Rocky Mountain Area
Voltage Coordination Guidelines

As Updated by the Voltage Coordination Work Group (VCWG)

for the

Colorado Coordinated Planning Group (CCPG)

December 2010

Voltage Coordination Guidelines

NOTE - FIGURE 1 (ROCKY MOUNTAIN AREA MAP / REGIONS 1 - 10), TABLES OF REACTIVE CONTROL DEVICES, VOLTAGE MEASUREMENT EQUIPMENT / ERROR RATINGS, AND GENERATOR REACTIVE CAPABILITY ("D") CURVES FOR EACH REGION ARE ATTACHED AS SEPARATE APPENDICES. A LISTING OF THE GENERATORS FOR WHICH D-CURVES HAVE BEEN SCANNED TO ELECTRONIC (*.JPG OR *.PDF) FILES, AND INCLUDED SEPARATELY ON CD-ROM AS PART OF THIS REPORT.

PHILOSOPHY OF THE VOLTAGE COOORDINATION GUIDELINES

Introduction:

The Voltage Coordination Guidelines ("Guidelines" or VCG) were developed to improve overall steady state voltage coordination between area utilities, transmission and/or generation companies, or similar organizations, hereafter referred to as "entities".

This coordination ensures:

- That different utilities and areas do not have conflicting voltage control objectives.
- That appropriate voltage scheduling objectives are defined for each area.
- That voltage control equipment capabilities and settings are documented.
- That appropriate attention is given to issues such as voltage collapse and/or circulating VAR problems.

The voltage control objectives outlined in these guidelines are intended to supplement NERC, WECC and entity planning and operating criteria. The philosophy of voltage coordination in the Rocky Mountain Region can be thought of as a voltage target, with three main levels defined as "ideal", "acceptable", and "emergency". These Voltage Coordination Guidelines are directed at ideal transmission system steady state voltages, to the extent possible. NERC, WECC, and entity planning and operating criteria are in place to ensure acceptable and emergency voltage levels are maintained. Please refer to the region-specific sections in this VCG document for the ideal, acceptable, and/or emergency voltage range data for a given region.

Compliance

This document, as formally accepted by each of the Transmission Operators (TOP) identified in a separate signature letter, helps serve to support compliance in a number of areas including NERC Standards VAR-001-1 and TOP-004-2.

VAR-001-01 – Voltage and Reactive Control, Requirements 1 and 8:

R1. Each Transmission Operator individually and jointly with other Transmission Operators, shall ensure that formal policies and procedures are developed, maintained, and implemented for monitoring and controlling voltage levels and Mvar flows within their individual areas and with the areas of neighboring Transmission Operators.

R8. Each Transmission Operator shall operate or direct the operation of capacitive and inductive reactive resources within its area – including reactive generation scheduling; transmission line and reactive resource switching; and, if necessary, load shedding – to maintain system and Interconnection voltages within established limits.

TOP-004-2 – Transmission Operations, Requirement 6:

R6. Transmission Operators, individually and jointly with other Transmission Operators, shall develop, maintain, and implement formal policies and procedures to provide for transmission reliability. These policies and procedures shall address the execution and coordination of activities that impact inter- and intra-Regional reliability, including:

R6.1. Monitoring and controlling voltage levels and real and reactive power flows.

R6.2. Switching transmission elements.

Ideal Voltages:

These ideal or optimum voltages are characterized primarily by transmission and generation system operators having options available to control transmission voltages in a region. The system is usually operating in this ideal state, and typically a system's ideal transmission voltage at key transmission substation buses is maintained in the range of 1.02 – 1.04 per-unit.

Acceptable Voltages:

When loads or utilization of available generation resources are at extremes, and control options have been exhausted, then system operators may not be able to maintain the ideal voltage profile, but voltages are normally still within an acceptable range which is typically 0.95 to 1.05 per unit.

Emergency Voltages:

This category is characterized by loads or utilization of available generation resources at extreme levels, combined with a forced outage of generation or transmission. The system rarely enters this state, but planning and operating criteria require that the system be capable of operation in this emergency state. Planning and operating studies are performed to assure compliance with emergency voltage standards. In the absence of voltage collapse issues, the emergency voltage ranges are typically 0.90 to 0.95 and 1.05 to 1.10 per unit. Further, the system can only be operated in this emergency range for a limited time, while system readjustments are made to get to a new secure state where voltages are restored to more acceptable limits.

ACKNOWLEDGEMENTS

In September 2002, the Voltage Coordination Work Group (VCWG) was reconvened, and reports to the Colorado Coordinated Planning Group (CCPG). The VCWG was organized in order to update the Voltage Coordination Guidelines, which were previously revised in October 1994. This was deemed necessary primarily due to the significant generation and transmission system changes that had occurred since 1994, and to re-visit the general as well as the region-specific voltage coordination philosophies to be followed by the Rocky Mountain Region, specifically the Colorado – Wyoming area systems. This document continues to be reviewed annually.

The membership of this VCWG is comprised of System Planning and/or Operations representatives from the major transmission and/or generation entity companies in the Rocky Mountain Region. The membership listing is:

Name	Company	Company Location	VCWG Title
Shawn Carlson	Basin Electric Power Coop.	Bismarck, ND	Regions 6 Coordinator
Eric Egge	Black Hills Corporation	Rapid City, SD	Region 10 Coordinator
Paul Morland	Colorado Springs Utilities	Colorado Springs, CO	
Cliff Berthelot	Colorado Springs Utilities	Colorado Springs, CO	
William Ruthruff	PacifiCorp	Portland, OR	Region 9 Coordinator
Jeremy Brownrigg	Platte River Power Authority	Fort Collins, CO	Region 3 Coordinator
John Collins	Platte River Power Authority	Fort Collins, CO	Chair
Mark Graham	Tri-State G & T Association	Westminster, CO	Regions 2, 5, 7 Coordinator
Bob Johnson	Xcel Energy / PSCo	Golden, CO	Regions 4, 8 Coordinator
David Graham	Xcel Energy / PSCo	Golden, CO	
Bill Anderson	Xcel Energy / PSCo	Denver, CO	
Jim Hirning	Western Area Power Admin. RM	Loveland, CO	Region 1 Coordinator
Joe Liberatore	Western Area Power Admin. RM	Loveland, CO	

These Guidelines would have never been updated, with acknowledgement and ownership of the stated philosophies, without the cooperative efforts of this group.

COORDINATED VOLTAGE CONTROL - OVERVIEW

Beginning in late 1993, utilities in Colorado and Wyoming initiated discussions regarding the coordinated control of voltages. Both NERC and WECC documents state the principle that interacting utilities must work together to coordinate voltage schedules. The effort resulted in an open discussion and general agreement regarding the underlying principles and the procedures to be used. This guide documents area reactive equipment capabilities, provides suggested voltage profiles, and discusses the preferred voltage control practices. This document, is reviewed and updated annually. .

Ten geographic areas with unique operating characteristics were identified, which are described below and shown graphically in Figure 1.

1. Northwest Colorado Region, generally encompassing the Craig, Hayden, Dillon, Grand Junction, and Flaming Gorge – Bonanza (N.E. Utah) areas.

2. Southwest Colorado Region, generally south of Grand Junction and extending to the Durango area.

3. Foothills Area of Colorado Region, generally encompassing Rawhide, Ault, Weld, Fort St. Vrain, and Estes Park.

4. Southeast Colorado Region, generally encompassing Comanche, Pueblo, Colorado Springs, Boone and Lamar.

5. South-Central Colorado Region, generally encompassing the Poncha - San Luis Valley area.

6. Southeast Wyoming / Western Nebraska Region, generally encompassing, Laramie River, and Sidney and Stegall DC ties, and the Alcova to Seminoe system.

