TRI-STATE
Generation and Transmission Association, Inc.
A Touchstone Energy® Cooperative

Document Control

Engineering Standards Bulletin

Preparation, Review, and Approval

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Engineering Standards Bulletin
Criteria for System Planning and Service Standards

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1.0 INTRODUCTION

This Engineering Standards Bulletin describes engineering methodologies and criteria to be used by Tri-State staff in bulk transmission system planning, in accordance with Tri-State Board of Director's policies and Tri-State's Engineering Design Standards. Criteria outlined in this document should guide planners in making engineering assessments of various generation, transmission, and load-serving alternatives.

Implementation of these standards is intended to ensure safe and reliable operation of Tri-State's portion of the interconnected transmission system, and result in a more secure Bulk Electric System (BES). The end goal is that current and future customer demands be served reliably with adequate system voltage and frequency performance.

These standards apply to steady-state conditions, including power quality issues of harmonics and voltage unbalance; and transient conditions after a fault is cleared. Ratings of Tri-State owned and operated transmission circuits are dependent upon the rating of the most limiting element within the equipment that comprises the circuit. When and where the system does not adhere to these standards, several solution methods will be considered to resolve the deficiency. Depending on the specific technical and economic considerations, system solutions may include no action, establishing operating procedures, remedial action schemes, or justifying a new transmission project.

These standards apply at all times to the Tri-State system, with noted and documented exceptions for black-start and other system restoration periods. It is intended that such exceptions will be explicitly described and documented in operating procedures and supportive studies.

These criteria and standards are established in accordance with standards ordered by the FERC; and developed by NERC and the Regional Reliability Organizations (RROs) with which Tri-State is associated, WECC and the MRO. The majority of Tri-State's Member systems are in the WECC reliability jurisdiction. Some Member systems in Nebraska, eastern Wyoming and northeastern Colorado are either exclusively or additionally in the MRO reliability jurisdiction. Both WECC and the MRO are members of NERC. These criteria were developed in accordance with Tri-State connection and design standards, Generator Interconnection Procedure (GIP), and Board of Director policies.

Other established electric utility industry standards and practices are used as guidelines to provide adequate reliability and service quality. See the Bibliography for more information. These standards are subject to change, as additional reliability practices develop and are adopted by FERC, NERC, WECC, MRO, and Tri-State.

2.0 <u>DISCLOSURE</u>

This bulletin includes facility rating methodologies which are in accordance with NERC Reliability Standard FAC-008-3.

Tri-State makes its Facility Ratings methodology available for inspection and technical review by those Reliability Coordinators, Transmission Operators, Transmission Planners and Planning Coordinators that have responsibility for the area in which the associated Facilities are located, within 21 calendar days of receipt of a request. If a Reliability Coordinator, Transmission Operator, Transmission Planner or Planning Coordinator provides documented comments on its technical review of Tri-State's Facility Ratings methodology, Tri-State will provide a response to that commenting entity within 45 calendar days of receipt of those comments. The response shall indicate whether a change will be made to the Facility Ratings methodology and, if no change will be made to that Facility Ratings methodology, the reason why.

Tri-State provides requested information as specified below (for its solely and jointly owned Facilities that are existing Facilities, new Facilities, modifications to existing Facilities and re-ratings of existing Facilities) to its associated Reliability Coordinator(s), Planning Coordinator(s), Transmission Planner(s), Transmission Owner(s) and Transmission Operator(s):

- As scheduled by the requesting entities:
    - Facility Ratings**.**
    - Identity of the most limiting equipment of the Facilities.

- Within 30 calendar days (or a later date if specified by the requester), for any requested Facility with a Thermal Rating that limits the use of Facilities under the requester's authority by causing any of the following: 1) An Interconnection Reliability Operating Limit, 2) A limitation of Total Transfer Capability, 3) An impediment to generator deliverability, or 4) An impediment to service to a major load center:
    - Identity of the existing next most limiting equipment of the Facility.
    - The Thermal Rating for the next most limiting equipment identified.

If and when Tri-State identifies any Planning SOL(s), whose process is described in Section 7.0, Tri-State shall provide them to its Planning Authority, Reliability Coordinators, Transmission Operators, and Transmission Service Providers that work within its Transmission Planning Area and to adjacent Transmission Planners in accordance with NERC FAC-014.

To ensure reliable systems are developed that meet specified performance requirements with sufficient lead time, and continue to be modified or upgraded as necessary to meet present and future system needs in accordance with NERC TPL standards, Tri-State annually assesses and documents its portion of the Bulk Electric System. Documentation of these reliability assessments shall be provided to the applicable RRO within 30 days, when requested.

3.0 RESPONSIBILITIES

The System Planning department will apply these standards for the typical planning horizon, which is generally from one to ten years.

For those maintenance plans that impact the planning horizon, System Operations will notify System Planning to allow the appropriate planning studies to be completed. Potential mitigating options may include load shedding plans, installation of temporary reactive devices, or other mitigating measures as appropriate. New system facilities are not anticipated to be useful to mitigate system issues created by maintenance plans because of the temporary nature of maintenance outages.

The Senior Manager of the Power System Planning Department at Tri-State Generation and Transmission Association, Inc. is responsible for assuring these standards are implemented.

4.0 LOAD SHEDDING

Tri-State will perform required studies, and seek to identify additional system conditions for which frequency or voltage mitigation measures are necessary.

Tri-State's Under Frequency Load Shedding (UFLS) is coordinated, system-wide, and complies with the WECC and MRO's Under-Frequency Load Shedding Programs (see Appendix G: Bibliography for links). Because of Tri-State's service area, Tri-State participates in three distinct UFLS programs. The first is in the MRO jurisdiction and the other two programs are both in WECC's jurisdiction which are; the "Coordinated Plan – Table 1a", and the "Southern Island Load Tripping sub-area Coordinated Plan – Table 1c" which are both defined in WECC's UFLS coordinated plan documentation.

Unacceptable voltages during normal and contingency conditions will be assessed in accordance with this document. Multiple contingency voltage issues may be addressed via automatic undervoltage load shedding protection systems (UVLS) and/or training of system operators to switch VAR devices and/or shed key loads, as permitted by NERC TPL standards criteria. Established UVLS must be modeled in applicable study work, including annual assessments. Also, upon request by Transmission Operations, Planning will review UVLS applicability.

5.0 <u>POWER FACTORS</u>

Tri-State plans the system to provide adequate voltage, as defined in Appendix A: Planning Criteria, for loads that operate at a minimum 0.95 power factor, either leading or lagging, at the point-of-interconnection. For loads that operate at a lower quality power factor during real-time operations, Tri-State will attempt to continue uninterrupted service. It is assumed that, if necessary, Tri-State Operations will take appropriate steps to maintain adequate system voltages. This includes switching nearby VAR devices or shedding an appropriate amount of load that is operating outside of acceptable power factor. Such load will be restored at the earliest opportunity, while maintaining adequate voltage levels.

6.0 <u>SYNCHRONIZING</u>

There exist no relevant techniques for studying synchronizing operations. It is primarily a real-time operating consideration. Planning may recommend switching sequence for system restoration based on power flow modeling.

Synch scopes are typically specified at key points in the transmission system to support black-start and restoration plans. Tri-State will participate in regional black-start and restoration studies and plan developments whenever such studies are required; and will recommend synch scopes locations to support the restoration plan.

7.0 <u>SYSTEM OPERATING LIMIT (SOL) AND INTERCONNECTION RELIABILITY OPERATING LIMITS (IROLS) METHODOLOGY</u>

7.1 INTRODUCTION

Tri-State is not a Planning Coordinator (PC), and is subordinate to PC's whose systems Tri-State's operating regions are within. As such, Tri-State will establish SOLs, including IROLs, for its transmission planning area in a manner consistent with its PC's SOL Methodology. If necessary, up to date SOL methodologies can be requested from the relevant PCs.

