Lamar HVDC Tie (PSCo)

Operating Guide 8/31/2005 Kevin Pera

These procedures apply during current commercial operation. The tie is available 5-210 MW →East, 5-210 MW →West.

Accepting Schedules

1. **Lookout is the primary operator of the tie.**

2. **Day-ahead (firm) schedules:**
   TTC 210 MW→East, 210 MW→West.

3. **Real-time (non-firm) schedules:**
   ATC posted after preschedule, but not updated to reflect later tags; check schedule before approving new OASIS reservations using the tie.

Running Schedules

4. **Program schedules into BSKED in EMS.**
   a. Tie should not be run at less than 5 MW. Curtail tags to avoid net schedules 1-4 MW.
   b. Set Pulses to 5. When desired schedule is reached, change this number to 1, then back to 5 just prior to next schedule change.

5. **BLOCK tie for zero schedules. WindVAR should be enabled when in BLOCK, disabled when in DEBLOCK.**

6. **Confirm schedule with SPS 20 minutes prior to ramp.**

7. ***SAFETY ISSUE*—Notify personnel checked-in at HVDC yard of DEBLOCK; many breakers close in a very short time.**

Plant Trip/Startup

8. **Energize main banks (STANDBY→BLOCK) 2350-0400 only.**
   a. Notify SPS, Tri-State, Lamar, and Colorado Green.
   b. Switch to BLOCK.

9. **Upon trip of HVDC converter:**
   a. RMRG activation available (required for 200 MW) for combination of loss of Colorado Green and East→West HVDC, a single contingency for loss of Boone—Lamar.
   b. Curtail all current day schedules.
   c. Enable WindVAR at Colorado Green.
   d. Dispatch Substation Maintenance.
   e. Determine ETR. Notify RDRC & SPS, post on OASIS.

Lamar HVDC Tie

Dispatcher Training Guide and Reference Manual

Kevin Pera

Revision 2, 8/31/2005

Table of Contents

Course Syllabus

Successful completion of this course qualifies for 12 NERC ceh's. Successful completion requires attendance at all sessions, and achieving a passing grade on a quiz, covering various material from lectures and the tour. We encourage taking notes in this notebook. We will place a copy at each desk at the control centers, and will update the manual periodically as we become more familiar with the HVDC tie and issues arise.

Instruction comprises three sections:

- **8 hours HVDC Plant Instruction**
  - HVDC Basic Theory
  - Operator HMI (MMI/LCU) System
  - Plant Control/Pole Control
  - AC & DC Protection
  - Alarms
- **2 hour Facility Tour**
- **2 hours Control Center Operations Instruction**
  - Operating Guides
  - Communication
  - Scheduling

Lamar HVDC Tie Background and History

Article—Consortium Details Construction of DC Tie

by Rick Chapel and Ernie Poggi, Xcel Energy; Moe Aslam, Siemens PTD; and George Brashear, Beta Engineering | Sep 01 '04

When New Century Energies and Northern States Power merged in 2000, the new company, Xcel Energy (Minneapolis), made a commitment to connect the two systems — the 345-kV Kansas system and the 230-kV Colorado system. In February 2003, after an extensive evaluation of technical, economic and commercial considerations, Xcel Energy awarded a turnkey contract to the consortium of Siemens Power Transmission & Distribution and Beta Engineering for the design, construction and commissioning of the 210-MW back-to-back dc tie located near Lamar, Colorado. The Lamar project will connect Xcel Energy's Southwestern Public Service Co. system in the east with its Public Service Co. of Colorado system in the west, and allow 210 MW of power transfer capability in each direction. Once completed, the Lamar project will be the seventh dc tie to connect the eastern grid to the western grid in the United States.

