Western Area Power Administration
Sierra Nevada Region

2013
Annual Transmission System Assessment

Study Plan

April 2013

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Introduction

The Western Area Power Administration – Sierra Nevada Region's (WASN) transmission system annual assessment will be conducted to provide a transmission plan spanning at least ten years (2014 thru 2023) and be consistent with meeting the requirements of NERC Transmission Planning Standards TPL-001 thru TPL-004. This is a technical analysis of WASN's transmission system and not of the load-serving entities and generation resources associated with it, but their interaction with the WASN transmission system will be investigated. WASN does not possess load and therefore is not an LSE nor is it registered as one. The assessment will focus on the ability of WASN's transmission system to reliably accommodate power imported on the California-Oregon Transmission Project 500 kV line and power generated by the U.S. Bureau Of Reclamation's Central Valley Project hydro generation plants to supply load within the cities of Redding and Roseville as well as in the Sacramento Area and beyond. Critical system conditions will be analyzed. Where potential reliability problems are identified, mitigation measures will be identified to maintain required system performance. Mitigation measures will include proposed new transmission projects or other mitigation measures such as operating procedures including operating nomograms and Special Protection Schemes.

This Study Plan is a guide for coordinating the base case modeling assumptions, conducting the technical analysis, preparing documentation and reports including proposing new transmission projects or other mitigation measures. While this assessment is the basis of a ten-year transmission plan and covers years 2014 through 2023, for maintaining system reliability, emphasis is placed on years 2014, 2018 and 2023 of the plan where the interconnected transmission system reliability is addressed and potential performance deficiencies are identified and corresponding projects that resolve these problems are developed. As required, analysis out to the year 2023 will be analyzed to identify potential reliability concerns, which may require longer lead-times associated with significant 230 kV and 500 kV (as applicable) systems reinforcements.

This assessment will build on previous assessments, but also not duplicate previous assessments such that if there is no significant change being planned to the system, therefore no change in the assessment would be expected. To this extent, additional contingencies and system scenario's will be investigated that have not been in previous assessments. These scenarios could involve other utilities transmission projects as well as different resource scenarios.

Specifically, an assessment of WASN's transmission facilities will be performed to identify reliability problems within the years 2014 to 2023 delivering transmission service obligations. For each identified potential reliability problem directly associated with WASN's transmission system and obligations to transport power through its transmission system, a mitigation plan will be proposed. As appropriate, alternative mitigation plans will be developed to determine the preferred engineering and economical mitigation plan. Existing transmission projects will be investigated to verify their continuing need and operation date.

Responsibilities and Objectives

With coordination and input from surrounding and interconnected utilities, WASN is responsible for performing a system assessment and developing a transmission plan of its transmission facilities covering the next 10 years. WASN will perform the following:

- As needed, revise power flow base cases obtained through the Western Electricity Coordinating Council (WECC) and commented on by the California Independent System Operator (CAISO), Pacific Gas and Electric (PG&E) and Sacramento Valley Utilities that model the 10 year span of the studies under various seasonal and load conditions;
- Conduct transmission system studies and benchmark the performance of WAPA's transmission facilities;
- Identify potential reliability problems for the 5 and 10-year planning horizons based on NERC Transmission Planning Standards and their requirements;
- Propose mitigation plans to address potential reliability problems for years 2014 to 2023; and
- Disseminate a report on the assessment to the WECC Reliability Coordinator as well as those utility entities within California or adjacent to it where the assessment results are relevant to the planning and operation of their electric transmission systems.

The projects proposed in the transmission plan will accomplish the following objectives:

- Comply with NERC Transmission Planning Standards TPL-001 thru TPL-004 and associated Requirements;
- Provide reliable transmission service to electric customers whose power is transmitted over WASN transmission lines;
- Maintain acceptable system voltages and reactive power support, thermal loadings on transmission facilities and synchronism of generator units directly connected to WASN's transmission system;
- Include planned transmission system additions and upgrades and verify their continued need and initial operation date;
- Support coordinated operation with interconnected and parallel utilities transmission systems; and
- Follow-up on the results and findings of various previous and on-going transmission planning studies

Reliability Standards

NERC Transmission Planning Standards TPL-001, TPL-002, TPL-003 and TPL-004 (included in Attachment 2) and their requirements will be the basis for establishing completion of this annual assessment.