7. Northeast Colorado Region, generally encompassing Pawnee, Wray, Burlington, and Big Sandy.

8. Metro Denver - Boulder – Ft. Lupton Region, including west to Cabin Creek, and north to Ft. Lupton, up to south of Fort Saint Vrain (FSV).

9. Western Wyoming Region, encompassing central and western Wyoming, up to and including the Yellowtail units in southern Montana, up to but not including the Jim Bridger units and 345kV associated system in western Wyoming, up to and including the Wyodak units in northeastern Wyoming.

10. Northeastern Wyoming / S.W. South Dakota Region, encompassing the Black Hills Power and PRECorp (Powder River Energy Corporation) systems up to, but not including, Dave

Johnston and Wyodak, and including the Lookout – Lange – West Hill system in the southwest corner of South Dakota and the northwest corner of Nebraska.

The discussions that began in 1993 resulted in a list of generalized operating principles and practices, which are listed below. These have been updated where possible, and incorporated into this current revision. Further discussion and clarification is given in the sections included for each of the Regions 1 through 10, where each region is discussed in more detail.

A complete review or audit of the principles and practices should be undertaken not less than every five years, or as necessary.

<u>COORDINATED VOLTAGE CONTROL - PRINCIPLES AND PRACTICES</u>

1. The voltage profile within a geographic area needs to be managed and coordinated among affected entities. **When a specific voltage is mentioned in subsequent principles, the intent is to refer to the "average" voltage level, not necessarily the voltage at a voltage control device or specific location.**

2. Key locations need to be identified that give an accurate overview of the voltage profile within a geographic area. For these key locations, it is imperative that the voltage measuring equipment has sufficient inherent accuracy for reliable use in Operations. In addition, extra attention should be paid to this equipment to ensure its proper calibration and reliability.

3. For each geographic area, a comprehensive list of equipment that can be used to control the voltage profile should be prepared. This list should also include any relevant data related to voltage control capabilities. For example, generating equipment data should include the generator reactive capability curve ("D" curve), terminal voltage maximums and minimums, step-up transformer tap ratios, or other limits that impose restrictions on VAR output. For transformers, pertinent data includes LTC ranges and no load tap settings. For fixed shunt equipment, relevant data includes voltage and VAR ratings. When VAR output from generating units is being referred to in this VCG and in the Appendices, “lagging” power factor means that the unit is producing VARs into the system, and “leading” VARs means that the unit is absorbing VARs from the system.

4. Unless specifically noted otherwise, operating entities within a geographic area should have real time information available indicating the voltage profile within that area. As a minimum, this real time data should include the voltages at the key locations identified in item 2 above. Ideally, real time data would also include the status and operating level of all major transmission and generation voltage control equipment within the area. This real time data should be presented in one unified SCADA display that presents the data for the entire geographic area. The medium used for transmitting this real time data to the various systems operations dispatch centers or other monitoring facilities may vary from dedicated leased line or microwave SCADA, inter-entity data link, or other means necessary, and may vary by region and entity. Line flows, real and reactive, are monitored on lines within the CCPG footprint by the respective Transmission Operators. For coordination, if real or reactive flows threaten Inter- or Intra-Area reliability including facility overloading, or are a contributor to moving the real time operating voltages outside of acceptable voltage range, the primary operating entity will take action to restore voltages to within the acceptable range. The operator will use operating procedures, redispatch generating units, cut schedules, switch shunt elements and/or contact neighboring transmission operators as necessary to mitigate the impact on Reliability and bring the voltages back to within the acceptable range

5. Circulating VARs should be minimized between adjacent generating units, adjacent transformers, or adjacent substations.

6. Static VAR sources (switched shunt capacitors, reactors) should be operated to control the voltage profile before relying on LTC or generator VAR output, and should be used in such a manner to keep LTC transformers near their nominal tap range and to keep reactive margin on generating equipment. The rationale for this goal is that the generator is a dynamic reactive source that can provide high-speed reactive support to the transmission system after a disturbance that results in low voltages, or conversely are in a position to reduce voltages after a contingency that results in high voltages. Keeping transformers near their mid-tap also allows for maximum range to either increase or decrease voltages following a disturbance.

7. Generation equipment should be periodically tested according to the NERC / WECC testing policies to verify that maximum (overexcited) and minimum (under-excited) VAR output levels can be obtained, consistent with the unit reactive capability D curve. Periodic testing should include generation excitation systems, voltage regulator, speed/governor control, and other equipment in accordance with the WECC 2006 Generator Test Policy posted at www.wecc.biz/library/rro and associated with NERC Standards MOD-024-1 and MOD-025-1. If system voltages do not permit VAR output at the maximum and minimum limits indicated by the D curve, then as a minimum the units should be tested at maximum and minimum terminal voltages, thereby indicating that the unit could operate at maximum and minimum VAR levels if system conditions warranted.

   Generation equipment should have a minimum excitation limiter in the voltage regulator that allows safe operation when under-excited (leading power factor, absorbing VARs from the system). This is especially important in areas with normally high voltage, but applies to all units equally since some system conditions (e.g., that following an under-frequency load shedding event) can suddenly result in system wide high voltage.

8. The maximum and minimum voltage levels referred to below are unique to a geographic area, as identified per Region in this document. These voltage levels generally reflect the "natural float," which in turn is a characteristic of the voltage and length of transmission lines, load level, and reactive equipment available.

   - When the system voltage exceeds the maximum ideal operating level, then at that point all capacitors should be off line, all reactors should be on line, and local generation should be operating in a manner to limit the voltage to be no higher than the maximum desired level. If necessary, and within design limitations, generators will operate in the lead in order to absorb VARs from the system to contribute to lowering the voltage.

   - When the system voltage is less than the minimum ideal operating level, all capacitors will be on line, all reactors will be off line, and local generation will be operating in a manner consistent to keeping the voltage from decreasing below the minimum level. For generators, this generally means that they will be operating with a lagging power factor and putting VARs into the system.

- When the system voltage is operating within the ideal voltage range for a given region, then the generators will operate with moderate net VAR output into the system. This will maximize the dynamic reactive reserve available to the overall transmission system. The status of capacitors and reactors will not be intentionally changed, except when switching may be required to increase reactive margin on generators and to allow LTC transformers to move to mid-tap.

Note that if daily switching of reactive equipment is appropriate, during on-peak hours, reactors are generally off line and capacitors on line. During off-peak hours, capacitors are generally switched off line and reactors switched on line. This operating mode typically means that reactive equipment switching will occur in the morning, while the voltage still remains high, and before the voltage has reached the minimum level, preferably while the voltage is closer to the maximum level. In the evening, the reactive equipment switching will occur before the voltage exceeds the maximum level, and preferably while the voltage is closer to the maximum level.

9. Generation that is located within a load area, or has load connected directly to it, may have a defined voltage schedule assigned, and therefore may or may not be able to maintain the desired or optimal reactive reserve margin (VARs) in the generators.

10. Localized areas that have large voltage differences, reflecting disparities in seasonal load patterns, should consider a change in transformer no-load tap settings. It may not be possible to adjust the overall grid voltages to fully compensate for the localized voltage differences.