Design Completed

After the merger, Xcel Energy, the fourth-largest combination natural gas and electric company in the United States, was faced with the technical challenge of integrating the company's two systems and confidently delivering power between the nation's east and west grids. Engineering specifications, procurement and project management for the Lamar project have been performed from Xcel Energy's Denver office. Xcel Energy engineers conducted a system-performance study using EMTDC/PSCAD, a software-based design that simulates voltage and transient flows in normal transfer conditions and contingency conditions from both sides of the grid. Transient Network Analysis (TNA) was conducted in the electrical laboratory to test the controls under various operational scenarios to confirm their performance and robustness prior to the field testing, energizing and commissioning.

Outsourcing Draws on Technical Expertise

A key component to the success in meeting the technical challenges of this important dc tie has been the decision to outsource for expertise and experience.

The partnership between Xcel Energy and the turnkey consortium of Siemens High Voltage Systems (HVS) division (Wendell, North Carolina), Siemens Reactive Power (Erlangen, Germany) and Beta Engineering (Pineville, Louisiana) has brought together the necessary experience and know-how. Xcel Energy has regulated operations in 11 western and Midwestern states. Xcel Energy provides a comprehensive portfolio of energy-related products and services to 3.3 million electricity customers and 1.7 million natural gas customers through its regulated operating companies.

The highly technical nature of the project calls for state-of-the-art power electronics to ensure a smooth and reliable interconnection. Siemens Power Transmission & Distribution (Siemens PTD; Raleigh, North Carolina) is providing the components and deploying Grid Power Flow Controller technology, which meets all of the protection and control requirements for the project design. Siemens has provided customized turnkey solutions and projects for high-voltage systems around the world. Siemens' expertise includes solutions for Series Capacitors, Static Var Systems and Grid Power Flow Controllers. The Grid Power Flow Controller design for the Lamar project is being managed under the Siemens HVS.

Beta Engineering, the construction partner, is a turnkey firm specializing in engineering, procurement and construction of high-voltage electrical substations, transmission lines, distribution systems and FACTS projects. Beta performs turnkey high-voltage projects throughout the United States and works with most of America's major utilities and general design/build firms. Siemens and Beta have jointly completed numerous electrical systems projects in the United States. Because of close communications between the turnkey consortium and Xcel Energy engineers, the project has remained on schedule with an on-time completion date of January 2005.

Reliability Control Strategy

State-of-the-art architecture has been design into the new tie to maximize reliability. Components provided by Siemens include a current source six-pulse converter, which uses the Grid Power Flow Controller design and three single-phase transformers on each HV side; light triggered thyristors converter valve modules in combination with outdoor filters, mechanically switched reactors and capacitors and other outdoors equipment; and Siemens' SIMADYN-D controls with dual redundancy. The ac and dc protection is also provided by Siemens' conventional solid-state and custom relays. The converter valves use a closed-loop cooling system with de-ionized water and glycol. All functions for the new dc tie are automated, and the subsystems also include redundancy for reliable operation. Furthermore, the dc tie is designed for the local ambient weather conditions.

Site Construction Criteria

Site construction is well underway for an on-time January 2005 completion date. The consortium staff are coordinating and supervising the day-to-day work of the construction contractors. Weekly conference calls and monthly meetings ensure timely progress and quality of the work. Siemens PTD is coordinating construction with respective procurement departments, project management and engineering from Beta and Siemens, Germany.

During field-testing, additional system models and capabilities studies will be completed using PSSE and PSLF. The operational performance is designed for a 210-MW power flow while maintaining a voltage of 0.95 p.u.-1.05 p.u. at both HV busses. Designed into the new dc tie is the capability of providing voltage support to the west (230 kV, CO) side when the east side is blocked. The tie is designed

for unmanned operation using SCADA systems. The Xcel Energy EMS system, also provided by Siemens, interfaces with the dc tie SCADA system. The power sources and loads on both sides will realize benefits from the dc tie's primary features of power transfer and voltage control and secondary features in system stability. Both east and west sides will have power scheduling and controlling capabilities under a hierarchy via their SCADA master stations, which also allows for coordinated redundant capabilities. In addition, local control is available using a Human Machine Interface system.

Conclusion

The dc tie will enable economic exchange of power between Xcel Energy's two control areas and an enhancement in system stability to the 200-mile transmission system connecting Finney, Kansas, to Boone, Colorado.