Standard TPL-001-0 — System Performance Under Normal (No Contingency) Conditions (Category A)

Standard TPL-002-0 — System Performance Following Loss of a Single Bulk Electric System Element (Category B)

Standard TPL-003-0 — System Performance Following Loss of Two or More Bulk Electric System Elements (Category C)

Standard TPL-004-0 — System Performance Following Extreme Events Resulting in the Loss of Two or More Bulk Electric System Elements (Category D)

Table I. 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 Yes Yes Yes	 No[b] No[b] No[b] No[b]	 No No No 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 Yes	 Planned/ Controlled[c] Planned/ Controlled[c]	 No 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 Yes	 Planned/ Controlled[c] Planned/ Controlled[c]	 No No
	SLG Fault, with Delayed Clearing[e] (stuck breaker or protection system failure): 6. Generator 7. Transformer 8. Transmission Circuit 9. Bus Section	 Yes Yes Yes Yes	 Planned/ Controlled[c] Planned/ Controlled[c] Planned/ Controlled[c] Planned/ Controlled[c]	 No No No No

Standard TPL-001-0 — System Performance Under Normal Conditions

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 3Ø Fault, with Normal Clearing [e]: 5. Breaker (failure or internal Fault) 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 a 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.	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.

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-recallable 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 breaker, 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.

Study Assumptions

The annual transmission planning process starts with the development of power flow base cases that model WASN's transmission system within Northern California as well within the WECC reliability area. This section discusses the assumptions used in developing the power flow base cases for this study.

A. Base Cases Developed for Transmission System Assessment

Power flow base cases for this annual assessment are derived from base cases developed by WECC members through the WECC basecase development effort. The basecases are commented on by PG&E and the California Independent System Operator (CAISO), represent the Northern Valley portion of California's Central Valley area with transmission and generation representation of Northern California. Specifically, the base cases were developed through review and any required revision by WASN, those entities that supply and receive power over WASN's transmission system and other utilities within Northern California as well as within the WECC area. The transmission system configuration was updated to reflect, according to the projected year of operation, new planned transmission system reinforcements expected to be approved and become operational. The cases include WASN transmission facilities updated to reflect any recent changes to the configuration of the transmission system as well as voltage support devices at WAPA owned and/or operated substations. Voltage support devices include shunt reactors, shunt capacitors and series capacitors. In general, the WECC system-wide cases include forecasted 1-in-5-year summer peak load.

Historically, maximum power flow through WASN's transmission system has occurred during summer peak load conditions when pre-dominate power flow through the 500 kV transmission system in California is from North to South. This flow along with near maximum hydro power generation in Northern California model the most stressed conditions on the WASN transmission system. Previous WASN Annual Transmission Assessments support this conclusion.

However, there are system conditions that occur during other seasons or load conditions that warrant investigation. These include summer off-peak conditions with lower load, spring peak load conditions when loads are lower and maximum hydro power is available or during winter peak when loads are lower, hydro power is minimal and the direction of pre-dominate power flow through the 500 kV transmission system in California is in a South to North direction. To address this issue and as needed to adequately assess the reliability of WASN's transmission system, additional seasonal WECC base cases will be utilized. These WECC cases were developed by WECC members with representation of the entire WECC area.

Base cases that will be utilized for this annual transmission assessment are summarized in Table 1.

Table 1: List of Study Base Cases Derived from WECC Base Cases

- 2015 Heavy Spring WECC approved case with TSS and OC comments reviewed and incorporated. WECC Base Cases: 18hsp1a2
- 2016 and 2022 Light Spring WECC approved case with TSS and OC comments reviewed and incorporated. WECC Base Cases: 16lsp1sa1, lsp1sb2
- 2014 through 2021 and 2023 Heavy Summer WECC approved case with TSS and OC comments reviewed and incorporated. WECC Base Cases: 14hs3sa2a, 15hs2a2, 16hs2a2, 17hs1a1, 18hs2a1, 19hs1a1, 20hs1a2, 21hs1a2, 23hs1a1
- 2022 Light Summer WECC approved case with TSS and OC comments reviewed and incorporated. WECC Base Cases: 22ls1sb2
- 2015 through 2019 and 2022 Heavy Winter WECC approved case with TSS and OC comments reviewed and incorporated. WECC Base Cases: 15hw2a2, 16hw2a2, 17hw2a1, 18hw2a1, 19hw1a1, 22hw1a1
- 2022 Light Winter WECC approved case with TSS and OC comments reviewed and incorporated. WECC Base Case: 17lw1a1s
- 2015 Heavy Autumn WECC approved case with TSS and OC comments reviewed and incorporated. WECC Base Case: 15ha1sa1
- 2014 and 2016 Light Autumn WECC approved case with TSS and OC comments reviewed and incorporated. WECC Base Case: 14la1sa2, 16la1sa2

See Attachment 1 for a diagram of the WAPA-SNR system within Northern California.