REGION 1 - NORTHWEST COLORADO

<u>Voltage Guidelines Specific to the Northwest Colorado Area</u>

The numbering of the items below is keyed to the numbering scheme used in the section on ***Coordinated Voltage Control - Principles and Practices.***

P&P Ref #	Region-Specific Notes or Comments.
2	The key locations to monitoring the voltage are Craig, Hayden, Rifle, Wolcott, Malta, Vernal, and Dillon. Accuracy of the metering has not been compared to any reference standard. State estimator output will identify suspect measurements.
3	Table 1 contains a list of switchable shunt equipment, fixed tap transformers and generation, which can be used to control the local voltage profile.
5	Adjacent units will not generate identical VAR quantities for technical reasons. However, they are normally operated to generate VARS in the same direction. There are no parallel LTCs in the area. However, the Rifle/Ute 345/230kV autotransformer's 230kV LTC is equipped for automatic operation.
7	PSCo adheres to the 5 year unit testing program of the WECC which includes VAR output testing. USBR completed testing of their generation units VAR capabilities in 2009.
8	The ideal range of operating transmission voltage is 1.00 to 1.03 per unit for buses operating at 115kV or higher. The following table should be the ideal, acceptable, and emergency steady state voltages ranges for the Western (WAPA) Dispatch Center Operators to use to operate the transmission grid in Region 1:

*Bus Type	Low Voltage Limit		High Voltage Limit	
	138kV Bus	230kV Bus	138kV Bus	230kV Bus
Regulating Bus: Ideal Voltage Range	139kV (1.01 PU)	232kV (1.01 PU)	142kV (1.03 PU)	237kV (1.03 PU)
Regulating Bus: **Ideal Voltage Range (unusual conditions)	141kV (1.02 PU)	237kV (1.03 PU)	145kV (1.05 PU)	242kV (1.05 PU)
Non-Regulating Bus: Ideal Voltage Range	138kV (1.00 PU)	230kV (1.00 PU)	142kV (1.03 PU)	236kV (1.03 PU)
Regulating Bus: Acceptable Voltage Range	132kV (0.96 PU)	221kV (0.96 PU)	145kV (1.05 PU)	242kV (1.05 PU)
Regulating Bus: Emergency Voltage Range	128kV (0.93 PU)	214kV (0.93 PU)	148kV (1.07 PU)	247kV (1.07 PU)

*A Regulating Bus is defined as any transmission or generation bus with a voltage schedule (voltage range) that is maintained using automatically controllable reactive power devices. Automatically controllable reactive power devices include generators, switchable capacitors and inductors, synchronous condensers, transformers with on load tap changers, static var compensators (SVC), etc.

	**Ideal Voltage Range may include operation under unusual conditions where upcoming heavy system loads or facility outages may be anticipated. To prepare for these events the Operators may adjust the system for higher initial voltages, in anticipation of these upcoming higher system stress conditions.
9	The Craig and Hayden units operate to observe the voltage requirements of nearby load buses while simultaneously maintaining as large as possible reactive margin for the units.
10	The Wolcott transformer taps will be changed seasonally as needed. The load is too remote for effective voltage control with the Craig and Hayden units.

REGION 2 - SOUTHWEST COLORADO

Voltage Guidelines Specific to the Southwest Colorado Area

The numbering of the items below is keyed to the numbering scheme used in the section on ***Coordinated Voltage Control - Principles and Practices.***

P & P Ref. #	Region-Specific Notes or Comments
2	The key locations to monitoring the voltage are Montrose, Curecanti, Lost Canyon, and Hesperus. Accuracy of the metering has not been compared to bureau of standards test equipment. State estimator output will identify suspect measurements.
3	Table 1 contains a list of switchable shunt equipment, fixed tap transformers and generation, which can be used to partially control the local voltage profile.
5	With the exception of the Aspinal (Blue Mesa, Crystal, Morrow Point) units there is no equipment, which would generate circulating VARs within a substation. The VAR flow between substations is dependent upon line loadings since the substations are geographically remote from each other.
7	PSCo adheres to the 5 year unit testing program of the WECC which includes VAR output testing. USBR completed testing of their generation units VAR capabilities in 2009.
8	The ideal range of operating transmission voltages is 1.01 to 1.04 per unit.
9	There is no load tied directly to the Aspinal (Blue Mesa, Crystal, Morrow Point) units. However they are normally scheduled to hold the Curecanti bus voltages (230kV and 115kV) voltages between 1.01 and 1.04 per unit. If other local voltages are high the units are scheduled towards the low end. Motoring of any of the Aspinal units (typically Morrow Point) is an acceptable means to control high voltages. If other local voltages are low the units are scheduled towards the high end.
10	Presently, there is no need for seasonal tap changes.

REGION 3 - FOOTHILLS AREA OF COLORADO

Voltage Guidelines Specific to the Foothills Area

The numbering of the items below is keyed to the numbering scheme used in the section on ***Coordinated Voltage Control - Principles and Practices.***

P & P Ref. #	Region-Specific Notes or Comments
2	The key locations which give an overall view of the voltage profile within the Foothills area are Weld, Fort Saint Vrain (FSV), Ault, Rawhide and Flatiron. Other locations that indicate extremes in the Foothills voltage profile are Richard Lake, Valley, Longs Peak, Greeley, and Fordham.
3	Table 1 contains a complete list of fixed shunt equipment, LTC transformers, fixed tap transformers and generating equipment that affect or can be used to alter the regional voltage profile.
5	The (PSCo / WAPA) Weld Substation has parallel LTC transformers, as well as shunt capacitors and reactors. The operating agent for the various pieces of equipment is PSCo, who is monitoring the various parameters to minimize circulating VARs and operating the shunt equipment to keep the LTC transformers in the proper range. The Weld autotransformers 115kV LTCs are operated either in manual (remote SCADA) control, or are sometimes operated in local automatic control mode.
7	PSCo adheres to the 5 year unit testing program of the WECC which includes VAR output testing. PRPA completed testing of their generation units including VAR capabilities in 2008. USBR completed testing of their generation units VAR capabilities in 2009.
8	The maximum ideal operating voltage on the 230kV system in the Foothills area is 1.025 per unit (235.75kV). The minimum ideal operating voltage is 1.0 per unit (230kV). The maximum ideal operating voltage on the 115kV system is 1.025 per unit (117.9kV). The corresponding minimum ideal operating voltage is 1.0 per unit (115kV). The ideal voltage range targeted by the WAPA control area is 1.02 to 1.04 per unit (352kV to 359kV) at the Ault 345kV bus, and 1.00 to 1.04 per unit (230kV to 239kV) at the Ault 230kV bus. The ideal voltage range targeted by the PSCo control area is 1.02 to 1.03 per unit (235kV to 237kV) at the Fort St.Vrain 230kV bus. System operators at the WAPA and PSCo control areas should coordinate reactive switching at Ault, Weld, and Fort St.Vrain such that the reactors at Ault are not competing with the capacitors at Fort St.Vrain, for example.
9	The hydro generation at Flatiron, Pole Hill, Estes Park, and Mary's Lake either has direct load connected to it or is adjacent to load areas. During on-peak hours, the reactive generation will operate to control the 115kV voltage to 1.01 per unit (116.2kV). During off-peak hours, the units will not absorb VARs from the system until the voltage exceeds 1.025 per unit (117.9kV), and 119.0kV at Longs Peak in the summer. Flatiron, Pole Hill, Estes and Mary's Lake are sometimes cycled off at night.