7.2 APPLICABILITY

This Methodology applies to SOLs in the planning horizon (1 to 10 years).

7.3 MEASURES

SOLs shall not exceed established Facility Ratings.

8.0 BES PERFORMANCE

BES performance must meet the criteria listed below for acceptable system performance during study simulations.

8.1 STEADY-STATE CRITERIA

A system is in a steady-state condition when all quantities exhibit only negligible change over long periods of time and no transients are present. A transmission system is usually in a steady-state condition and, after a disturbance, will settle into a new steady-state condition typically between 10 seconds and one minute. Steady-state system performance criteria are summarized in Appendix A. Steady-State conditions are modeled using powerflow modeling tools.

8.1.1 Operating Voltages

Acceptable operating voltages allow all loads, including machinery, lighting, and electronics, to operate as they were designed, without overloading and excessive loss-of-life. Tri-State's acceptable operating voltage criteria, which are in accordance with industry standard practices and standards, are summarized in Appendix A of this document.

8.1.1.1 Normal Conditions

Under normal system conditions, all transmission facilities are in service, with the exception of normally open transmission circuits. Acceptable steady-state transmission bus voltages will be between 0.95 and 1.05 per unit (p.u.) as shown in Table A 1 of Appendix A. Exceptions may be granted for high side buses of Load-Tap-Changing (LTC) transformers that violate this criterion, if the corresponding low side buses are well within the criterion.

Further, modeling results must demonstrate acceptable facility loading and stable voltages. All Facilities must be operating within their Facility Ratings and thermal, voltage, and stability limits.

8.1.1.2 Single Contingency Outage Conditions

Under single contingency outage (N-1) conditions, acceptable steady-state transmission bus operating voltages will be between 0.90 and 1.10 p.u. as shown on

Table A 1, Appendix A of this document. All system devices designed to regulate operating voltages are allowed to adjust in simulations to meet this criterion. Exceptions may be granted for high side buses of LTC transformers that violate this criterion, if the corresponding low side buses are well within the criterion.

Following the single contingency types P1 and P2 identified in Table A3, Appendix A of this document, system simulations must demonstrate transient, dynamic and voltage stability with all Facilities operating within their Facility Ratings.

8.1.1.3 Multiple Contingencies

Following the multiple contingency types P3, P4, P5, P6, and P7 identified in Table A3, Appendix A of this document, system simulations must demonstrate transient, dynamic and voltage stability with all Facilities operating within their Facility Ratings. System operating voltages will meet WECC performance criteria, summarized in Table A 3, of Appendix A. TSGT maintains a list of credible multiple contingencies. This list will change as the system changes.

8.1.1.4 System Adjustments

Tri-State allows system adjustments, to occur during single contingency outage simulations. This philosophy allows weaker rural systems to capture the advantages of installed LTC and switched VAR devices. This also prepares the system for the next contingency.

8.1.1.5 Post-Transient Voltage Deviation

Tri-State has set voltage deviation to be 8% across the entire system. This is summarized in Table A 2 of Appendix A.

8.1.1.6 Extended Outages

Known outages of generation facilities or transmission facilities of at least six month durations will be modeled as part of planning studies.

8.1.1.7 VAR Capability

The VAR consumption of loads is addressed in section 5.0. The VAR capability (power factor – pf) of generation facilities that interconnect with Tri-State's system are expected to be 0.95, leading and lagging, at a minimum, as monitored / measured at the main Point of Interconnection (POI). They are also expected to be in automatic voltage control so that the voltage schedule at the bus to which they are connected is met. If the system is unable to satisfy these standards in real-time operations or in planning cases, additional VAR capability will be added to the system. The additional VAR capability can and will include both dynamic and switched VAR devices, as necessary, to meet transient and steady state VAR requirements. Reactive Power & voltage regulation requirements for generation interconnections are included in Appendix A of this document.

8.1.1.8 Voltage, Reactive Power and Power Factor Control

System simulations should assume that Tri-State will have the ability to directly control, or order prompt reactive power adjustments with all generation facilities that interconnect to the Tri-State system. Such control will be made a part of an interconnection agreement with any generation.

8.1.2 Cascading

Cascading is uncontrolled successive loss of system elements triggered by an incident (or condition) at any location resulting in the interruption of widespread electric service that cannot be restrained from sequentially spreading beyond a predetermined area by studies. It is Tri-State's intent to operate the system such that cascading or uncontrolled separation does not occur - in all but the most catastrophic outage situations.

Cascading outages might conceivably result from the following initial conditions:

- Outages of major transfer path elements with high actual flows.
- Uncontrolled clearing of overloaded lines, causing overloads of other system elements.
- Failure or incorrect readings of line flow metering that "hide" overloads.
- Failure of load shedding relay schemes.

Modeling cascading outages requires knowledge of protective relay settings (relay loadability), load shedding schemes, and switching operations.

Extreme contingencies identified in Table A6, Appendix A of this document, that are expected to produce more severe system impact will be studied to determine potential cascading. If cascading is found to be caused by the occurrence of extreme events, an evaluation of possible actions designed to reduce the likelihood or mitigate the consequences of the event will be conducted.

8.1.3 Loading

Transmission lines and transformers require acceptable loading levels so they do not exceed thermal or relay loadability limits. Exceeding the thermal limit of transmission line conductor can cause the conductor to sag excessively and fail to meet the minimum clearances required by applicable safety codes. Exceeding the thermal limit of transformers or other facilities can reduce the useful life of the equipment. Exceeding the relay loadability limits could cause undesired tripping of transmission facilities.

Methods to establish transmission line static thermal ratings and transformer ratings are summarized in Appendix B.

When performing system studies, flows on Transmission Transfer Paths must be monitored to assure that total path flows are below the ratings identified in the WECC Path Rating Catalog. Details for assessing these paths are included in Appendix H: Transmission Transfer Capability Assessment.

8.1.3.1 Normal Conditions

Acceptable loading on any transmission line will not exceed 100% of its established continuous rating, as determined by the static thermal limits of that transmission line. Transmission line conductors exceeding 80% of their ratings will be closely monitored during the study process for potential remediation. This criterion is in recognition of the high losses, high voltage drop, and possible steady-state stability problems associated with a line loaded above 80% of its static thermal rating.

Other facilities such as transformers and terminal equipment, including circuit breakers, current transformers, circuit switchers, line disconnects, wave traps, line inductors, series capacitors, relays, and meters will be allowed to load to 100% of their continuous capabilities. These facilities do not create high losses, high voltage drops, or steady-state stability problems when heavily loaded, as do high voltage transmission lines.

8.1.3.2 Single or Multiple Contingency Outage Conditions

The maximum loading on any transmission line, transformer or terminal facility may not exceed 100% of its established continuous rating. If a short-term emergency rating has been established for a facility, it may be utilized in study simulations, but shall not be exceeded without remediation.

Use of the emergency ratings must be limited to their proper application. Typically, established short-term ratings are 15-minute duration for transmission lines and 30-minute duration for transformers. Short-term emergency ratings are established and documented in Appendix B and C.

8.1.4 <u>Voltage Collapse</u>

Voltage collapse usually is a concern in regions that import a large amount of power. Often the operating voltage criteria are sufficient to mitigate voltage collapse concerns. However, receiving regions with sufficient shunt VAR support can approach voltage collapse even though the system operating voltages in the receiving region are acceptable. These voltage collapse criteria are intended to mitigate the voltage collapse risks of such systems by establishing a margin from the point of collapse of that system. The point of collapse can be measured in MW of load within the receiving region or MW flow across an interface. The point of collapse can also be expressed in terms of reactive power margin in MVAR. These voltage collapse criteria will be assessed though a voltage stability study, utilizing a P-V or Q-V analysis.