Please note that these base cases are considered a “base” starting point when studying a particular area. Other electric load, generation, or import-export scenarios may be studied to determine their influence on system performance.

B. Electric Demand and Power Factor Assumptions and Methodology

Base case assumptions for electric demand and power factor will represent projected summer peak load conditions as reported by WASN’s Load Serving Entities (LSE) (the cities of Redding, Roseville, Lawrence Livermore Lab, Ames Research etc.) consistent with the California Energy Commission’s (CEC) Integrated Energy Policy Report (IEPR) which includes load projections for all of Northern California as well as separately for public and privately owned electric utilities. Electric demand and power factor assumptions for the WECC system-wide base cases will incorporate a 1-in-5 year adverse weather assumption based on ambient temperature. Similarly, the PG&E North Valley area base cases incorporate a 1-in-10 year adverse weather assumption. Additional information on the electric demand forecast is listed below:

Forecasted Load in MW represented in summer peak load power flow cases (4)

Year	2014	2018	2023
SMUD	3285	3463	3801
City of Redding(3)	327	335	357

City of Roseville	368	381	405
MID	756	740	820
WASN Direct Service(1)	177	162	168
Total Northern California Area Load (2)	28,386	28,329	29,870

(1) Includes the Tracy Pumping Plant, City of Shasta Lake, Lawrence Livermore Lab

(2) Includes - PG&E, SVP, SMUD, MID, TID, WAPA Direct Svc, LMUD, NCPA, Roseville, Redding, CDWR and Other Muni's

(3) Redding includes load at Knauf

(4) Forecasted 1-in-10 year load for the Sacramento Valley was used when appropriate. In several years forecasted load was greater than Load Serving Capability load, in which case load was adjusted while monitoring WAPA's Elverta bus voltage. WASN is not an LSE and has no obligation to support the load of adjacent Sacramento Valley LSE's.

C. Major Path Flow Assumptions

The summer peak base cases will model 4,800 MW of north-to-south flow on the California-Oregon Intertie, COI (Path 66). The flow on the Midway-Vincent 500 kV lines (Path 26) at Midway Substation will be modeled at 4,000 MW (North-to-South), but varied as necessary to balance loads and resources in Northern California. Table 2 summarizes the major path flow assumptions.

Import-Export and Major Path Assumptions

The summer peak base cases modeled approximately 4,800 MW flowing north-to-south on the California-Oregon Intertie, COI (Path 66). The flow on the Midway-Vincent 500 kV lines (Path 26) at Midway Substation varied as necessary to balance loads and resources in Northern California. Additionally, Northern California Hydro conditions were modeled at 100% output.

D. Generation Assumptions

Assumptions on existing generation facilities such as capability and output levels were developed based on generation dispatch data for Northern California for most base cases that would provide the most stressed conditions during heavy summer conditions. In recent years Northern California total generation for both hydro and thermal have greatly changed and as a result impacts on the COI versus Northern California Hydro nomogram have been impacted. In order to capture impacts and the changing nature of Northern California generation as a whole, 100% Northern California hydroelectric generation was assumed in the heavy summer cases. Although this generation dispatch exceeds generation levels of current nomogram generation levels, it captures possible concerns in the planning horizon. These extreme planning conditions will highlight possible weak areas in the WASN transmission grid, while capturing the changing nature of Northern California generation patterns. US Bureau of Reclamation Central Valley Project hydro generation was modeled at maximum output to provide maximum stress to the northern portions of the Western system as well as PG&E hydro generation.

The overall generation pattern and level of generation modeled in power flow base cases was representative of recent utility information provided for both PG&E and WECC seasonal base cases representing peak and off-peak load conditions.

By studying different study years and seasons, various generation patterns that could influence system reliability was analyzed.

System Assessment

The WASN transmission system will be evaluated against NERC's Planning Standards listed below.