	Rawhide reactive generation is determined by the PSCo control area needs for voltage support. The Rawhide 230kV bus ideal voltage range is 230kV to 234kV. The Fort St.Vrain voltage is operated as much as possible in the ideal voltage range of 1.02 to 1.03 per unit (235kV to 237kV), with off-peak voltages allowed to go slightly higher at 1.04 to 1.045 per unit (239kV to 240kV), if conditions warrant. The reactive generation at UNC (Greeley), and Thermo Carbonics and Thermo Industry (TCTI – Ft. Lupton) will be operated in a manner consistent with maintaining ideal voltages at Weld 115kV and Ft. Lupton 115kV. These units can be operated within the range of 0.95 power factor lead or 0.90 lag. The Thermo Carbonics and Thermo Industry QFs units are sometimes cycled off at night
10	Seasonal changes are not required in the no-load tap settings for any LTC or fixed tap transmission transformers within the Foothills area.

REGION 4 - SOUTHEAST COLORADO

Voltage Guidelines Specific to the Southeast Colorado Area

The numbering of the items below is keyed to the numbering scheme used in the section on ***Coordinated Voltage Control - Principles and Practices.***

P & P Ref. #	Region-Specific Notes or Comments
2	The key locations, which give an overall view of the voltage profile in the Southeastern Colorado area, are the regulating buses at Birdsall, Boone, Comanche, Reader (69kV), Lamar, Cottonwood, Drake, Kelker, Midway, and Nixon. These are the places that have autotransformers, generation, and/or switchable reactive compensation equipment. These key locations are owned, operated, maintained, and controlled by PSCo, Western Area Power Administration, the Colorado Springs Utilities, Tri-State, Arkansas River Power Authority's member cities, and/or Black Hills Energy and the accuracy of metering is sufficient.
3	Table 1 contains a complete list of the electrical characteristics of the generating, reactive compensation, and LTC transformer equipment.
5	There are two substation locations in this region with parallel 230/115/13.8kV autotransformers with under load tap changers (LTCs). One of these locations, Midway, has shunt reactors on the tertiary of each auto. The 115kV bus is normally operated open to prevent the flow of circulating current. One auto is Western's and the other is PSCo's. The other double autotransformer location is Comanche, with two 360 MW generation units operated by PSCo. Since PSCo has the most control in this area, they continuously monitor the various parameters to minimize circulating VARs, and can operate the reactive equipment to keep the LTC transformers in the proper voltage range. There are also two substation locations Cottonwood and Kelker, with parallel 230/115kV autotransformers with under load tap changers (LTC's). These units do not contain a tertiary winding. They are manually operated by Colorado Springs Utilities with 230kV and 115kV bus ties closed. Two other locations, Birdsall and Drake, have double 115/34.5kV autotransformers. At both of these locations the tap changers are manually operated by the Colorado Springs Utilities.
6	Reactive compensating and voltage regulating equipment are used year around. This practice helps to extend the effective influence of the autotransformers LTCs on the system voltage range, and keep the VAR requirements from local generation to a minimum, saving the generation VAR capacity for system voltage regulation needs. There are additional sources of voltage support and regulation in the area with the generation at Fountain Valley (240MW total); Front Range (480MW total for 3 units), and Nixon GCTs (60MW total for 2 units). Other major additions

are the Comanche 3 unit (750 MW total) and the two 345-kV lines from Comanche to Daniels Park.

In the Boone to Lamar area, major PSCo operated installations include the Colorado Green and Twin Buttes Wind Generation facilities near Lamar (162 MW and 75 MW respectively), and the Lamar +/- 210MW DC tie station with a set point ideal operating voltage of 1.03 per-unit (237kV). Autotransformer tertiary reactors installed at Boone Substation are switched daily to meet voltage support needs.

In Southeast Colorado, voltage control is accomplished by using the Lamar HVDC Tie, the Colorado Green Wind Park, the Walsh 69kV capacitors and tertiary reactors at Lamar. Small local generating units assist in controlling voltages in the area. The most serious voltage conditions can occur if the Boone – Lamar 230kV line is out during peak summer load conditions.

7 PSCo adheres to the WECC 5 year unit testing program which includes VAR output testing.

8 The following table should be the target ideal, acceptable, and emergency steady state voltage ranges for Dispatch Center Operators to use to operate the PSCo system:

***Bus Type**	**Low Voltage Limit**		**High Voltage Limit**	
	115kV Bus	**230kV Bus**	**115kV Bus**	**230kV Bus**
Regulating Bus: Ideal Voltage Range	117kV (1.02 PU)	234kV (1.02 PU)	118kV (1.03 PU)	236kV (1.03 PU)
Regulating Bus: **Ideal Voltage Range (unusual conditions)	119kV (1.03 PU)	239kV (1.04 PU)	121kV (1.05 PU)	242kV (1.05 PU)
Non-Regulating Bus: Ideal Voltage Range	115kV (1.0 PU)	230kV (1.0 PU)	118kV (1.03 PU)	236kV (1.03 PU)
Regulating Bus: Acceptable Voltage Range	110kV (0.96 PU)	221kV (0.96 PU)	121kV (1.05 PU)	242kV (1.05 PU)
Regulating Bus: Emergency Voltage Range	107kV (0.93 PU)	214kV (0.93 PU)	124kV (1.07 PU)	247kV (1.07 PU)

* A Regulating Bus is defined as any transmission or generation bus with a voltage schedule (voltage range) that is maintained using automatically controllable reactive power devices. Automatically controllable reactive power devices include generators, switchable capacitors and inductors, synchronous condensers, transformers with on load tap changers, static var compensators (SVC), etc.

**Ideal Voltage Range may include operation under unusual conditions where upcoming heavy system loads or facility outages may be anticipated. To prepare for these events the Operators may adjust the system for higher initial voltages, in anticipation of these upcoming higher system stress conditions.

10 Seasonal changes are not required in the no-load tap settings for any of the LTC or fixed tap transformers in the Southeastern Colorado Area.

REGION 5 - SOUTH CENTRAL COLORADO

Voltage Guidelines Specific to the South-Central Colorado Area

The numbering of the items below is keyed to the numbering scheme used in the section on ***Coordinated Voltage Control - Principles and Practices.***

P & P Ref. #	Region-Specific Notes or Comments
2	The key locations, which give an overall view of the voltage profile within the South-Central Colorado area, are: Poncha, Alamosa Terminal, and San Luis Valley Substations. The most critical outage is the loss of the Poncha-San Luis Valley 230kV transmission line. If this line is lost during heavy summer loads, with the combustion turbines off line, the remaining 115kV lines may load to their thermal ratings.
3	Table 1 contains a list of fixed shunt equipment, LTC transformers, fixed tap transformers, and generating equipment that affect or can be used to alter the regional voltage profile. In the San Luis Valley, low voltage conditions are most likely to occur during the heavy summer period. With system intact, 1.0 per unit voltage levels are difficult to maintain. Should the Poncha – San Luis Valley 230kV line trip open, the area system voltages will drop well below acceptable levels, as occurred in 1998 and 2002, resulting in manual or automatic low voltage load dropping (shedding). Tri-State has installed undervoltage relaying in the valley as a result of previous low voltage conditions. These conditions, during peak load periods, will continue until major transmission enhancements are made in the valley.
7	PSCo adheres to the WECC 5 year unit testing program which includes VAR output testing.