P-V and Q-V analysis will be performed in accordance with the WECC reports titled, "Voltage Stability Criteria, Undervoltage Load Shedding Strategy, and Reactive Power Reserve Monitoring Methodology", dated May 1998,and "Guide to WECC/NERC Planning Standards I.D: Voltage Support and Reactive Power", dated March 2006.

8.1.5 RAS or Special Protection Schemes

A Remedial Action Schemes (RAS) or Special Protection Systems as defined by NERC, is an automatic protection system designed to detect abnormal or predetermined system conditions, and take corrective actions other than and/or in addition to the isolation of faulted components to maintain system reliability. Such action may include changes in demand, generation (MW and MVAR), or system configuration to maintain system stability, acceptable voltage, or acceptable power flow. A RAS does not include (a) underfrequency or undervoltage load shedding, (b) fault conditions that must be isolated, or (c) out-of-step relaying (not designed as an integral part of a RAS).

Established RAS must be modeled in applicable study work, including annual assessments. Also, upon request by Transmission Operations, Planning will review RAS applicability. For reference, a summary of existing RAS is included in Appendix F: RAS or Special Protection Schemes.

8.2 TRANSIENT CONDITIONS

Transient conditions exist during a transition from one steady-state condition to another. Transients may be caused by, for example, lightning strikes, faults, motor starting, and/or, switching shunt devices or circuit breakers. Although the duration of a transient condition depends on system characteristics, it typically will last between ten seconds and one minute.

8.2.1 Transient Stability

To mitigate any unstable generator unit operation, Tri-State will plan and design the system such that the clearing times of all primary and secondary protection systems are less than all critical clearing times for the system's most severe three-phase faults. The system must also demonstrate positive damping within a ten-second transient stability simulation of the most severe three-phase faults. These transient criteria apply after fault clearing. It is expected that generating facilities have no consequential impact on the ability of the bulk electric system to meet transient stability performance criteria. Table A4 in Appendix A is a summary of these transient stability performance criteria.

8.2.1.1 Single Contingency Disturbances

Positive damping must be demonstrated in a ten-second dynamic simulation. After the fault is cleared, transient voltages will not drop below pre- disturbance values more than 0.25 p.u. or drop more than 0.20 p.u. below pre-disturbance values for more than 20 cycles from pre-disturbance values anywhere on the system. System frequency will not drop below 59.6 hertz for more than 0.1 seconds.

8.2.1.2 Multiple Contingency Disturbances

Positive damping must be demonstrated in a ten-second dynamic simulation. After the fault is cleared, transient voltages will not drop below pre-disturbance values more than 0.30 p.u. or drop more than 0.20 p.u. below pre-disturbance values for more than 40 cycles anywhere on the system. If the disturbance is loss of a bus section, the acceptable duration of the transient voltage drops below 0.20 p.u. is limited to 20 cycles. System frequency will not drop below 59.0 hertz for more than 0.1 seconds or below 59.4 hertz for more than 0.1 seconds if the disturbance is loss of a bus section.

9.0 POWER QUALITY

Power quality impacts are not typically identifiable in power flow or dynamics studies. The cause of poor power quality must be identified before mitigation measures can be implemented. Therefore, inadequate power quality will be identified through real-time operations, and studied with appropriate fault study, harmonics or transients tools to identify mitigation options.

Poor power quality is typically an indication of the harmonic content in the system voltage and current, off-nominal voltages, or the degree to which the system is unbalanced between the phases. Poor power quality is not caused by power system disturbances or faults. Instead, it is usually caused by neighboring load, inverter systems and/or power electronics devices with improper levels of harmonic filtering equipment, or a misoperating device.

9.1 VOLTAGE FLICKER

This quantity describes the initial voltage drop experienced on the system when a large motor starts, or step-changes in voltage associated with switched devices such as shunt capacitor banks or reactors. Excessive voltage flicker can trip sensitive electronic equipment and cause general customer irritation. This criterion limits the magnitude of the voltage flicker and the starting frequency of large industrial motors. The maximum voltage flicker will not exceed 0.06 p.u. (6%) on a distribution bus voltage, or 0.03 p.u. (3%) on a transmission system bus.

Although this criterion is directed at motor starting, it will be used as an indication of acceptable switching operations at Tri-State facilities. Unacceptable switching transients will be investigated on a case-by-case basis, as necessary.

The allowable voltage flicker is summarized in Appendix D: Reactive Power & Voltage Regulation Requirements for Generation Interconnections

<u>Tri-State Generation and Transmission Assoc. (TP) –Reactive Power & Voltage Regulation Requirements for Generation Interconnections</u>

A. Tri-State's Steady State VAR, and Voltage Regulation Requirements: Note - while these generally make reference to wind generation facilities, they shall apply to all generation interconnections, PV solar plants may be exempt if the requirement is not feasible.

1) All interconnections are subject to detailed study and may require mitigation in excess of minimums imposed by published standards, according to the best judgement of Tri-State engineers. <u>The IC's Large Generating Facilities (LGF) shall be capable of either producing or absorbing reactive power (VAR) as measured at the HV POI bus at an equivalent 0.95 pf, across the range of near 0% to 100% of facility MW rating</u>, with the magnitude of VAR calculated on the basis of nominal POI voltage (1.0 p.u. V). This would be the net MVAR able to be either produced or absorbed by the IF facility, depending upon the voltage regulating conditions at the POI (see next item).

2) The POI voltage range where the IC's LGF may be required to produce VAR is from 0.90 p.u. V through 1.04 p.u. V. In this range the IC facilities are being utilized to help support or raise the POI bus voltage.

3) The POI voltage range where the IC's LGF may be required to absorb VAR is from 1.02 p.u. V through 1.10 p.u. V. In this range the IC facilities are being utilized to help reduce the POI bus voltage.

4) Note that the POI voltage range where the IC's LGF may be required to either produce VAR or absorb VAR is 1.02 p.u. V through 1.04 p.u. V, with the typical target regulating voltage being 1.03 p.u. V.

5) The IC's LGF may supply reactive power from the generators, from the generators' inverter systems alone (if capable), or a combination of the generators, generators' inverter systems plus switched capacitor banks and/or reactors, or continuously variable STATCOM or SVC type systems. The IC's LGF is required to supply a portion of the reactive power (VAR) in a continuously variable fashion, such as supplied from either the generators, the generators' inverter systems, or a STATCOM or SVC system. The amount of continuously variable VAR shall be a value equivalent to a minimum of 0.95 pf produced or absorbed <u>at the generator terminal Low Voltage (LV) bus</u>, across the full range (0 to 100%) of rated MW output. The remainder of VAR required to meet the 0.95 pf net criteria at the HV POI bus may be achieved with switched capacitors and reactors, so long as the resultant step-change voltage is no greater than 3% of the POI operating bus voltage. This step change voltage magnitude shall be initially calculated based upon the minimum system (N-1) short circuit POI bus MVA level as supplied by the TP.

6) Under conditions when the IC's LGF is not producing any real power (near 0 MW, and typically less than 2 MVAR), the reactive power exchange at the POI shall be

near 0 MVAR (“VAR neutral”). This condition assumes that the facility needs to remain energized to supply base-level station-service “house power” for the control facilities, maintain wind turbines on turning gear, etc., and that tripping open the IC transmission line supply is not a normal or acceptable means to create this VAR neutral condition. In this non-generating mode, the IC Facility appears as a transmission connected load customer, and therefore must meet TP's requirements for load pf, which requires that the load pf be 0.95 or better.

7) All interconnections are subject to additional detailed study, utilizing more complex models and software such as PSCAD, EMTP, or similar, and may require mitigation in excess of minimums imposed by published standards, according to the best judgement of the TP’s engineers.

B. Tri-State’s Dynamic VAR and Low Voltage Ride-Through Requirements (consistent with FERC Order 661-A):

Note - while these requirements generally make reference to wind generation facilities, they shall apply to all types of generation interconnections. PV solar plants may be exempt if the requirement is not feasible.