Category A (NERC Planning Standard TPL-001): All Facilities in Service, (N-0)

Category B (NERC Planning Standard TPL-002): Single Element Outage, (N-1)

Category C (NERC Planning Standard TPL-003): Double Element Outages, (N-2)

Category D (NERC Planning Standard TPL-004): Extreme Events (N-2 plus) covering the contingencies included for Categories B and C above.

The various contingencies analyzed as associated with NERC Planning Standards will be listed in the study report.

Assessment Study Scope

The assessment process will test the WASN transmission system against NERC Planning Standards. This process will evaluate the transmission grid for the following:

- Thermal Loading and Voltage Limits
- Transient Stability
- Voltage Stability – Post Transient Voltage
- Proposed new transmission projects
- Transmission Upgrades to support import of generation from Renewable Resources

A. Thermal Loading and Voltage Limits

A thermal loading assessment will be performed on all WASN transmission facilities. This analysis will examine thermal loadings under normal and contingency conditions. Should a WAPA transmission facility be determined to exceed its thermal capability normally or during contingency conditions, WAPA will address the thermal loading with a mitigation plan.

WASN will examine system voltages to determine if they stay within acceptable post transient and steady state limits. As with the thermal loading assessment, the analysis will include examining base case (normal) conditions and contingency conditions.

B. Transient Stability

Transient stability assessments will be conducted in accordance with the WECC Stability Standards for selected contingency conditions. The scope of these studies will be sufficient to establish the existence of any stability problems. A transient stability contingency list can be reviewed within Attachment 3. The analysis will follow the latest transient stability modeling methodology recommended by the WECC. Transient stability analysis will include modeling the impact of either a three-phase fault on the mentioned facilities with normal clearing times and any associated remedial action schemes or a single-phase to ground fault with delayed clearing.

Transient stability studies will focus on the 230 kV systems between Olinda, Cottonwood, O'Banion, Roseville and Elverta Substations as determined by their location between generation resources and load centers as well as being between generation sub-regional generation resources such as Northern California hydro and San Francisco Bay Area thermal generation. The 500 kV system (California/Oregon Transmission Project), but also will assess.

C. Voltage Stability – Post Transient Voltage

Voltage stability studies will be performed in accordance with the Guide to WECC/NERC Planning Standards I.D: Voltage Support and Reactive Power under normal and contingency conditions. For voltage stability analysis, a 1-in-10 year adverse weather-load condition will be used. The voltage stability assessment consists of two components: Reactive margin and power margin. The reactive margin will be achieved by keeping the load level constant to determine how much reactive margin can be obtained at a given point in the network. Power margin is achieved by increasing the local load level from that in the reactive margin portion incrementally up until the system collapses. When analyzing voltage stability, the WECC requires a 5% increase in load for single contingencies (Category B) and 2.5% for double contingencies (Category C). These percent increases in load amount to margin between where normal and contingency related operations are expected and where voltage instability is projected to occur.

Post-transient voltage analysis will be conducted at points where the WASN transmission system connects to customer load-serving points such as for the Cities of Redding and Roseville as well as connections to the Sacramento Municipal Utility District (SMUD) and USBR Pumps at Tracy as well as recognition of the 500 and 230 kV connections to PG&E's system at Cottonwood and Tracy Substations.

Annual Transmission Assessment Report

The WASN 2013 Annual Transmission Assessment will document compliance with NERC Transmission Planning Standards, the study assumptions used, study methodologies, study results, conclusions, recommendations, and proposed mitigation measures to resolve reliability issues and any other relevant information required to meet NERC Standards. Mitigation measures can include transmission reinforcement projects, re-rating of transmission facilities, special protection systems, or operating procedures. The information will include when mitigation is needed and how it will be achieved.