Rick Chapel is a project manager at Xcel Energy in Denver. He has been in the electric utility industry for 34 years.

rick.chapel@xcelenergy.com

Ernie Poggi , PE, has been with Xcel Energy Energy for 15 years. He has 28 years of experience in protection/substation engineering and in his present position as substation maintenance engineer for four years.

ernie.poggi@xcelenergy.com

Moe Aslam , PE, is a program/project manager at Siemens PT&D. He has been with Siemens for eight years and in the T&D industry, in project management and engineering, for 25 years. His responsibilities on the project include overall project management for the Siemens-BETA Consortium and chief customer interface for Siemens.

moe.aslam@siemens.com

George Brashear , PE, is vice president/project manager at Beta Engineering. He has 16 years of experience in the design, management and construction of engineering projects.

George.Brashear@BetaEngineering.com

Reliability Issues

Lamar Switching Station

The 230 kV Lamar switching station comprises four interconnected sources in a four-breaker ring formation, Figure 1.

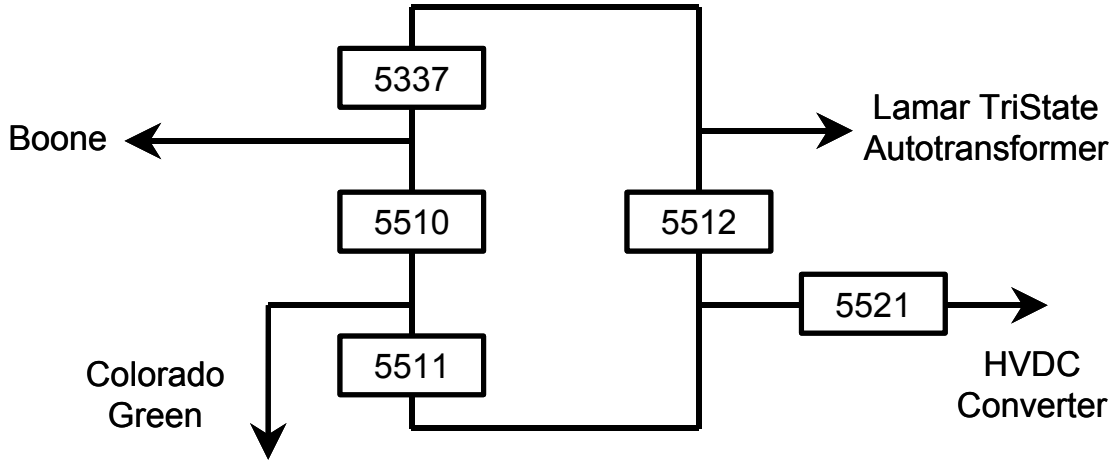


Figure 1. Lamar ring-bus switching station

Colorado green requires the Boone—Lamar line to generate, both as a contract path and a short-circuit current source for fault detection. Colorado Green also may not generate without a ground source nearby, for ground fault detection. The Lamar autotransformer and/or the HVDC tie transformer provide grounding. These limitations require cross-tripping the wind farm for certain other fault interruptions. Table 1 shows the combinations of trips and the results.

Table 1. Cross-tripping truth table for Lamar switching station

Trip these…	Transfer trip…
5510, 5511 (Colorado Green)	Colorado Green
5337, 5510 (Boone—Lamar)	Colorado Green, HVDC (5521, etc.)
5337, 5512, 5511	Colorado Green, HVDC (5521, etc.), 5510
5510, 5512	Colorado Green, HVDC (5521, etc.)
5511, 5337	Colorado Green, HVDC (5521, etc.), 5510, 5512

Finney Switching Station

The 345 kV switching station at Finney, Figure 2 connects the Holcomb generating station, and the rest of Sunflower Electric to SPS between Lamar HVDC and Potter County. The Holcomb plant strengthens the connection, supporting voltage at Finney, and providing short circuit current for fault detection. For the trip of the line to Holcomb, the HVDC tie should stabilize, so the connection to Potter will persist. Presently, for a trip of the Finney-Potter line,

the operator will ramp the tie to zero. Once approved by SPP, a cross trip of the Finney-Lamar line will be implemented.

