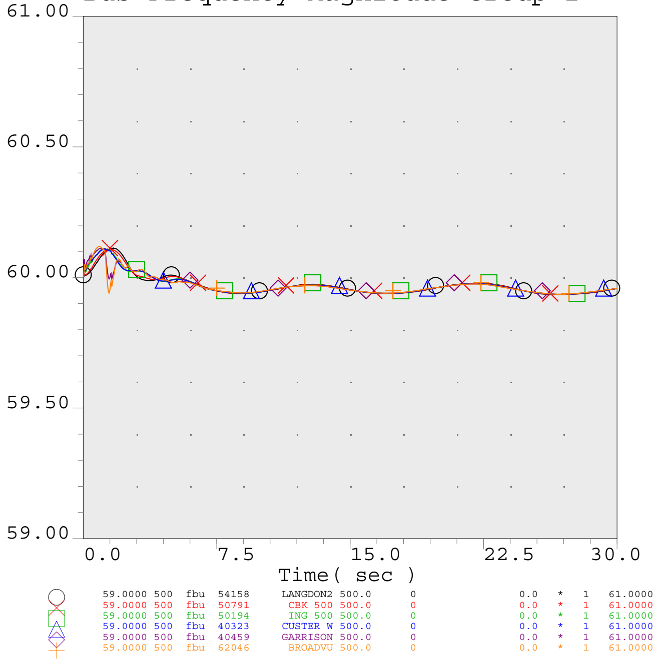
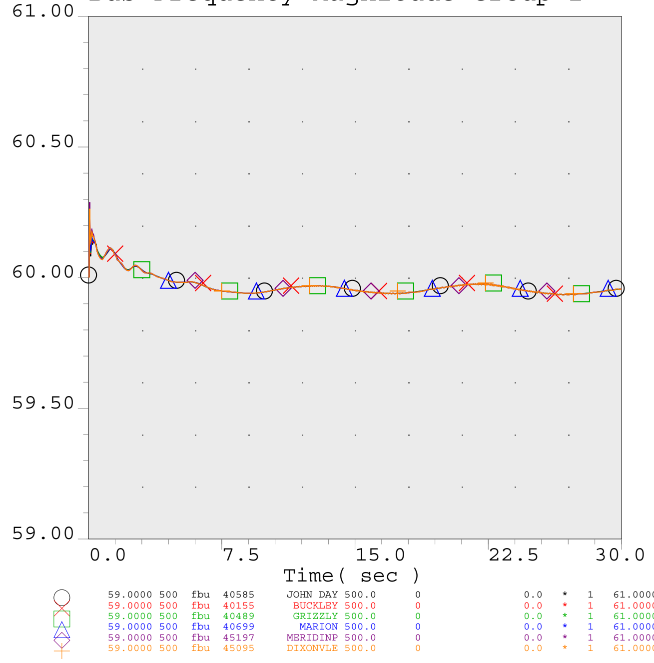
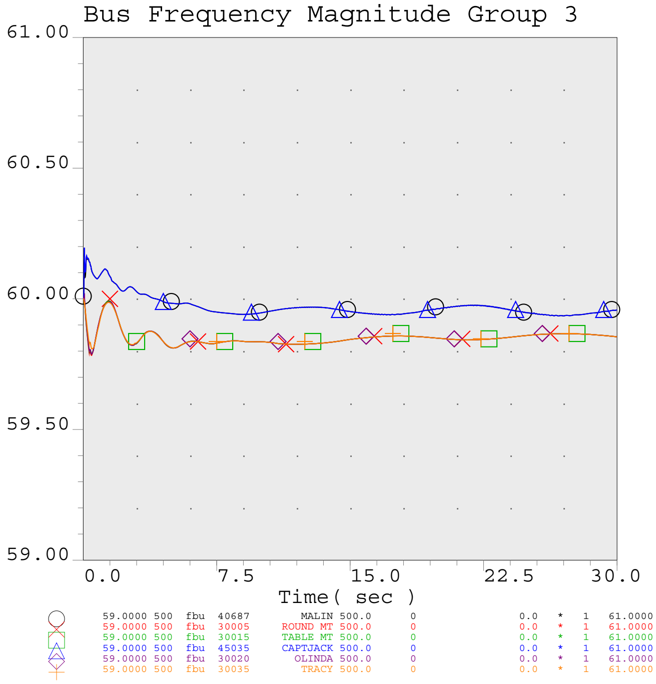
Bus Frequency Magnitude Group 1