Study Schedule

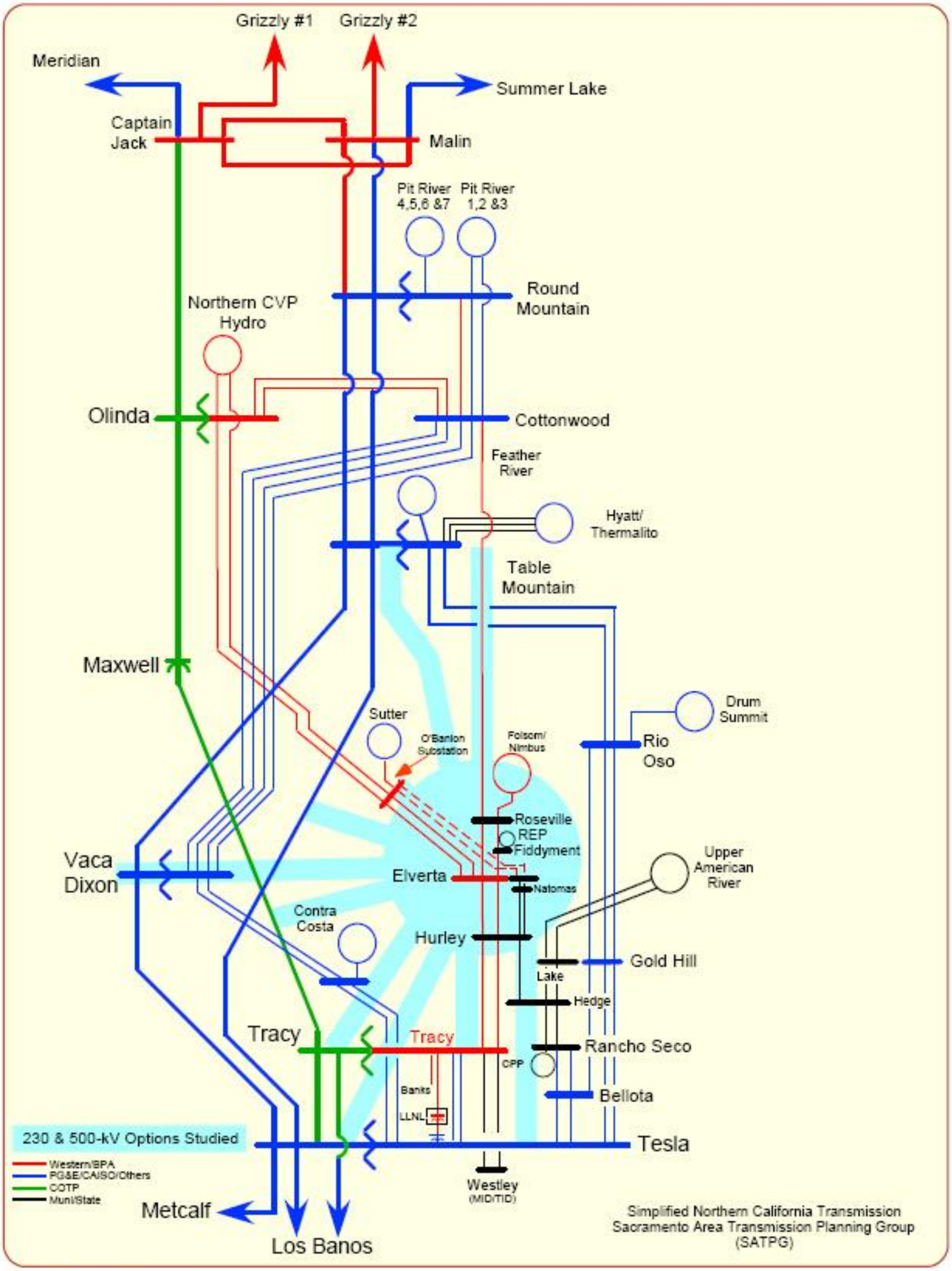
Table 3 – Below is WASN's study schedule to conduct the 2009 Annual Assessment.

Table 2: Study Schedule[1]

Reference #	Milestone	Date
1	Draft a Study Plan	April 16, 2013
2	Acquire Study Data (Power Flow and Dynamic)	May 1, 2013
3	Perform Analysis	Aug. 1, 2013
4	Put Together Assessment Report and Related Documentation	Sept. 1, 2013
5	Perform Additional Analysis and Documentation as Needed	Oct, 1, 2013
6	Finalize 2013 Transmission Assessment Report	Nov. 1, 2013

[1] This Study Schedule is a working document and can be revised from time to time.