REGION 6 - SOUTHEAST WYOMING / WESTERN NEBRASKA

Voltage Guidelines Specific to the Southeastern Wyoming Area

The numbering of the items below is keyed to the numbering scheme used in the section on ***Coordinated Voltage Control-Principles and Practices.***

P & P Ref. #	Region-Specific Notes or Comments
2	The key locations which give an overall view of the voltage profile within the Southeastern Wyoming area correspond to locations of generation, LTC transformers, DC ties, reactive equipment, buses with the greatest extremes in voltage and buses which define the boundary to the Southeastern Wyoming area. These buses are Laramie River 345kV and 230kV, Dave Johnston 230kV and 115kV (Region 9), Glendo 115kV, Stegall 230kV and 115kV, Sidney 230kV and 115kV, Archer 230kV and 115kV, Alcova 115kV, Miracle Mile 115kV (being representative of voltages at the nearby hydro facilities), Gem City 115kV, and Laramie 115kV. Dave Johnston, Ault, Story, Sidney 115kV and Beaver Creek 115kV locations define boundary conditions with adjacent areas.
3	Table 1 for Region 6, S.E. Wyoming / W. Nebraska Voltage Control Equipment" contains a complete list of shunt reactive equipment, LTC transformers, fixed tap transformers, DC ties, and generating equipment that affect or can be used to alter the regional voltage profile. The Glendo hydro facility is unavailable during the winter. Alcova, Kortes, Seminoe and Fremont generation may be off at night.
5	Study cases sometimes show VARs circulating between Miracle Mile area hydro units. Adjust voltage schedules as needed to prevent circulating VARs.
7	The VAR capability of the LRS units was tested in accordance with WECC requirements. Testing indicates that under system normal conditions we can expect the terminal voltage limits of 1.05 to .95 per unit to be reached before the D curve limits are reached. During contingencies, where bulk system voltages are initially abnormal, we expect that LRS should be capable of operating further into the region defined by the D curve and by the under-excitation limiter characteristic, before terminal voltage limits are encountered. All LRS auxiliary transformers have LTCs, which eliminates transformer coordination problems internal to the station. USBR completed testing of generation units VAR capabilities at Alcova, Fremont Canyon and Kortes in 2009.
8	Dave Johnston (DJ) station is on the boundary of the SE Wyoming Region 6, and voltage scheduling at DJ is addressed in Region 9. Western's system operators operate according to general voltage range guidelines that specify operating in an ideal 1.0 per unit to 1.025 per unit voltage range. Sidney DC tie provides continuous regulation when it is on line, and the

	voltage set point is approximately 1.04 per unit. This was done to minimize reactor switching which was a cause of control problems with the tie. Subject to LRS generator terminal voltage limitations, LRS 345kV voltage can be scheduled as high as 1.04 per unit during high transfer conditions where LRS needs to help support the regional voltage profile. During periods of low transfer across the HV system, the LRS unit can be operated in the lead, as needed, to help reduce voltages on the system. Voltages at Alcova, Kortes, Seminoe, and Fremont will be adjusted to prevent circulating VARs and to keep the voltage at Miracle Mile within limits.
9	Generation at Alcova, Seminoe, Kortes, Fremont, and Glendo are connected to the 115kV system, and the units should utilize available VAR capability, as needed, to improve the local area voltage profiles without regard for providing a VAR "margin".

REGION 7 - NORTHEAST COLORADO

Voltage Guidelines Specific to the Northeast Colorado Area

The numbering of the items below is keyed to the numbering- scheme used in the section on ***Coordinated Voltage Control-Principles and Practices.***

P & P Ref. #	Region-Specific Notes or Comments
2	The key locations which give an overall view of the voltage profile within the Northeastern Colorado area correspond to locations of generation, LTC transformers, reactive equipment, buses with the greatest extremes in voltage, and buses which define the boundary to the Northeastern Colorado area. These buses are Pawnee 230kV and 115kV, Story 230kV, Beaver Creek 115kV, North Yuma 230kV and 115kV, Wray 230kV and 115kV, Burlington 230kV and 115kV, Big Sandy 230kV and 115kV, Haxtun 69kV, and Sterling 69kV or 115kV. Pawnee 230kV, Sidney 115kV, and Big Sandy locations define boundary conditions with adjacent areas. Holyoke 69kV generally experiences the lowest voltage in the Northeastern Colorado area.
3	Table 1 contains a complete list of shunt reactive equipment, LTC transformers, fixed tap transformers, and generating equipment that affect or can be used to alter the regional voltage profile.
7	PSCo adheres to the 5 year unit testing program of the WECC which includes VAR output testing.
8	WAPA and Tri-State system Operators generally prefer to operate the 115kV system at about 1.03 per unit (118kV). With the Sidney DC tie on line, the established practice is to lock the Sidney 230/115kV LTC transformer so that the reactive switching on the tie does not cause a corresponding LTC tap change. LTCs at Sidney, Burlington and Big Sandy are normally under manual control. Both of the Beaver Creek 230/115kV autotransformers' (PSCo's and Tri-State's) LTCs are operated under manual control, per direction of PSCo. Tri-State has developed a number of voltage control / monitoring tools on its ABB SCADA system. These tools allow the dispatchers to monitor voltages throughout the entire system. Alarms are set at various high and low levels, using 1.03 per unit as the ideal voltage for all stations. All capacitors and reactors, except line reactors, are on manual control via SCADA. Most LTCs are on manual control, via SCADA to minimize excessive tap change operations. Northeast Colorado has the most significant concentration of irrigation loads in the system, therefore more reactive control equipment is available for

	controlling voltages during the summer irrigation season. Tri-State's philosophy is to operate the Burlington and Wray 115kV bus voltages slightly higher during the morning hours (0600-1000) in order to stay ahead of the expected load pickup. These buses are run as high as 1.04 - 1.05 per unit during these hours, and generally settle out at 1.03 around 1000 - 1100 hrs. This allows for a stronger voltage profile during the remainder of the day, and often provides one or two off line capacitor banks for emergency operations. The following table should be the target ideal, acceptable, and emergency steady state voltage ranges for Dispatch Center Operators to use to operate the PSCo systems:

*Bus Type	Low Voltage Limit		High Voltage Limit	
	115kV Bus	230kV Bus	115kV Bus	230kV Bus
Regulating Bus: Ideal Voltage Range	117kV (1.02 PU)	234kV (1.02 PU)	118kV (1.03 PU)	236kV (1.03 PU)
Regulating Bus: **Ideal Voltage Range (unusual conditions)	119kV (1.03 PU)	239kV (1.04 PU)	121kV (1.05 PU)	242kV (1.05 PU)
Non-Regulating Bus: Ideal Voltage Range	115kV (1.0 PU)	230kV (1.0 PU)	118kV (1.03 PU)	236kV (1.03 PU)
Regulating Bus: Acceptable Voltage Range	110kV (0.96 PU)	221kV (0.96 PU)	121kV (1.05 PU)	242kV (1.05 PU)
Regulating Bus: Emergency Voltage Range	107kV (0.93 PU)	214kV (0.93 PU)	124kV (1.07 PU)	247kV (1.07 PU)

* A Regulating Bus is defined as any transmission or generation bus with a voltage schedule (voltage range) that is maintained using automatically controllable reactive power devices. Automatically controllable reactive power devices include generators, switchable capacitors and inductors, synchronous condensers, transformers with on load tap changers, static var compensators (SVC), etc.

**Ideal Voltage Range may include operation under unusual conditions where upcoming heavy system loads or facility outages may be anticipated. To prepare for these events the Operators may adjust the system for higher initial voltages, in anticipation of these upcoming higher system stress conditions.