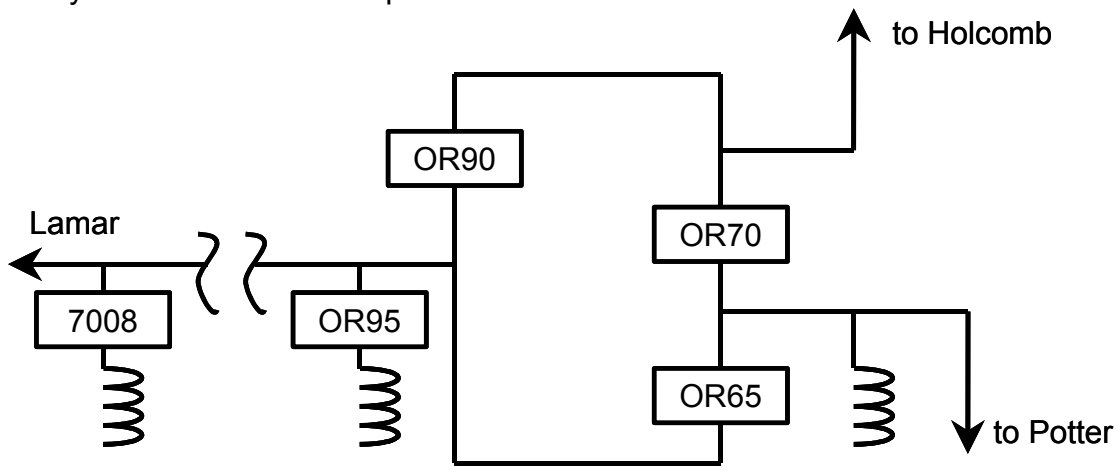


Figure 2. Finney Switching Station

Table 2. Cross-tripping truth table for Finney switching station. *(FUTURE)*

Trip these…	**Transfer trip…**
OR70, OR65 (Potter)	OR90 (Lamar)

Operating Guides

General Operation

Flow Reduction

Plant Tripping

Table 3 shows various causes of plant tripping, according to the tie's AC & DC protection schemes. Other circumstances may necessitate plant tripping by the operator. Manual tripping is a backup for automatic trip failure, as well as a means to quickly eliminate power flow on bulk lines in the vicinity of the tie.

Table 3. Lamar HVDC tie automatic tripping schemes

	Full plant trip, including line breakers	Automatic curtailment
DC fault	**X**	
Loss of harmonic filter	**X**	
Loss of 1 West side MSC		
Loss of 1 East side MSR		
Loss of other MSC/MSR	**X**	**X**

Relays surrounding the tie trip transmission lines as necessary to disconnect the tie from each grid as underfrequency load shedding. Table 4 shows the setting

for each interconnected system. These relays detect the direction of flow, and trip only when flow across the tie looks like load to the interconnection.

Table 4. Underfrequency Load Shedding Settings

East	59.3 Hz
West	59.1 Hz

Transfer Limits

Prior outages introducing a new N-1 safe operating limit may impose a transfer limit on the HVDC tie. Table 5 indicates calculated stability or thermal limits that decrease TTC. Presently, only contract path limits have been determined.

Table 5. Lamar HVDC tie transfer limits for prior outages

Outage	HVDC Limit
Boone—Lamar	0 MW
Boone—Comanche	210 MW
Boone—Midway	210 MW
Lamar TSGT Autotransformer	210 MW
Finney—Lamar	0 MW
Finney—Holcomb	210 MW
Finney—Potter	0 MW

First Responder for Forced Outages

In the event of a forced outage, PSCo and SPS will confer, confirming the nature of the outage. First responders called will depend on facilities needing investigation or repair. The first responders will coordinate work assignments based on field personnel available in the area, to return the equipment to service as needed. For substation issues, PSCo Southern Subs will be the first responder. For transmission lines west of the tie, PSCo Line Maintenance will be first responder. For the Lamar—Finney line, Dwayne Marchbanks will be called. He will coordinate with his counterpart in Colorado for line patrol and repair. Figure 3 indicates the party to call for an forced outage in and around the Lamar HVDC tie.