Attachment 1: Simplified Diagram of the Western Area Power Administration – Sierra Nevada Region Transmission System



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Attachment 2: North American Electric Reliability Corporation (NERC) Planning Standards

The NERC Planning Standards available on the NERC web site at http://www.nerc.com/page.php?cid=2

Attachment 3: Contingencies Studied

The following list of contingencies were included for thermal, voltage, post-transient and transient stability. For transient stability analysis and while Table 1 within the NERC Planning Standards TPL-001 thru 004 allow for simulating a single-line to ground(SLG) fault for certain contingencies, this WASN transmission assessment was conducted simulating 3-phase faults for all of the contingencies studied, but included SLG faults for some contingencies to verify that this type of fault would produce less of an impact to system reliability. The fault was applied on the leading bus. For example, a 3-phase fault was applied at Captain Jack for a fault on the Captain Jack to Olinda 500 kV line that's results in an outage of the line after the fault is cleared in 4 cycles.

Event resulting in the loss of a single element – NERC Level B

- Captain Jack – Olinda 500 kV
- Olinda – Tracy 500 kV
- Folsom Power Plant Units 1, 2 or 3
- Nimbus Power Plant Units 1 or 2
- Roseville Generation Units Rep1, 2 or 3
- Roseville Generation CT's 1 or 2
- Sutter Power Plant Units 1, 2, or 3
- Airport – Cottonwood 230 kV
- Cottonwood – Round Mountain 230 kV
- Cottonwood – Roseville 230 kV
- Cottonwood – Shasta 230 kV overlapping with Shasta Units 1 & 2
- Cottonwood – Shasta 230 kV overlapping with Shasta Units 3 & 4
- Elverta WAPA – Hurley 230 kV
- Fiddyment – Elverta WAPA 230 kV
- Fiddyment – Roseville 230 kV
- Flanagan – Keswick 230 kV
- Folsom – Lake 230 kV
- Folsom – Nimbus 115 kV
- Folsom – Orangevale 230 kV
- Folsom – Roseville 230 kV
- Goldhill – Lake 230 kV
- Keswick – Airport 230 kV
- Keswick – JF Carr 230 kV
- Keswick – O'Banion 230 kV
- Keswick – Spring Creek 230 kV overlapping with Spring Creek Unit 1
- O'Banion – Elverta WAPA 230 kV
- O'Banion – Natomas 230 kV
- Olinda – Cottonwood 230 kV
- Olinda – Keswick 230 kV
- Olinda – O'Banion 230 kV
- Rancho Seco – Bellota 230 kV
- Roseville – Elverta WAPA 230 kV
- Roseville – Folsom 230 kV

- Shasta – Flanagan 230 kV
- Sutter – O'Banion 230 kV and Sutter Power Plant
- Trinity – JF Carr 230 kV overlapping with Trinity Units 1 & 2
- Tracy – Hurley 230 kV
- Tracy – Lawrence Livermore 230 kV
- Tracy – Tesla 230 kV
- Tracy – Wesley 230 kV
- Olinda 500/230 kV Transformer Bank
- Roseville 230/60 kV Transformer Bank
- Tracy 500/230 kV Transformer Bank

Event(s) resulting in the loss of two or more (multiple) elements – NERC Level C

- Cottonwood 230 kV bus section
- Elverta 230 kV bus section
- Keswick 230 kV bus section
- Tracy 230 kV bus section
- Cottonwood – Shasta #1 & #2 230 kV
- Elverta - Hurley #1 & #2 230 kV
- O'Banion – Elverta #1 & #2 230 kV
- O'Banion – Elverta and O'Banion – Keswick 230 kV
- O'Banion – Elverta and O'Banion – Natomas 230 kV
- Olinda – Cottonwood #1 & #2 230 kV
- Olinda-Cottonwood 230 kV & Captain Jack-Olinda 500 kV
- Olinda-OBanion 230 kV & Olinda-Tracy 500 kV
- Rancho Seco – Bellota #1 & #2 230 kV
- Roseville – Elverta & Fiddyment – Elverta 230 kV
- Roseville – Elverta & Fiddyment – Roseville 230 kV
- Sutter-O'Banion – Keswick- O'Banion 230 kV
- Tracy – Hurley #1 & #2
- Tracy-Hurley 230 kV & Olinda-Tracy 500 kV
- Tracy – Tesla #1 & #2 230 kV
- Keswick – JF Carr #1 & #2 230 kV
- Over-lapping Tracy 500/230 kV transformer & Olinda 500/230 kV transformer
- Airport-CottonwoodX-FailAirport-1182
- Airport-CottonwoodX-FailAirport-2182
- Airport-CottonwoodX-FailCottonwood-352
- Airport-KeswickX-FailAirport-2082
- Airport-KeswickX-FailAirport-2086
- Airport-KeswickX-FailKeswick
- J.F.Carr #1-KeswickX-FailCarr-482-Whiskey
- J.F.Carr #1-KeswickX-FailKeswick-Whiskey
- J.F.Carr #1X-Keswick-FailCarr-482-Whiskey
- J.F.Carr #2X-Keswick-FailCarr-582-Whiskey
- J.F.Carr #2-KeswickX-FailKeswick
- Elverta1-HurleyX-FailElverta
- Elverta1-Hurley-FailHurley