1) The IC’s LGF shall be able to meet the dynamic response Low Voltage Ride-Through (LVRT) requirements consistent with the latest WECC / NERC criteria. In particular, as per the Tri-State LGIP, Appendix H: Transmission Transfer Capability Assessment and FERC Order 661A for LVRT (applicable to Wind Generation Facilities).

2) Generating plants are required to remain in service during and after faults, three-phase or single line-to-ground (SLG) whichever is worse, with normal total clearing times in the range of approximately 4 to 9 cycles, SLG faults with delayed clearing, and subsequent post-fault voltage recovery to pre-fault voltage unless clearing the fault effectively disconnects the generator from the system. The clearing time requirement for a three-phase fault will be specific to the circuit breaker clearing times of the effected system to which the IC facilities are interconnecting. The maximum clearing time the generating plant shall be required to withstand for a fault shall be 9 cycles after which, if the fault remains following the location-specific normal clearing time for faults, the wind generating plant may disconnect from the transmission system. A wind generating plant shall remain interconnected during such a fault on the transmission system for a voltage level as low as zero volts, as measured at the Point of Interconnection (POI). To elaborate, before time 0.0, the voltage at the POI is the nominal voltage. At time 0.0, the voltage drops. The plant must stay online for at least 0.15 seconds regardless of voltage during the fault. Further, if the voltage returns to 90 percent of the nominal voltage within 3 seconds of the beginning of the voltage drop, the plant must continuously stay online. The Interconnection Customer may not disable low voltage ride-through equipment while the wind plant is in operation.

3) This requirement does not apply to faults that would occur between the generator terminals and the POI.

4) Generating plants may be tripped after the fault period if this action is intended as part of a special protection system.

5) Wind generating plants may meet the LVRT requirements of this standard by the performance of the generators or by installing additional equipment (e.g., Static VAR Compensator) within the wind generating plant or by a combination of generator performance and additional equipment.

Appendix .

9.2 HARMONICS

The allowable harmonic voltage content at a Tri-State bus caused by a harmonic current producing load on the Tri-State or a Member system is described in IEEE Standard 519-1992 “IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems”.

9.3 VOLTAGE UNBALANCE

The acceptable amount of voltage unbalance will be in accordance with ANSI C84.1. The goal is to limit the maximum steady-state voltage unbalance to 3 percent. Voltage unbalance will be measured at the customer’s service entrance with all loads disconnected.

The customer’s load may affect voltage measurements because of 3-phase load and power factor unbalance. Since it is not always practical to require the customer to disconnect all load, Tri-State may take measurements by measuring individual phase loads and power factors and calculating their effect on measurements taken without disconnecting the load.

When a customer’s three-phase service voltage is found to have an unbalance greater than 3 percent, Tri-State will act to reduce the unbalance and bring it within these limits within a reasonable length of time.

Percent Voltage Unbalance will be calculated as follows:

$$Percent\ Voltage\ Unbalance = 100\ X\ \frac{Maximum\ \ Voltage\ Deviation\ from\ Average\ Voltage}{Average\ Voltage}$$

10.0 <u>TRANSFORMER EFFICIENCY</u>

Transformer efficiency is a fundamental parameter for purchasing and evaluating power transformers. The following methodology follows the format of transformer efficiency standards issued by the US Department of Energy in 10 CFR Part 431, Energy Conservation Program for Commercial Equipment: Distribution Transformers Energy Conservation Standards dated October 12, 2007.

10.1 DETERMINATION

Transformer efficiency is to be determined at the base rating by the following formula:

$$\text{Xfmr Eff.} = \frac{\text{Base Rating MVA}}{\text{Base Rating MVA + NLL+LL}} * 100$$

where Xfmr Eff = transformer efficiency expressed as a percentage
NLL = no load losses
LL = load losses

10.2 MINIMUM TRANSFORMER EFFICIENCY

The minimum transformer efficiency for new HV and EHV transformers are indicated in Table 1 below. The appropriate efficiency should be used in specifying the purchase of a new transformer. Actual transformer efficiency should be verified by test data. These minimum efficiencies do not apply to existing units in the Tri-State transformer fleet.

Table 1 efficiency values are at 50 percent of nameplate rated load, using base MVA. MVA ratings in Table 1 are for a Delta-Wye, Wye-Wye, or auto-trans formers with voltage ratio (HV/LV) of greater than 3.

Procedure to determine efficiency requirements for an auto-transformer with voltage ratio of less than or equal to 3 is as follows:

1. Co-ratio = 1-(LV/HV)

2. MVA rating used from chart = (Base MVA rating)/co-ratio

Example:

115kV-69kV, 30/40/50 MVA autotransformer

Co-ratio = 1 - (69kV/115kV) = 0.4

MVA rating used from chart = 30MVA/0.4 = 75 MVA, therefore an efficiency rating of 99.74% is required.

Table 1 Minimum Transformer Efficiency

SINGLE-PHASE		THREE-PHASE	
MVA	Efficiency %	MVA	Efficiency %
1	99.53	3	99.53
1.667	99.55	5	99.55
2.5	99.56	7.5	99.56
3.33	99.58	10	99.58
4	99.60	12	99.60
5	99.62	15	99.62
6.66	99.64	20	99.64
8.33	99.66	25	99.66
10	99.68	30	99.68
15	99.70	45	99.70
20	99.72	60	99.72
25	99.74	75	99.74
33.3	99.76	100	99.76
50	99.77	150	99.77
66.67	99.78	200	99.78
83.3	99.80	250	99.80
100	99.82	300	99.82
133.3	99.83	400	99.83
150	99.84	450	99.84
166.7	99.84	500	99.84
200	99.86	600	99.86
250	99.90	750	99.90

Notes:

- Transformers with MVA ratings not appearing in the table shall have their minimum efficiency level determined by linear interpolation of the MVA and efficiency values immediately above and below that MVA rating.
- Since "power class" transformer can have additional ratings such as 55/65° C Rise or Forced Cooled ratings, all efficiency values to be at:
  - No Load Losses @ 100% rated voltage, corrected to a temperature of 20°C
  - Load Losses @ the lowest nameplate rated MVA, corrected to a temperature of 75°C
  - Determined according to the DOE Test-Procedure. 10 CFR Part 431, Subpart K, Appendix A.

10.3 TRANSFORMER LOSS EVALUATION

New transformer purchases should be evaluated using estimated losses provided by the manufacturer, applying appropriate loss values. The estimated losses should be verified with acceptance test data for each transformer delivered to Tri-State. Any losses higher than represented in the manufacturers estimate should be addressed according to the purchase contract requirements. Loss evaluation values are as follows:

No Load Losses	=	$ 2,976 per kW
Load Losses	=	$ 1,819 per kW
Aux Losses	=	$ 1,939 per kW
(For banks with 55C rating up to 45 MVA)		
Aux Losses	=	$ 6759 per kW
(For banks with 55C rating up to 450 MVA)		

Note: These loss evaluation values are subject to change and the values should be verified prior to transformer purchase specifications.

11.0 DATA PREPARATION PROCEDURE FOR STEADY-STATE, SHORT CIRCUIT, AND DYNAMICS MODELING AND SIMULATION DATA

11.1 INTRODUCTION

These procedures set forth the practices implemented by Tri-State Generation and Transmission Association (TSGT) to comply with North American Electric Reliability Corporation (NERC) standards MOD-010-0 and MOD-012-0 and MOD-032-1, R1.[1] These procedures are in conformance with the WECC Data Preparation Manual for Power Flow Base Cases and Dynamic Stability Data as well as the data requirements and reporting procedures defined in Reliability Standards MOD-011-0, R1 and MOD-013-0, R1

11.2 STEADY STATE AND SHORT CIRCUIT DATA FOR TRANSMISSION SYSTEM MODELING AND SIMULATION

TSGT shall provide equipment characteristics, system data, and Interchange Schedules for steady-state and short circuit modeling and simulation to WECC and NERC as specified in Standard MOD-010-0, R1 and MOD-010-0, R2, and MOD-032-1, R1 and as specifically set forth in the WECC Data Preparation Manual for Power Flow Base Cases and Dynamic Stability Data (see Appendix G: Bibliography for link).