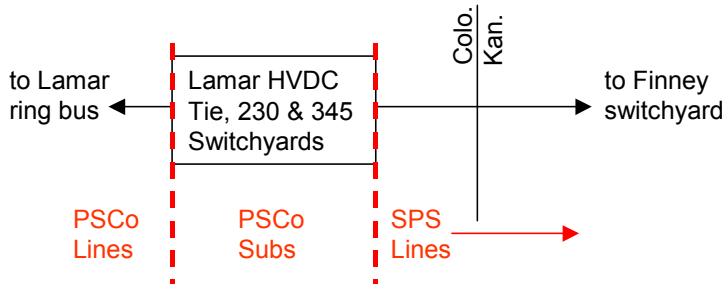


Figure 3. First Responders for Emergency Outages

Maintenance

Scheduled Equipment Maintenance

Xcel Energy operates and maintains equipment around and including the Lamar HVDC tie requiring three groups to respond according the nature and location of work to be done. As a rule, work will be distributed as follows. All substation maintenance, including HVDC tie work, will be assigned to PSCo Southern Substations. All line work in Colorado, including a portion of the Lamar—Finney 345 kV line, will be assigned to PSCo Transmission Line Maintenance. All line work in Kansas will be assigned to SPS Transmission Line Maintenance. Seven days notice is required for scheduled maintenance.

Figure 4 indicate the parties responsible for maintaining lines and equipment in and around the Lamar HVDC tie.

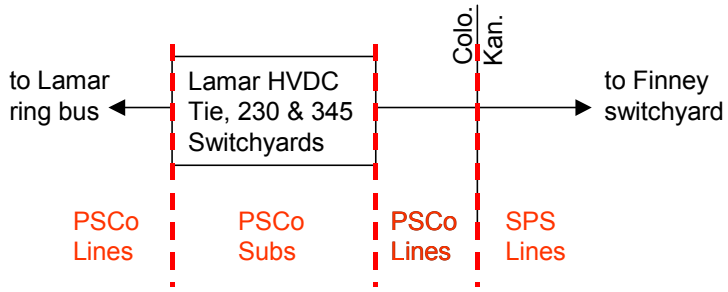


Figure 4. Scheduled Maintenance Work Assignments

Substation Switching

All field switching at Lamar HVDC Tie and 230 and 345 kV switchyards will be assigned to PSCo field personnel, coordinated by PSCo Lookout Control Center. See Figure 4. Southern Substations is responsible for Lamar HVDC tie maintenance.

Clearances

PSCo Lookout Control Center will give equipment clearances on Lamar HVDC tie and related substation equipment to PSCo personnel.

For Lamar—Finney line clearances, PSCo will grant a “source of power” clearance to the SPS system operator from breaker 7002 at Lamar if SPS crews are working on the line. A source of power clearance guarantees an open terminal with visual open and tag. SPS will issue a clearance to the PSCO control center from the Finney end of the line if PSCO crews are working on the line. SPS will open and tag line side disconnects OR89 and OR86 at Finney. After receiving a clearance from the other control center, each control center will issue a line clearance to its own crew. Clearances may be held simultaneously by both operating companies, along with line clearances to crews on both sides.

TWRs

Transmission Work Requests (TWRs) will be handled by each control center, as if working with an independent neighboring utility. The TWR number for the source of power clearance will be noted on the TWR for the line clearance, to cross-reference the documents within Xcel Energy.

Alarms

All alarms received at the control centers are catalogued and explained in *Lamar HVDC Alarm Dispatch Response Guide*. This document explains what response is required.