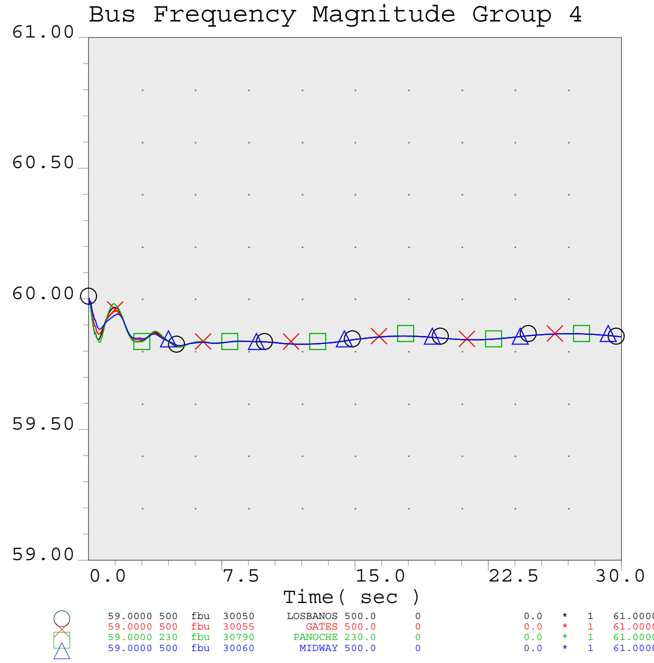
Bus Frequency Magnitude Group 2



Bus Frequency Magnitude Group 3



Bus Frequency Magnitude Group 4



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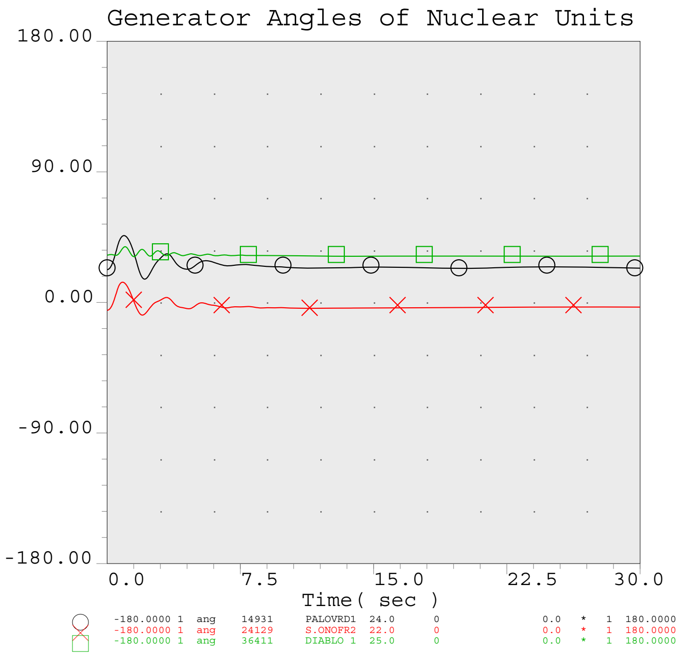