9	Voltage schedules of 1.03 to 1.04 per unit (237kV to 239kV) are ideal for the Pawnee, and Manchief NUG transmission buses. When transfers on the HV system are low, or area loads are light, the area may require Pawnee to absorb VARs to reduce area voltages.

REGION 8 - METRO DENVER-BOULDER–Ft.LUPTON

Voltage Guidelines Specific to the Metro Denver–Boulder–Ft.Lupton Region

The numbering of the items below is keyed to the numbering scheme used in the section on ***Coordinated Voltage Control - Principles and Practices.***

P & P Ref. #	Region-Specific Notes or Comments
2	The key locations which give an overall view of the voltage profile in the Denver Metro area are considered the regulating buses. These buses are identified in Tables 1 and 2 in the Appendices for this Region 8. These are the locations that have autotransformers, generation, and/or switchable reactive compensation equipment. All of these key locations are operated, maintained, and controlled by PSCo and accuracy of metering is sufficient.
3	The Table 1 in the Appendix for this Region contains a complete list of the electrical characteristics of the generating, reactive compensation, and LTC transformer equipment.
4	PSCo has a system display at their Dispatch Center with SCADA display showing voltage levels at all regulating buses, status of reactive compensation devices, and generator output (MWs and MVARs) for their entire system.
5	There are many locations with parallel autotransformers with LTCs, as well as shunt capacitors and/or reactors and even multiple generation units. Since PSCo is the operator of this equipment, they continuously monitor the various parameters to minimize circulating VARs and can operate the reactive equipment to keep the LTC transformers in the proper range. The Waterton (#1 and #2) 230/115kV autotransformers', and Tarryall 230/115kV autotransformer's 115kV LTCs are equipped and normally operated in local / automatic mode. All of the other 230-115kV transmission system autotransformer tap changers in this region are normally operated manually by SCADA due to the fact that better regulation can be done by the generation.
6	Reactive compensation equipment (shunt reactors and capacitors) are basically used year around not only to help extend the range of the autotransformers LTCs, but to keep the VAR requirements of local generation to a minimum, saving this capability for voltage regulation.
7	PSCo adheres to the 5 year unit testing program of the WECC which includes VAR output testing.
8	The following table should be the ideal, acceptable, and emergency steady state voltage ranges for Dispatch Center Operators to use to operate the PSCo system:

Bus Type	Low Voltage Limit		High Voltage Limit	
	115kV Bus	**230kV Bus**	**115kV Bus**	**230kV Bus**
Regulating Bus: Ideal Voltage Range	117kV (1.02 PU)	234kV (1.02 PU)	118kV (1.03 PU)	236kV (1.03 PU)

Regulating Bus: **Ideal Voltage Range (unusual conditions)	119kV (1.03 PU)	239kV (1.04 PU)	121kV (1.05 PU)	242kV (1.05 PU)
Non-Regulating Bus: Ideal Voltage Range	115kV (1.0 PU)	230kV (1.0 PU)	118kV (1.03 PU)	236kV (1.03 PU)
Regulating Bus: Acceptable Voltage Range	110kV (0.96 PU)	221kV (0.96 PU)	121kV (1.05 PU)	242kV (1.05 PU)
Regulating Bus: Emergency Voltage Range	107kV (0.93 PU)	214kV (0.93 PU)	124kV (1.07 PU)	247kV (1.07 PU)

* A Regulating Bus is defined as any transmission or generation bus with a voltage schedule (voltage range) that is maintained using automatically controllable reactive power devices. Automatically controllable reactive power devices include generators, switchable capacitors and inductors, synchronous condensers, transformers with on load tap changers, static var compensators (SVC), etc.

**Ideal Voltage Range may include operation under unusual conditions where upcoming heavy system loads or facility outages may be anticipated. To prepare for these events the Operators may adjust the system for higher initial voltages, in anticipation of these upcoming higher system stress conditions.

9	Generation listed is basically all located in a load area and operators have the ability to manually operate or set the voltage regulators on automatic. System connections are sufficient that generators that have direct load connected are set to respond to system fluctuations.
10	Seasonal changes are not required in the no-load tap settings for any of the LTC or fixed tap transformers in the Denver Metro Area.

REGION 9 – WESTERN WYOMING

Voltage Guidelines Specific to the PACE Wyoming System

The numbering of the items below is keyed to the numbering scheme used in the section on ***Coordinated Voltage Control - Principles and Practices.***

7. Generator Testing: PacifiCorp is in the process of testing its generating units, in accordance with the WECC specified guidelines. Testing of thermal units has already been completed, and hydro units are in the process of being tested.

General

8. PacifiCorp Wyoming system is part of the eastern control area referred to as PACE, and consists of 230kV, 115kV and 69kV lines. The 230kV system is operated to maintain the following voltage profile:

	Low		High	
	PU	kV	PU	kV
Ideal Range:	1.0	230.0	1.05	241.5
Acceptable Range:	0.96	220.8	1.05	241.5
Emergency Range:	0.93	213.9	1.075	247.25

Soft limit is defined as that voltage level which alerts the operator to initiate an appropriate action, if the voltage falls outside the specified limits. The hard limit specifies the lower and upper voltage levels, which are not to be violated in order to avoid any damage to the equipment and excessive voltage deviation at customers' facilities. Operating guidelines for the 115kV and 69kV system are similar to the 230kV system.

Voltage Control

The system voltage is controlled through switching of reactive devices. The existing and planned reactive devices are listed in the attached table. No major problems have been encountered in regulating system voltage through use of the existing reactive devices, during normal operating conditions. In general, the reactive capability of the generating units in Wyoming (Dave Johnston 1-4 and Wyodak) is not depended upon for voltage control. The units are normally operated in a constant voltage mode and with 0.98-1.00 lagging power factor. It is rare when the units are operated in a bucking mode. Such mode of operation may occur during light loading hours and under generation outage conditions involving two large units not being available.

Most of the high voltage transformers are equipped with LTC, and some are operated in automatic mode. The attached table (Appendix, Region 9, Table 1) shows the list of transformers equipped with LTC, tap range and mode of operation.

Some of the situations when voltage problems have been experienced are the following:

a. During coordinated phase shifter operation to mitigate loop flow, low voltage has occurred around Sheridan, Goose Creek and Oregon Basin areas. The installed 230 kV capacitor banks at Sheridan and Oregon Basin alleviate this problem.
b. During generation outages in Montana, low voltage has been observed between Buffalo and Yellowtail. The installation of the capacitor bank at Sheridan alleviates this low voltage situation.
c. During light load hours and with Wyodak and a large Dave Johnston unit being out of service, high voltage has been encountered in Wyoming. With load growth in the area, the extent of this problem has significantly diminished.

In conclusion, the Wyoming voltage is controllable with the existing reactive devices, use of the transformer LTC, and through utilization of reactive capability of the generating units.

Operation of Foote Creek Generation (Wind Farm)

General

The 135 MW Foote Creek Wind Farm is located in southeast Wyoming at two sites: Foote Creek (85 MW) and Rock River (50 MW). The generation voltage is stepped up to 34.5kV and it is delivered at Foote Creek substation through 34.5kV feeders. The voltage is further stepped up to 230kV through two 34.5/230kV transformers (84 and 112 MVA). The generation is integrated with the PACE system at Miners substation, through a 28.9-mile 230kV line, having 1272 MCM ACSR conductor. The line rating is over 400 MW.