Plant/Substation Alarms

This category of alarm encompasses alarms that impact any control system or electrical connection at the substation. They are prioritized, and acted upon, just as any other.

Communication Alarms

These alarms include status of SCADA and load control circuits. Because each control center is backed-up by the other, the first action is to confer with the other control center. As an unmanned power flow controller, it is critical to restore communication circuits, and dispatch Southern Subs to site to take control of the tie if SCADA control is not possible. Since many circuits share a common communication path, it may not be possible to deduce power flow across the tie from surrounding lines' data.

Special Op Guides

From time to time, system limitations for maintenance or forced outages will require the use of special operating guides. These will be prepared as necessary to meet reliability needs.

Reserve Group Activation

RMRG

Three types of reportable losses may occur for RMRG:

1. Colorado Green
2. Lamar HVDC Tie
3. Colorado Green *and* Lamar HVDC Tie

As with other generation loss, reportable disturbances (≥200 MW) require activation. Reserve activation is limited to the amount of generation at the time of loss.

Colorado Green

Activation is allowed for the loss of generation due to plant tripping or turbine generator overspeed tripping. Activation may not be used to cover sudden loss of wind.

Lamar HVDC Tie

Activation is allowed for loss of net power into PSCo control area (virtual generation).

Combined Loss

Tripping the Boone—Lamar 230 kV line will cause the sudden disconnection of the HVDC tie and Colorado Green. This contingency potentially causes the loss of up to 372 MW of net power flow into PSCo's system. Activation of up to this amount is allowed.

Activation is limited to the net loss only. The direction of the HVDC tie must be considered when calculating the loss of resources. For example, if Colorado Green were generating full-out (162 MW), and the tie full-out (210 MW) to the East, the net loss of resources is actually a *gain* of 48 MW! Obviously, we do not want to activate shared reserves for net increase of resources.

SPP

Since XEM schedules will normally be firm power on Firm Network Transmission, the sudden loss power flowing from the tie may be entered in the SPP ARS as a contingency.

Communication

Between Amarillo & Lookout

Communication normally will be by calls speed dialed over the corporate phone network. Both control centers have alternate phone numbers to reach each other.

Reliability Coordinator

Each control center will make notifications and coordinate activities with its respective Reliability Coordinator. SPS will post Lamar DC tie limitations and outages on the SPP OPS1 tool. Lookout will post Lamar DC tie limitations and outages on PSCo OASIS and report these on morning call to RDRC.

Field Personnel

PSCO field personnel will normally communicate directly with Lookout Center. SPS field personnel will normally communicate directly with the SPS control center. Both control centers will coordinate field personnel activities between the control centers.

XEM

Both control centers will communicate with XEM under the FERC Standard of Conduct. Between PSCO and SPS, the sink control area will notify XEM of curtailments or reloads of XEM schedules across the tie. PSCO will post outages and limitations of the Lamar DC tie on the PSCO OASIS page as transmission provider for the tie.

Energy Market

If the tie trips, schedules will be immediately curtailed and a notification posted on the PSCO OASIS. After it has been determined that the tie can be returned to service, the Market will be notified via OASIS and E-tag that schedules may resume at the start of the next scheduling hour.

Disturbance Reports

The sudden loss of the Lamar DC tie doesn't require filing a disturbance report.

Scheduling

SPS and PSCO will approve and implement schedules across the DC tie according to NERC policy. PSCO uses Etag for scheduling. SPS uses the SPP RTO scheduling system for scheduling.

Tagging

Firm Network

Two OASIS numbers for each control area have been established, one in each direction. Xcel Energy Markets has 210MW of Firm Network transmission in each direction across the tie. These oasis numbers are not to be used for off-system sales or point-to-point service.

Each tag will include one OASIS number for each side, and will require approval by SPS and PSCo, both as transmission operators and control area operators, as well as XEM on both sides and SPP as an approving entity for SPS.

Point-to-Point

Point-to-point transmission may be made available in the future as we become more familiar with how the tie is used by XEM.