- Elverta-RosevilleX-FailElverta
- Elverta-RosevilleX-FailRoseville-182
- Elverta-RosevilleX-FailRoseville-582
- Elverta2-HurleyX-FailElverta
- Elverta2-HurleyX-FailHurley
- ElvertaEAST-BUS
- Elverta-West-BUS
- Fiddyment-ElvertaX-FailElverta
- Fiddyment-ElvertaX-FailFiddyment-1182
- Fiddyment-ElvertaX-FailFiddyment-1582
- Fiddyment-RosevilleX-FailFiddyment-1182
- Fiddyment-RosevilleX-FailFiddyment-1482
- Fiddyment-RosevilleX-FailRoseville-782
- Fiddyment-RosevilleX-FailRoseville-1282
- Flanagan-KeswickX-FailFlanagan-182-fln-
- Flanagan-KeswickX-FailFlanagan-382-fln-
- Flanagan-KeswickX-FailKeswick-fln-Whiskey
- FolsomX-Lake-FailFolsom
- FolsomX-Lake-FailLake-5242
- FolsomX-Lake-FailLake-5236
- FolsomX-NIM-FailFolsom-562
- FolsomX-Orangevale-FailFolsom
- FolsomX-Orangevale-FailOrangevale
- FolsomX-Roseville-FailFolsom
- FolsomX-Roseville-FailRoseville-1182
- FolsomX-Roseville-FailRoseville-782
- Keswick-Redding#1X-FailKeswick-566
- Keswick-Redding#1X-FailRedding#1-3635
- Keswick-Redding#2X-FailKeswick-666
- Keswick-Redding#2X-FailEUR-3231
- KnaufX-Keswick-FailKeswick-462
- KnaufX-Keswick-FailKeswick-466
- KnaufX-Keswick-FailKnauf-TB42
- KnaufX-Keswick-FailKnauf-TB62
- LLL230-115-LLN424X-FailLLL230-115-662
- LLL230-115-LLN424X-FailLLN424-652
- LLL230-115-LLN424X-FailLLN424-952
- New Melones-BellotaX-FailBellota
- New Melones-BellotaX-FailNew Melones
- New Melones-WilsonX-FailNew Melones
- New Melones-WilsonX-FailWilson
- O'Banion-Elverta1X-FailElverta
- O'Banion-Elverta1X-FailO'Banion-1086
- O'Banion-Elverta1X-FailO'Banion-1182
- O'Banion-Elverta2X-FailElverta
- O'Banion-Elverta2X-FailO'Banion-2182

- O'Banion-Elverta2X-FailO'Banion-2086
- O'Banion-ElvertaSX-FailElvertaS
- O'Banion-ElvertaSX-FailO'Banion-A-4086
- O'Banion-ElvertaSX-FailO'Banion-A-4182
- O'Banion-KeswickX-FailKeswick-fln-Whiskey
- O'Banion-KeswickX-FailO'Banion-1082
- O'Banion-KeswickX-FailO'Banion-1086
- O'BanionX-Natomas-FailNatomas-400
- O'BanionX-Natomas-FailNatomas-410
- O'BanionX-Natomas-FailO'Banion-3086
- O'BanionX-Natomas-FailO'Banion-3182
- O'BanionX-Olinda-FailO'Banion-2082
- O'BanionX-Olinda-FailO'Banion-2086
- O'BanionX-Olinda-FailOlinda-186
- O'BanionX-Olinda-FailOlinda-286
- O'BanionX-Sutter-FailO'Banion-3082
- O'BanionX-Sutter-FailO'Banion-3086
- O'BanionX-Sutter-FailSutter
- Olinda1X-Cottonwood-FailCottonwood-332
- Olinda1X-Cottonwood-FailOlinda-282
- Olinda1X-Cottonwood-FailOlinda-286
- Olinda2X-Cottonwood-FailCottonwood-332
- Olinda2X-Cottonwood-FailOlinda-182
- Olinda2X-Cottonwood-FailOlinda-186
- OlindaX-Keswick-FailKeswick-fln-Whiskey
- OlindaX-Keswick-FailOlinda-282
- OlindaX-Keswick-FailOlinda-386
- Round MountainX-Cottonwood1-FailCottonwood1
- Round MountainX-Cottonwood1-FailRound Mountain
- RosevilleX-Cottonwood-FailCottonwood-362
- RosevilleX-Cottonwood-FailRoseville-284
- RosevilleX-Cottonwood-FailRoseville-382
- Spring CreekX-Keswick-FailKE
- Spring CreekX-Keswick-FailSpring Creek
- ShastaX-Cottonwood1-FailCottonwood
- ShastaX-Cottonwood1-FailShasta
- ShastaX-Cottonwood2-FailCottonwood
- ShastaX-Cottonwood2-FailShasta-A
- ShastaX-Flanagan-FailFlanagan-482
- ShastaX-Flanagan-FailFlanagan-282
- ShastaX-Flanagan-FailShasta
- TrinityX-Carr-FailCarr-Whiskey
- TrinityX-Carr-FailTrinity-982
- TrinityX-Carr-FailTrinity-1082
- Tracy1X-Hurley-FailHurley
- Tracy1X-Hurley-FailTracy