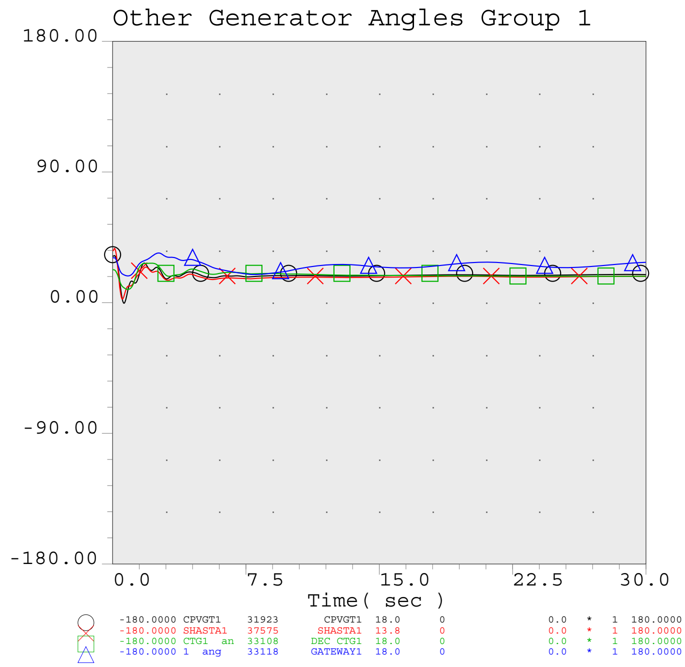

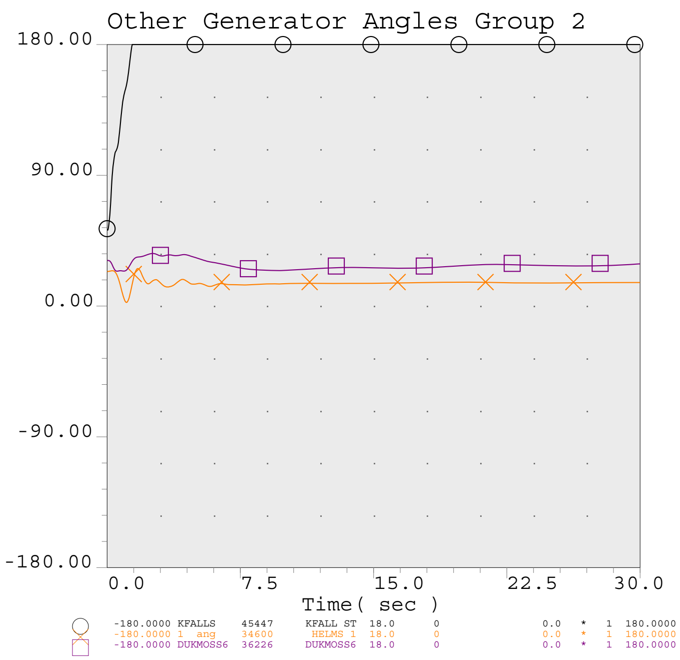

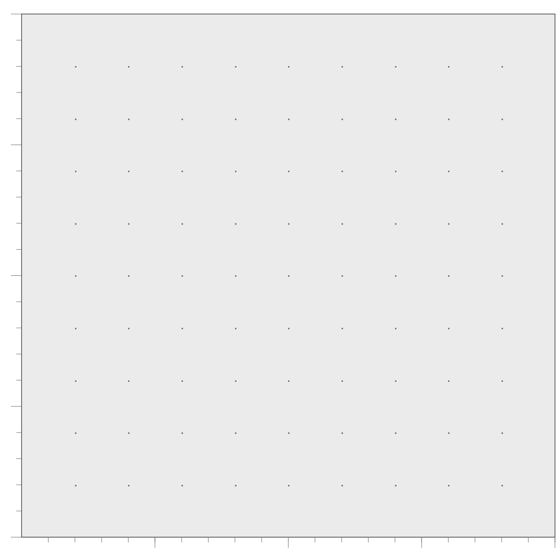

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