Within TSGT, Power System Planning is responsible for preparing data as required by NERC and WECC Reliability Standards. TSGT assigns responsibility to a planning

[1]NERC standard MOD-032-1 Requirement 1 (R1), is effective on July 1st, 2015. MOD-032-1 is a consolidation and replacement for MOD-010-0, MOD-011-0, MOD-012-0, MOD-013-1, MOD-014-0 and MOD-015-0.1. MOD-032-1 will completely replace these standards on July 1, 2016 when MOD-032-1 R2, R3 and R4 become effective.

engineer to prepare and submit the data as required. The assigned planning engineer shall provide this modeling and simulation data to WECC[2] in accordance with the schedule and procedures established by WECC in its annual Data Bank Compilation Schedule – Attachments 2 through 4. The TSGT planning engineer shall also provide this data to NERC, and those entities specified within Reliability Standard MOD-011-0, R1 according to a reporting schedule established by these entities. If no schedule exists, then TSGT will provide the data on request (30 calendar days).

11.3 DYNAMICS DATA FOR MODELING AND SIMULATION OF THE INTERCONNECTED TRANSMISSION SYSTEM

TSGT shall provide appropriate equipment characteristics and system data in compliance with the WECC dynamics system modeling and simulation data requirements and reporting procedures as defined in Reliability Standard MOD-013-1, R1 and as specifically set forth in the WECC Data Preparation Procedural Manual for Power Flow and Stability Studies (see Appendix G: Bibliography for link).

Within TSGT, Power System Planning is responsible for preparing dynamics data as required by NERC and WECC standards. TSGT assigns responsibility to a planning engineer to prepare and submit the data as required. The assigned planning engineer shall provide this dynamics modeling and simulation data to WECC[3] in accordance with the schedule and procedures established by WECC. The TSGT planning engineer shall also provide this data to NERC, and those entities specified within Reliability Standard MOD-013-1, R1 and MOD-032-1 R1 according to a reporting schedule established by these entities. If no schedule exists, then TSGT will provide the data on request (30 calendar days).

[2] TSGT submits its steady-state data to the WECC data collection Area Coordinator for TSGT, who in turn submits the data directly to WECC.
[3] TSGT submits its dynamics data directly to the WECC dynamic data collector.

APPENDIX A: PLANNING CRITERIA

Table A 1

Summary of Tri-State Steady-State Planning Criteria

System Condition	Operating Voltages [1] (per unit)		Maximum Loading [2] (Percent of Continuous Rating)	
	Maximum	Minimum	Transmission Lines	Other Facilities
Normal	1.05	0.95	80/100	100
N – k	1.10	0.90	100	100

(1) Exceptions may be granted for high side buses of Load-Tap-Changing (LTC) transformers that violate this criterion, if the corresponding low side busses are well within the criterion.

(2) The continuous rating is synonymous with the static thermal rating. Facilities exceeding 80% criteria will be flagged for close scrutiny. By no means, shall the 100% rating be exceeded without regard in planning studies.

Table A 2

Tri-State Voltage Criteria		
Conditions	**Operating Voltages**	**Delta-V**
Normal (P0 event)	0.95 - 1.05	
Contingency (P1 event)	0.90 - 1.10	8%
Contingency (P2-P7 event)	0.90 - 1.10	-

Table A 3

Steady State & Stability Performance Planning Events

Steady State & Stability:

- a. The System shall remain stable. Cascading and uncontrolled islanding shall not occur.
- b. Consequential Load Loss as well as generation loss is acceptable as a consequence of any event excluding P0.
- c. Simulate the removal of all elements that Protection Systems and other controls are expected to automatically disconnect for each event.
- d. Simulate Normal Clearing unless otherwise specified.
- e. Planned System adjustments such as Transmission configuration changes and re-dispatch of generation are allowed if such adjustments are executable within the time duration applicable to the Facility Ratings.

Steady State Only:

- f. Applicable Facility Ratings shall not be exceeded.
- g. System steady state voltages and post-Contingency voltage deviations shall be within acceptable limits as established by the Planning Coordinator and the Transmission Planner.
- h. Planning event P0 is applicable to steady state only.
- i. The response of voltage sensitive Load that is disconnected from the System by end-user equipment associated with an event shall not be used to meet steady state performance requirements.

Stability Only:

- j. Transient voltage response shall be within acceptable limits established by the Planning Coordinator and the Transmission Planner.

Category	Initial Condition	Event[1]	Fault Type[2]	BES Level[3]	Interruption of Firm Transmission Service Allowed[4]	Non-Consequential Load Loss Allowed
P0 No Contingency	Normal System	None	N/A	EHV, HV	No	No
P1 Single Contingency	Normal System	Loss of one of the following: 1. Generator 2. Transmission Circuit 3. Transformer[5] 4. Shunt Device[6]	3Ø	EHV, HV	No[9]	No[12]
		5. Single pole of a DC line	SLG			
P2 Single Contingency	Normal System	1. Opening of a line section w/o a fault[7]	N/A	EHV, HV	No[9]	No[12]
		2. Bus Section Fault	SLG	EHV	No[9]	No
				HV	Yes	Yes
		3. Internal Breaker Fault (non-Bus-tie Breaker)[8]	SLG	EHV	No[9]	No
				HV	Yes	Yes
		4. Internal Breaker Fault (Bus-	SLG	EHV,	Yes	Yes

		tie Breaker)[8]		HV		
P3 Multiple Contingency	Loss of generator unit followed by System adjustments[9]	Loss of one of the following: 1. Generator 2. Transmission Circuit 3. Transformer[5] 4. Shunt Device[6]	3Ø	EHV, HV	No[9]	No[12]
		5. Single pole of a DC line	SLG			
P4 Multiple Contingency *(Fault plus stuck breaker[10])*	Normal System	Loss of multiple elements caused by a stuck breaker[10] (non-Bus-tie Breaker) attempting to clear a Fault on one of the following: 1. Generator 2. Transmission Circuit 3. Transformer[5] 4. Shunt Device[6] 5. Bus Section	SLG	EHV	No[9]	No
				HV	Yes	Yes
		6. Loss of multiple elements caused by a stuck breaker[10] (Bus-tie Breaker) attempting to clear a Fault on the associated bus	SLG	EHV, HV	Yes	Yes
P5 Multiple Contingency *(Fault plus relay failure to operate)*	Normal System	Delayed Fault Clearing due to the failure of a non-redundant relay[13] protecting the Faulted element to operate as designed, for one of the following: 1. Generator 2. Transmission Circuit 3. Transformer[5] 4. Shunt Device[6] 5. Bus Section	SLG	EHV	No[9]	No
				HV	Yes	Yes
P6 Multiple Contingency *(Two overlapping singles)*	Loss of one of the following followed by System adjustments[9]. 1. Transmission Circuit 2. Transformer[5] 3. Shunt Device[6] 4. Single pole of a DC line	Loss of one of the following: 1. Transmission Circuit 2. Transformer[5] 3. Shunt Device[6]	3Ø	EHV, HV	Yes	Yes
		4. Single pole of a DC line	SLG	EHV, HV	Yes	Yes
P7 Multiple Contingency *(Common Structure)*	Normal System	The loss of: 1. Any two adjacent (vertically or horizontally) circuits on common structure[11] 2. Loss of a bipolar DC line	SLG	EHV, HV	Yes	Yes

Basic WECC Dynamic Criteria:

Tri-State's dynamic reactive power and voltage control / regulation criteria are in accordance with the NERC/WECC dynamic performance criteria and are as follows:

- Transient stability voltage response at applicable BES buses should recover to 80 percent of pre-contingency voltage within 10 seconds of the initiating event.
- Oscillations should show positive damping within a 30-second time frame.