Voltage Control

The desired operating mode is to maintain closer to unity power factor at Foote Creek on the 34.5kV side, in order to avoid any undue reactive burden on PACE system. For voltage regulation, there are six 5 MVAR and three 6.67 MVAR each, 34.5kV shunt capacitor banks installed at Foote Creek. These banks can be operated in an automatic mode or through local or remote manual operation. Currently these are being operated in an automatic mode with the following settings:

Lower limit to switch on: 0.984 per unit
Upper limit to switch off: 1.0279 per unit

These settings were derived with the intent of maintaining 1.0-1.05 per unit voltage at Miners 230 kV bus.

In addition, a ±8 MVAR, 34.5kV DVAR device has been installed at Foote Creek to reduce the wind farm voltage deviations during capacitor bank switching (local or network) operations. It also provides control of the 34.5kV capacitor bank switching. The various DVAR device settings, as currently contemplated, are the following:

- With the 34.5kV voltage being 0.98-1.02 per unit, no DVAR regulation will be provided.

- DVAR will provide immediate response and turn-off capacitor banks if voltage exceeds 1.03 per unit for 2 seconds. The backup function setting to turn-off capacitor banks is 1.05 per unit for 1 second.

- DVAR will provide immediate response and turn-on capacitor banks if the voltage drops below 0.97 per unit for 2 seconds. Backup setting to turn on the capacitor banks is 0.95 per unit for 1 second.

- The DVAR will shut down if the 34.5kV voltage exceeds 1.1 per unit for 0.1 second or drops below 0.80 per unit for 1.5 seconds.

In addition to the voltage control equipment provided at Foote Creek as noted above, PAC will be installing several shunt capacitor banks, as noted below, to avoid any degradation of TOT4-A/4-B transfer capability:

- 1x15 MVAR bank at Atlantic City 230kV bus.

- 3x30 MVAR banks at Mustang 230kV bus.

- 4x25 MVAR banks at Platte 230kV (existing 2x45 MVAR banks have been replaced with 4x25 MVAR banks).

- 1x25 MVAR at Miners 230kV.

Due to wide variation in the generation output, some difficulties were experienced in the past to maintain desired voltage profile. However, with the installation of adequate reactive devices and operating experience, the operating issues are now within manageable level.

REGION 10 – NORTHEASTERN WYOMING / S.W. SOUTH DAKOTA

Voltage Guidelines Specific to the NE Wyoming and SW South Dakota Area

The numbering of the items below is keyed to the numbering scheme used in the section on ***Coordinated Voltage Control - Principles and Practices.***

P & P Ref. #	Region-Specific Notes or Comments
2	The key locations in this area, which give an overall view of the voltage profile, are: Hughes, Lookout, Yellow Creek, Osage, Lange, South Rapid City, West Hill and Wyodak.
3	Table 1 for Region 10 contains a complete list of fixed shunt equipment, LTC transformers, fixed tap transformers and generating equipment that affect or can be used to alter the regional voltage profile. Although not part of this region, the Wyodak steam plant has a major impact on voltage control in Region 10. Area combustion turbine support is required during peak load conditions, if Wyodak is off line, or for other critical prior outages.
5	The Wyodak and the Lange substations have parallel LTC transformers as well as shunt capacitors and reactors. Black Hills Power continuously monitors various parameters and manually adjusts equipment in order to minimize circulating VARs. Automatic voltage control equipment include the Rapid City DC Tie, the Teckla capacitor banks and the Teckla, Reno, South Rapid and Osage transformers. All other voltage control equipment is manually controlled via SCADA.
6	Voltage regulating equipment is used year-round to preserve generator dynamic VAR capabilities, maintain adequate range on autotransformer LTCs and to minimize high reactive power imports or exports.
7	All Black Hills Power operated generating units have been tested per the WECC testing requirements.
8	BHP system operators try to maintain the 230kV system voltage between 230kV (1.00 per unit) and 239kV (1.04 per unit). During light load conditions, and with all reactors online, voltages in the West Hill area may approach 242kV. Due to the Wyodak plant, 230kV bus voltages in the Western part of the region remain fairly constant year round. Bus voltages on the 69kV system are maintained between 69kV and 70kV (1.015 per unit). LTCs on the 230kV/69kV autotransformers are used to fine-tune the 69kV bus voltages. With the exception of the new Rapid City DC Tie, the Teckla capacitor bank and the Teckla, Reno, South Rapid and Osage transformers, all voltage control equipment is operated manually via SCADA. LTCs at Teckla, Reno, South Rapid and Osage are tapped automatically based on the bandwidth shown in Table 1 for Region 10. The Rapid City DC tie will provide limited voltage control through its Reactive Power Controller (RPC), which controls all

	reactors and filters (capacitive) associated with the DC tie. The RPC controls filter switching to maintain the minimum DC tie filter requirements. Once the minimum filter requirements are met, the RPC will switch reactors and extra filters in order to maintain the 230KV voltage between 0.95 per unit and 1.05 per unit. The DC tie also has a Voltage Dependent Power Order Limiter (VDPOL), which will reduce the DC tie power schedule if the 230KV bus voltage on the rectifier side drops below 0.95 per unit.
9	Rapid City combustion turbines, which consist of four Frame 5s (26MW each), and the Lange CT (40MW), are located in Rapid City, SD., which is the largest load area in Region 10. Under peak load conditions or during critical contingencies, these combustion turbines provide voltage support and maintain reactive reserve margins at the Lange, South Rapid and Lookout 230kV buses.
10	There is no need for seasonal tap changes.

LIST OF GENERATOR D-CURVES SCANNED AND SAVED ON CD-ROM

Region 1: Northwest Colorado:

Apndx1 AmerAtlasRifle GTG 1-3-4
Apndx1 AmerAtlasRifle GTG
Apndx1 PSCo Cameo1
Apndx1 PSCo Cameo2
Apndx1 PSCo Craig1-2
Apndx1 PSCo Craig3
VCG Reg 1 – PSCo Fruita 1-Base
VCG Reg 1 – PSCo Fruita 1-Base
VCG Reg 1 – PSCo Fruita 1-Peak
Apndx1 PSCo Fruita1-Rev
Apndx1 PSCo Hayden1
Apndx1 PSCo Hayden2
Apndx1 TS Craig1-2
VCG Reg 1 – WAPA-USBR Flaming Gorge 1-3
VCG Reg 1 – WAPA-USBR Green Mtn 1-2
VCG Reg 1 – WAPA-USBR Molina-Lower
VCG Reg 1 – WAPA-USBR Molina-Upper
VCG Reg 1 – WAPA-USBR Mt.Elbert 1-2

Region 2: Southwest Colorado:

VCG Reg 2 – PSCo Tacoma Hydro 1-2
VCG Reg 2 – WAPA-USBR Blue Mesa 1-2
VCG Reg 2 – WAPA-USBR Crystal 1
WAPA 1-9-02 Apndx2 – McPhee 1
Apndx2 WAPA-USBR MorrowPoint1
VCG Reg 2 – WAPA-USBR Morrow Point 2
VCG Reg 2 – Nucla 1,2,3
VCG Reg 2 – Nucla 4
WAPA 1-9-02 Apndx2 – Towaoc 1
VCG Reg 2 – WAPA-USBR Towaoc UE Oper

Region 3: Foothills:

Apndx3 PRPA Rawhide1
VCG Reg 3 – PRPA Rawhide A-B-C-D
VCG Reg 3 – PRPA Rawhide F
VCG Reg 3 – PSCo FSV 1-old
VCG Reg 3 – PSCo FSV 2
VCG Reg 3 – PSCo FSV 3
VCG Reg 3 – PSCo UNC QF GTGs A-B
VCG Reg 3 – PSCo UNC QF ST1
WAPA 1-9-02 Apndx7-RevReg3 – Big Thompson 1
Apndx3 WAPA-USBR Big Thompson
VCG Reg 3 – WAPA-USBR Estes 1-2-3 Table
WAPA 1-9-02 Apndx7-RevReg3 – Estes 1-2-3 100

WAPA 1-9-02 Apndx7-RevReg3 – Estes 1-2-3 115
Apndx3 WAPA-USBR Estes
WAPA 1-9-02 Apndx7-RevReg3 – Flatiron 1-2-3
Apndx3 WAPA-USBR Flatiron 1-2
VCG Reg 3 – WAPA-USBR Flatiron 1-2 MEL
VCG Reg 3 – WAPA-USBR Flatiron 1-2 OE Reg
VCG Reg 3 – WAPA-USBR Flatiron 1-2 UE Reg
WAPA 1-9-02 Apndx7-RevReg3 – Pole Hill 1
VCG Reg 3 – WAPA-USBR Pole Hill
VCG Reg 3 – WAPA-USBR Pole Hill MEL
VCG Reg 3 – WAPA-USBR Estes 1-2-3

Region 4: Southeast Colorado:

Apndx4 Aquila-WPE Canyon City1
Apndx4 Aquila-WPE Canyon City2
Apndx4 Ark Rvr PA Lamar Utility Board
Apndx4 Aquila-WPE Canyon City1
Apndx4 CSU Drake5
Apndx4 CSU Drake6
Apndx4 CSU Drake7
Apndx4 CSU Front Range 1-2
Apndx4 CSU Front Range 3
Apndx4 CSU Nixon 2-3
Apndx4 CSU Pueblo 1949Adn
Apndx4 CSU RD Nixon1
Apndx4 PSCo Comanche1
Apndx4 PSCo Comanche2
Apndx4 PSCo FtnVly NUG 1-6

Region 5: South-Central Colorado:

VCG Reg 5 – PSCo Alamosa Term 1
VCG Reg 5 – PSCo Alamosa Term 2-Base
VCG Reg 5 – PSCo Alamosa Term 2-Peak
WAPA 1-9-02 Apndx5 – Mt Elbert 1
WAPA 1-9-02 Apndx5 – Mt Elbert 2

Region 6: Southeast Wyoming:

Apndx6 BHP LRS 1-2-3
WAPA 1-9-02 Apndx6 – Alcova 1-2 100
WAPA 1-9-02 Apndx6 – Alcova 1-2 115
Apndx6 WAPA-USBR Alcova OE-Reg
VCG Reg 6 – WAPA-USBR Alcova 1-2 MEL
VCG Reg 6 – WAPA-USBR Fremont Canyon 1-2
VCG Reg 6 – WAPA-USBR Glendo 1-2 MEL
VCG Reg 6 – WAPA-USBR Guernsey 1
VCG Reg 6 – WAPA-USBR Guernsey 2
VCG Reg 6 – WAPA-USBR Guernsey OE-Reg
Apndx6 WAPA-USBR Kortes OE-Reg

VCG Reg 6 – WAPA-USBR Kortes 1-2-3
Apndx6 WAPA-USBR Seminoe OE-Reg
VCG Reg 6 – WAPA-USBR Seminoe 1-2-3

Region 7: Northeast Colorado:

VCG Reg 7 – PSCo Brush NUG 4D ST4
VCG Reg 7 – PSCo Brush NUG BCP GTG3 ST2
VCG Reg 7 – PSCo Brush NUG CPP GTG 1-2
VCG Reg 7 – Limon 1, 2
VCG Reg 7 – PSCo Manchief NUG GTG11-12
Apndx7 PSCo Pawnee1
Apndx7 TS Burlington

Region 8: Metro Denver-Boulder-Ft.Lupton:

Apndx8 PSCo Arapahoe1
Apndx8 PSCo Arapahoe2
Apndx8 PSCo Arapahoe3
Apndx8 PSCo Arapahoe4
VCG Reg 8 – PSCo Arap-BlkHills NUG GTG5-6
Apndx8 PSCo Blue Spruce NUG 1-2
Apndx8 PSCo Brighton-BarrLk NUG 1-2
Apndx8 PSCo Cabin Creek A
Apndx8 PSCo Cabin Creek B
Apndx8 PSCo Cherokee 1
Apndx8 PSCo Cherokee 2
Apndx8 PSCo Cherokee 3
Apndx8 PSCo Cherokee 4
Apndx3-RevReg8 PSCo FtLupton 1-2
VCG Reg 8 – PSCo RMEC NUG GTG1-2
VCG Reg 8 – PSCo RMEC NUG STG
VCG Reg 8 – PSCo TCTI QF GTGs 1-5
VCG Reg 8 – PSCo TCTI QF STGs 1-2
Apndx8 PSCo Valmont 5
Apndx8 PSCo Valmont 6
VCG Reg 8 – PSCo Valmont-BlkHills NUG GTGs 7-8
Apndx8 PSCo Zuni 1
Apndx8 PSCo Zuni 2
Appendx PSCo IPP Spindle Hill CTs
Appendx PSCo Ft. St. Vrain 5 & 6

Region 9: Western Wyoming:

VCG Reg9 - BHP PacifiCorp Wyodak
Apndx6 RevReg9 PacifiCorp DJ 1-2
Apndx6 RevReg9 PacifiCorp DJ 3
Apndx6 RevReg9 PacifiCorp DJ 4
VCG Reg9 – WAPA-USBR Boysen 1-2
VCG Reg9 – WAPA-USBR Boysen 1-2 UE-Reg
WAPA 1-9-02 Apndx6-RevReg9 – Boysen 1-2

VCG Reg9 – WAPA-USBR Buffalo Bill 1-2-3
WAPA 1-9-02 Apndx6-RevReg9 – Buffalo Bill 1-2-3
VCG Reg9 – WAPA-USBR Fontenelle Hydro Table
WAPA 1-9-02 Apndx6-RevReg9 – Heart Mountain 1
WAPA 1-9-02 Apndx6-RevReg9 – Pilot Butte 1-2
WAPA 1-9-02 Apndx6-RevReg9 – Shoshone WAPA N3
VCG Reg9 – WAPA-USBR Shoshone 3
WAPA 1-9-02 Apndx6-RevReg9 – Spirit Mountain 1
VCG Reg9 – WAPA-USBR Spirit Mtn
VCG Reg9 – WAPA-USBR Yellow Tail 1-4 OE-Reg
VCG Reg9 – WAPA-USBR Yellow Tail 1-4 UE-Reg

Region 10: N.E. Wyoming – S.W. South Dakota:

Reg 10 – Black Hills – Ben French Gen
Reg 10 – Black Hills – Lang CT – NSS CT1 CT2
Reg 10 – Black Hills – NSS 1
Reg 10 – Black Hills – NSS 2
Reg 10 – Black Hills – Osage 1-3
Reg 10 – Black Hills – Rapid City GCTs 1-4

Version	Date	Action	Change Tracking
1	**October 1994**	**Original document**	**New**
2	**12-8-03**	**VCGS review and update**	**Revise**
3	**7-17-06**	**VCGS review and update**	**Revise**
4	**12-9-09**	**VCGS review and update. Approved by CCPG at 12-9-09 meeting.**	**Revise**
5	**12-14-10**	**VCWG review and update. Approved by CCPG at 12-14-10 meeting.**	**Revise**