Tag Adjustments

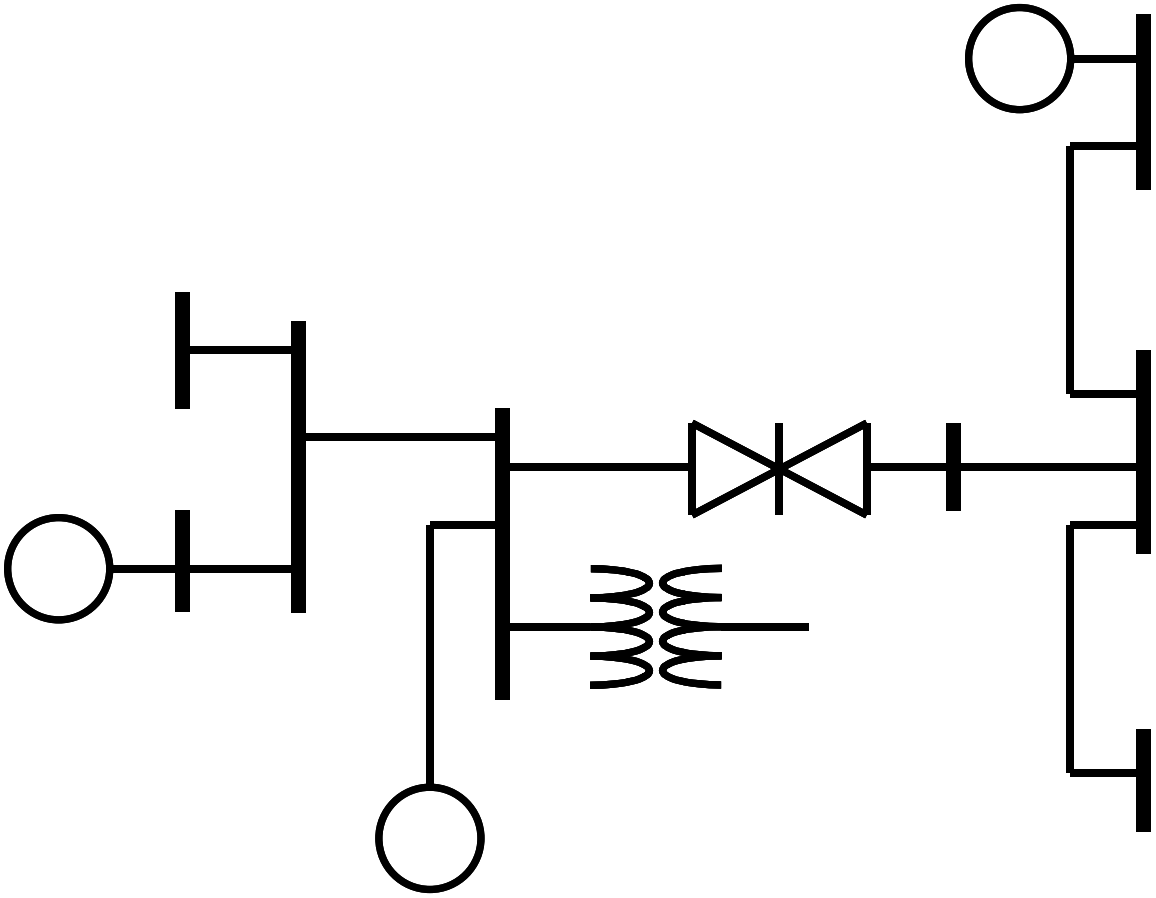
Tags may be adjusted for reliability reasons within the hour, as per NERC, SPP, and WECC rules.

Tie Line Checkout

PSCo and SPS control centers will checkout actual and scheduled as required by NERC policy. Deviation between actual and scheduled flow will be tracked by

SPS and worked off by small adjustments to tie flow settings as agreed by both PSCO and SPS operators.

Appendix A. SE Colorado & Near Eastern Interconnection Transmission System >=230 kV



Appendix B. Cigré Paper on Lamar HVDC Tie

This is attached separately.