Table A 4

Table 1

WSCC VOLTAGE STABILITY CRITERIA(*)

Performance Level	Disturbance (1)(2)(3)(4) Initiated By: Fault or No Fault DC Disturbance	MW Margin (P-V Method) (5)(6)(7)	MVAR Margin (V-Q Method) (6)(7)
A	Any element such as: One Generator One Circuit One Transformer One Reactive Power Source One DC Monopole	$\geq$ 5%	Worst Case Scenario (8)
B	Bus Section	$\geq$ 2.5%	50% of Margin Requirement in Level A
C	Any combination of two elements such as: A Line and a Generator A Line and a Reactive Power Source Two Generators Two Circuits Two Transformers Two Reactive Power Sources DC Bipole	$\geq$ 2.5%	50% of Margin Requirement in Level A
D	Any combination of three or more elements such as: Three or More Circuits on ROW Entire Substation Entire Plant Including Switchyard	> 0	> 0

(1) This table applies equally to the system with all elements in service and the system with one element removed and the system readjusted (see Section 2.2).

(2) For application of this criteria within a member system, controlled load shedding is allowed to meet Performance Level A (see Section 2.2 for a description of provisions for application of this criteria within a member system).

(3) The list of element outages in each Performance Level is not intended to be different than the Disturbance Performance Table in the WECC Reliability Criteria. Additional element outages have been added to this table to show more examples of contingencies. Determination of credibility for contingencies for each Performance Level is based on the definitions used in the existing WECC Reliability Criteria.

(4) Margin for N-0 (base case) conditions must be greater than the margin for Performance Level A.

(5) Maximum operating point on the P axis must have a MW margin equal to or greater than the values in this table as measured from the nose point of the P-V curve for each Performance Level.

(6) Post-transient analysis techniques shall be utilized in applying the criteria.

(7) Each member system should consider, as appropriate, the uncertainties in Section 2.3 to determine the required margin for its system.

(8) The most reactive deficient bus must have adequate reactive power margin for the worst single contingency to satisfy either of the following conditions, whichever is worse: (i) a 5% increase beyond maximum forecasted loads or (ii) a 5% increase beyond maximum allowable interface flows. The worst single contingency is the one that causes the largest decrease in the reactive power margin.

(*) Table 1 is an excerpt from the WSCC Reliability Criteria for Transmission System Planning in effect at the time of this document's approval. The most current version of the Council's Table of Allowable Effects on Other Systems should be referred to when conducting studies.

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Table A 5

<table>
<tr><th colspan="2">Table A 6 – Steady State & Stability Performance Extreme Events</th></tr>
<tr><td colspan="2">Steady State & Stability
For all extreme events evaluated:
a. Simulate the removal of all elements that Protection Systems and automatic controls are expected to disconnect for each Contingency.
b. Simulate Normal Clearing unless otherwise specified.</td></tr>
<tr><td>Steady State
1. Loss of a single generator, Transmission Circuit, single pole of a DC Line, shunt device, or transformer forced out of service followed by another single generator, Transmission Circuit, single pole of a different DC Line, shunt device, or transformer forced out of service prior to System adjustments.

2. Local area events affecting the Transmission System such as:
a. Loss of a tower line with three or more circuits.[11]
b. Loss of all Transmission lines on a common Right-of Way[11].
c. Loss of a switching station or substation (loss of one voltage level plus transformers).
d. Loss of all generating units at a generating station.
e. Loss of a large Load or major Load center.

3. Wide area events affecting the Transmission System based on System topology such as:
a. Loss of two generating stations resulting from conditions such as:
i. Loss of a large gas pipeline into a region or multiple regions that have significant gas-fired generation.
ii. Loss of the use of a large body of water as the cooling source for generation.
iii. Wildfires.
iv. Severe weather, e.g., hurricanes, tornadoes, etc.
v. A successful cyber attack.
vi. Shutdown of a nuclear power plant(s) and related facilities for a day or more for common causes such as problems with similarly designed plants.
b. Other events based upon operating experience that may result in wide area disturbances.</td><td>Stability

1. With an initial condition of a single generator, Transmission circuit, single pole of a DC line, shunt device, or transformer forced out of service, apply a 3Ø fault on another single generator, Transmission circuit, single pole of a different DC line, shunt device, or transformer prior to System adjustments.

2. Local or wide area events affecting the Transmission System such as:
a. 3Ø fault on generator with stuck breaker[10] or a relay failure[13] resulting in Delayed Fault Clearing.
b. 3Ø fault on Transmission circuit with stuck breaker[10] or a relay failure[13] resulting in Delayed Fault Clearing.
c. 3Ø fault on transformer with stuck breaker[10] or a relay failure[13] resulting in Delayed Fault Clearing.
d. 3Ø fault on bus section with stuck breaker[10] or a relay failure[13] resulting in Delayed Fault Clearing.
e. 3Ø internal breaker fault.
f. f. Other events based upon operating experience, such as consideration of initiating events that experience suggests may result in wide area disturbances</td></tr>
</table>

Table A6 – Steady State & Stability Performance Footnotes
(Planning Events and Extreme Events)

1. If the event analyzed involves BES elements at multiple System voltage levels, the lowest System voltage level of the element(s) removed for the analyzed event determines the stated performance criteria regarding allowances for interruptions of Firm Transmission Service and Non-Consequential Load Loss.

2. Unless specified otherwise, simulate Normal Clearing of faults. Single line to ground (SLG) or three-phase (3Ø) are the fault types that must be evaluated in Stability simulations for the event described. A 3Ø or a double line to ground fault study indicating the criteria are being met is sufficient evidence that a SLG condition would also meet the criteria.

3. Bulk Electric System (BES) level references include extra-high voltage (EHV) Facilities defined as greater than 300kV and high voltage (HV) Facilities defined as the 300kV and lower voltage Systems. The designation of EHV and HV is used to distinguish between stated performance criteria allowances for interruption of Firm Transmission Service and Non-Consequential Load Loss.

4. Curtailment of Conditional Firm Transmission Service is allowed when the conditions and/or events being studied formed the basis for the Conditional Firm Transmission Service.

5. For non-generator step up transformer outage events, the reference voltage, as used in footnote 1, applies to the low-side winding (excluding tertiary windings). For generator and Generator Step Up transformer outage events, the reference voltage applies to the BES connected voltage (high-side of the Generator Step Up transformer). Requirements which are applicable to transformers also apply to variable frequency transformers and phase shifting transformers.

6. Requirements which are applicable to shunt devices also apply to FACTS devices that are connected to ground.

7. Opening one end of a line section without a fault on a normally networked Transmission circuit such that the line is possibly serving Load radial from a single source point.

8. An internal breaker fault means a breaker failing internally, thus creating a System fault which must be cleared by protection on both sides of the breaker.

9. An objective of the planning process should be to minimize the likelihood and magnitude of interruption of Firm Transmission Service following Contingency events. Curtailment of Firm Transmission Service is allowed both as a System adjustment (as identified in the column entitled 'Initial Condition') and a corrective action when achieved through the appropriate re-dispatch of resources obligated to re-dispatch, where it can be demonstrated that Facilities, internal and external to the Transmission Planner's planning region, remain within applicable Facility Ratings and the re-dispatch does not result in any Non- Consequential Load Loss. Where limited options for re-dispatch exist, sensitivities associated with the availability of those resources should be considered.

10. A stuck breaker means that for a gang-operated breaker, all three phases of the breaker have remained closed. For an independent pole operated (IPO) or an independent pole tripping (IPT) breaker, only one pole is assumed to remain closed. A stuck breaker results in Delayed Fault Clearing.