- Tracy2X-Hurley-FailHurley
- Tracy2X-Hurley-FailTracy
- TracyX-LLL-FailLLL
- TracyX-LLL-FailTracy
- TracyX-Tesla1-FailTesla
- TracyX-Tesla1-FailTracy
- TracyX-Tesla2-FailTesla
- TracyX-Tesla2-FailTracy
- TracyX-Wesley1-FailTracy
- TracyX-Wesley1-FailWesley-2358
- TracyX-Wesley1-FailWesley-2359
- TracyX-Wesley2-FailTracy
- TracyX-Wesley2-FailWesley-2361
- TracyX-Wesley2-FailWesley-2362
- ElvertaERTA-BUS-TIE-182
- Tracy-BUS-TIE-1082
- ElvertaERTA-BUS-TIE-1182
- Cottonwood 472 stuck BKR
- Cottonwood 482 stuck BKR

Note: An X indicates location of the fault applied

Extreme event resulting in two or more (multiple) elements removed of Cascading out of service – NERC Level D

- Sutter Power Plant Units 1, 2, and 3 entire power plant outage
- Shasta – Cottonwood #1 & #2 and Shasta – Flanagan and Flanagan – Keswick 230 kV
- Keswick – Airport and Flanagan – Keswick and Keswick – Olinda and Keswick – O'Banion
- Keswick – Olinda and Keswick – O'Banion and Shasta – Cottonwood #1 & #2
- Cottonwood – Olinda #1 & #2 and Shasta – Cottonwood #1 & #2 230 kV and Captain Jack – Olinda 500 kV
- Cottonwood – Olinda #1 & #2 and Keswick – O'Banion 230 kV and Captain Jack – Olinda 500 kV
- Cottonwood – Olinda #1 & #2 and Keswick – O'Banion 230 kV and Olinda – Tracy 500 kV
- O'Banion – Elverta #1 & #2 and Cottonwood – Roseville 230 kV
- Cottonwood – Roseville and Roseville – Elverta and Fiddyment – Elverta 230 kV
- O'Banion – Elverta #1 & #2 and Roseville – Elverta and Fiddyment – Elverta 230 kV
- Tracy – Hurley #1 & #2 230 kV and Olinda – Tracy 500 kV

  In addition, circuit breaker failure was analyzed for each of the following substations. For some, the failure of a circuit breaker to clear a faulted transmission line resulted in the outage of two lines. In some cases, failure of a circuit breaker to open resulted in the outage of multiple transmission lines and part or all of one voltage level at a substation. In addition, some of the outages modeling failure of a circuit breaker to open also included failure of the primary protection system and therefore the dynamic stability simulation included a longer period of time to clear the fault as well as the impacted transmission, generation and substation facilities.

- Airport 230 kV
- JF Carr 230 kV
- Elverta 230 kV
- Fiddyment 230 kV
- Flanagan 230 kV
- Folsom 230 kV
- Keswick 230 kV
- O”Banion 230 kV
- Olinda 230 kV
- Roseville 230 kV
- Shasta 230 kV
- Tracy 230 kV