11. Excludes circuits that share a common structure (Planning event P7, Extreme event steady state 2a) or common Right-of-Way (Extreme event, steady state 2b) for 1 mile or less.

12. An objective of the planning process is to minimize the likelihood and magnitude of Non-Consequential Load Loss following planning events. In limited circumstances, Non-Consequential Load Loss may be needed throughout the planning horizon to ensure that BES performance requirements are met. However, when Non-Consequential Load Loss

is utilized under footnote 12 within the Near-Term Transmission Planning Horizon to address BES performance requirements, such interruption is limited to circumstances where the Non-Consequential Load Loss meets the conditions shown in Attachment 1. In no case can the planned Non-Consequential Load Loss under footnote 12 exceed 75 MW for US registered entities. The amount of planned Non- Consequential Load Loss for a non-US Registered Entity should be implemented in a manner that is consistent with, or under the direction of, the applicable governmental authority or its agency in the non-US jurisdiction.

13. Applies to the following relay functions or types: pilot (#85), distance (#21), differential (#87), current (#50, 51, and 67), voltage (#27 & 59), directional (#32, & 67), and tripping (#86, & 94).

APPENDIX B: EQUIPMENT RATING METHODOLOGIES

Major BES Equipment Rating Methodologies

Power system facilities are the circuitry between the nodes of the network. The most common facilities are transmission lines, transformers, generators and VAR devices. **Tri-State's facility ratings equal the most limiting applicable Equipment Rating of the individual equipment associated with that Facility and will consider manufacturer ratings, design criteria, ambient conditions, operating limitations, and/or other applicable assumptions when calculated**.

Generators

Tri-State's Transmission function utilizes the generator ratings provided by the merchant function. Nameplate capability is utilized unless superseded by actual test data. Performance tests are performed periodically to confirm VAR capability and dynamic characteristics.

Overhead Conductors

Tri-State's conductor rating methodology is based on a detailed statistical analysis of historical mean hourly weather data across the Tri-State service territory. Tri-State uses Electric Power Research Institute (EPRI) developed software, StatRat, to perform the analysis.

The conductor ratings apply to the entire line, including the last span of the line entering the substation. Static thermal ratings of conductors at standard design temperatures and overload percentages utilized by Tri-State are summarized in Appendix C: Equipment Thermal and Emergency Ratings. Static thermal ratings of transmission lines which are designed to a non-standard temperature will be calculated on a case-by-case basis using the methods described in IEEE Standard 738-1993.

The regional conductor rating methodology utilizes five fundamental weather regions in establishing conductor ratings. The regions are described as follows:

- **Region 1** – North and Central Wyoming
- **Region 2** – South Eastern Wyoming; Western Nebraska; North Eastern Colorado
- **Region 3** – Western Colorado; North Western New Mexico
- **Region 4** – Eastern Colorado; North Eastern New Mexico
- **Region 5** – Central and Southern New Mexico

A map detailing the regional boundaries across Tri-State's system can be found in Tri-State's Geographic Information System (GIS). Any transmission line routed through two or more regions will be rated using the lowest conductor rating listed for its associated regions.

Tri-State's conductor ratings are calculated using Typical Meteorological Year (TMY3) data. TMY3 data for the following weather stations were averaged together in determining the regional ratings:

- **Region 1** – Casper, WY; Cody, WY; Lander, WY; Riverton, WY
- **Region 2** – Akron, CO; Denver International Airport, CO; Fort Collins, CO; Golden, CO; Greeley, CO; Scottsbluff, NE; Cheyenne, WY; Laramie, WY, Rawlins, WY
- **Region 3** – Alamosa, CO; Cortez, CO; Durango, CO; Grand Junction, CO; Hayden, CO; Leadville, CO; Montrose, CO; Farmington, NM; Taos, NM

- **Region 4** – Colorado Springs, CO; La Junta, CO; Lamar, CO; Limon, CO; Pueblo, CO; Trinidad, CO; Goodland, KS; Clayton, NM
- **Region 5** – Albuquerque, NM; Deming, NM; Holloman Air Force Base, NM; Las Cruces, NM; Las Vegas, NM; Santa Fe, NM; Sierra Blanca, NM; Truth or Consequences, NM; Tucumcari, NM, El Paso, TX

The following assumptions[4] were used in calculation of conductor ratings:

Emissivity	0.7
Absorption	0.9
Wind Angle	45°
Wind Speed (ft/s)	**Day time**: 4 ft/s unless TMY3 weather data is larger **Night Time**: 2 ft/s unless TMY3 weather data is larger

For each conductor type in service at Tri-State, an hourly capacity is determined for each of the hourly weather observations following IEEE 738-1993, establishing a complete picture of the weather and its effects on conductor ratings. This extensive rating data for a given conductor is then sorted from lowest to highest, and the static thermal rating for that conductor is set at the first percentile based on the sorted data. This is also the point at which the local weather can be expected to support the established static thermal conductor rating 99% of the time. The first percentile rating is used as a year around static thermal rating for each conductor.

To calculate a year around 15-minute and 30-minute emergency ratings, a normalized overload percentage is calculated using Southwire's SWRate software v3.02 assuming the following:

Emissivity	0.7
Absorption	0.9
Wind Speed	4 ft/sec
Wind Angle	45°
Ambient Temperature	40°C
Frequency	60 Hz
Altitude	5000 ft
N. Latitude	38 degrees
Line Azimuth	0 degrees
Local Time	12 – noon
Solar Day	July 15th
Max Conductor Temperature	100°C
Pre-disturbance Loading	80%

The normalized overload percentage for 15 minutes and 30 minutes is applied to the first percentile rating to determine the year around emergency ratings. Tri-State does not normally establish seasonal emergency ratings. If they are deemed necessary, however, they will be determined on a case by case basis.

[4] Assumptions based on research documented in the Tri-State report, "Statistically Determined Static Thermal Ratings of Overhead High Voltage Transmission Lines in the Rocky Mountain Region" dated April 1998, and the Electric Power Research Institute (EPRI) report, "Determination of Static Conductor Thermal Rating using Statistic Analysis in the Rocky Mountain and Desert Southwest Area" dated June 2007.

Transformer Ratings

Transformer ratings are determined by the nameplate ratings based on maximum cooling. If available, the rating with a 65°C oil temperature rise will be used, otherwise, the 55°C oil temperature rise will be used. Summer ambient temperatures will be presumed, unless a winter rating is necessary. The Rated Operating Temperature for Power Transformers at TSGT is 85ºC (55ºC Rise over a 30ºC Ambient) or 95 ºC for 65 ºC rated transformers which is limited by the coil insulation. The outdoor ambient temperature is a 24-hour average temperature as specified by ANSI C57.12.00 – 2006 "IEEE Standard for Standard General Requirements For Liquid-Immersed Distribution, Power, and Regulating Transformers". Thirty minute and four-hour short-term Emergency Ratings for large power transformers shall be determined using guidance found in ABB Electrical Transmission and Distribution Reference Book, Fifth Edition, Copyright 1997, Table 9 in Chapter 5,"Permissible Daily Short-Time Transformer Ratings Based on Normal Life Expectancy. A pre-emergency loading of 70% of maximum nameplate is used to conservatively account for various ages of equipment and variety of operating conditions on the Tri-State system. This reference recommends a thirty-minute short-term emergency rating of 146% of maximum nameplate rating, and a four-hour short-term emergency rating of 110% of the maximum nameplate rating. Tri-State chooses to take a more conservative approach and uses the following emergency limits:

- 30-minute short-term emergency rating – 125% of maximum nameplate rating
- 4 hour short-term emergency rating – 110% of maximum nameplate rating

Transformers that have compromised cooling systems or show accelerated aging using dissolved gas analysis shall be handled, if necessary, on a case-by-case basis.

Relay Protective Devices

There are two basic types of relay protective devices that can limit loading and the methodology for their ratings is slightly different.

Impedance type relay load limits are based on the value of the pickup of their most sensitive phase impedance element for a given load power factor. Typically, a load power factor angle of 30 degrees (0.87 pf) at .85 p.u. voltage will be assumed, as required in NERC Reliability Standard PRC-023-2. Special cases, however, may necessitate using a different loading criterion. In these cases, the loading criteria will be based on special studies. In non-radial systems, there will likely be a relay at each terminal of the line affecting relay loadability. In these cases, the most limiting relay element of the two will be used.

Phase overcurrent relay load limits will be based on the pickup value of their most limiting phase overcurrent element, independent of the load power factor.

Tri-State will also specify relays with a minimum 10-Ampere continuous capability, so that the relaying equipment can withstand the full capability of its associated current transformer, at a minimum. Emergency Ratings for relay protective device settings will be identical to the Normal ratings.

Circuit Breaker Ratings

Circuit Breakers will be rated according to the manufacturer's nameplate ampacity at the nominal applied voltage which defines guaranteed minimum capacities under Usual Service Conditions as specified in ANSI C37.04-1999. This rating is a continuous 24-hour rating. Bushing-mounted current transformers that are supplied power circuit breakers will be rated according to the corresponding unit's nameplate in accordance with IEEE C57.13-2008 Section 6.6.3 and C37.06-2000, respectively.

The ratings of the connectors will be assumed identical to the nameplate ratings of the devices to which they are fitted, and will not be separately calculated. Continuous current ratings for connectors used to terminate conductors to bushings and other conductors will be rated the same as the conductor per ANSI C119.4, and will not be separately calculated. For facilities that terminate in a multiple breaker arrangement, such as in a ring bus, breaker-and-a-half, or double-breaker-double-bus configuration, the rating of the lowest rated circuit breaker associated with the circuit will be used. This will allow maintenance to occur on one of the breakers without re-rating the facility during maintenance.

Short-term emergency ratings shall be determined using the guidance provided by IEEE Standard C37.010-1999 "Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis" Section 5.4.4.4.2, and Table 5b, respectively. Assuming the 40°C ambient and pre-load of 100% of nameplate rated current, the Emergency Rating for 30-minute duration is 119% and for four-hour duration is 112%. Circuit Breakers that have bushings or internal CTs that are non-standard or have an observed tendency to run hotter than the device tank shall have emergency ratings determined on a case-by-case basis, using provisions in the above standards documents.

Current Transformer Ratings

Outdoor Current Transformer ratings will be determined by manufacturer provided information, such as the nameplate, by the setting of the device, and by other technical documents as detailed below. Bushing-mounted current transformers that are supplied with power transformers and power circuit breakers will be rated, for both normal and short-time emergency ratings, according to the corresponding unit's nameplate and applicable standard in accordance with IEEE C57.13-2008 Section 6.6.3 and C37.06-2000, respectively. Tri-State's outdoor current transformers follow the industry standard that includes nominal five-Ampere secondary windings. A thermal rating factor will be applied to determine if the current transformer is capable of more than 5.0 Amperes continuously in the secondary winding. The thermal rating factor is provided by the manufacturer on the nameplate per C57.13-2008 Section 6.8. If a thermal rating factor is not available due to incomplete manufacturer documentation provided by the manufacturer, a thermal rating factor may be developed based on a Westinghouse "Memorandum on Thermal Current Characteristics of Current Transformers used with Power Circuit Breakers and Power Transformers" dated June 26, 1969. Both of these values reflect to the primary winding of the current transformer, establishing a high side rating for the device.

Mathematically, a current transformer rating is determined as follows:

Primary Winding Rating = CT Primary Setting * CT Thermal Rating Factor (TRF)

where TRF is the product, not normally exceeding 2.0, of any manufacturer-provided thermal rating factor and the factor developed from the referenced Westinghouse memorandum. TRF may exceed 2.0 only in those cases where the manufacturer explicitly provides a TRF greater than 2.0.

For facilities that terminate in a multiple breaker arrangement, such as in a ring bus, breaker-and-a-half, or double-breaker-double-bus configuration, the rating of the lowest rated current transformer associated with the circuit will be used. This will allow maintenance to occur on one of the breakers without re-rating the facility during maintenance.

Short-term emergency ratings shall be determined using the guidance provided by Figure 20, "Overload Capability of Current Transformers" found in the ABB publication Instrument Transformers: Technical Information and Application Guide, Revision A, from December 2004 and IEEE Standard C37.010-1999 "Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis" Section 5.4.4.4.2. Assuming the 30°C average ambient and pre-load of 100% of nameplate rated current, the Emergency Rating for 30-minute duration is 170% and for four-hour duration is 119%. Outdoor Current Transformers that are non-standard or have an observed tendency to run hotter than normal shall have emergency ratings determined on a case-by-case basis, using provisions in the above standards documents and the judgment of substation maintenance personnel.

Disconnect Switches

Switches will be rated according to the manufacturer's nameplate ampacity at the nominal applied voltage which defines guaranteed minimum capacities under Usual Service Conditions as specified in ANSI C37.37-1996. Continuous current ratings for connectors used to terminate conductors to switches will be rated the same as the conductor per ANSI C119.4, and will not be separately calculated.

For facilities that terminate in a multiple breaker arrangement, such as in a ring bus, breaker-and-a-half, or double-breaker-double-bus configuration, the rating of the lowest rated disconnect switch associated with the circuit will be used. This will allow maintenance to occur on one of the breakers without re-rating the facility during maintenance.

Short-time Emergency Ratings shall be assigned to outdoor switches using provisions of ANSI 37.37-1996, Annex A, Figure 3. The short-time Emergency Rating shall be 122% of the continuous rating for both 30-minute and 4-hour ratings. For switches of non-standard design or construction and switches that exhibit anomalous thermographic patterns, short-term emergency ratings shall be determined on a case-by-case basis, using provisions in the above standards documents and the experience of substation maintenance personnel.

Wave Traps

Power line carrier wave trap (line trap) ratings are determined by the manufacturer's nameplate rating of the device consistent with ANSI C93.3-1981, "Requirements for Power-Line Carrier Line Traps".

Emergency Ratings shall be based on the altitude correction factor in Section 4.2.2.1, Table 2 and in Table A1 of the above standard based on the 40°C ambient consistent with the transmission line emergency ratings. The 30-minute Emergency Rating of Wave Traps is 129% and the four-hour emergency rating is equal to the normal rating, due to thermal considerations. Wave Traps determined to have limited capability due to aging or damage shall have emergency ratings determined on a case-by-case basis, using provisions in the above standard document.

Metering Equipment

Metering equipment will be specified to have a minimum 10-Ampere continuous capability, so that the metering equipment can withstand the full capability of its associated current transformer, at a minimum. Normal and Emergency Ratings for Metering Equipment are identical.

Monitoring equipment, such as WATT/VAR transducers, panel meters, and RTU interface circuitry are used for monitoring by system operators, among others. These subsystems may have limitations or saturation points that cause a ceiling or floor on observed parameters if exceeded, even though the hardware limitations are not exceeded. As operation of the system in excess of these values would render observed SCADA values incorrect, they should not be exceeded and must be taken into account when metering equipment ratings are determined.

Other Secondary Terminal Equipment

In general, other terminal equipment not specifically identified in this document will be rated via a nameplate rating. Further, where applicable, such equipment will have minimum 10-Ampere continuous capability. Normal and Emergency Ratings will be identical.

Series Capacitors and Reactors

Tri-State does not currently have any series capacitor or reactor installations. However, the series capacitor or reactor ratings, if installed, will be based on the nameplate capability as determined by the manufacturer, and the Normal and Emergency Ratings will be determined consistent with "IEEE Standard for series capacitors in power systems", current revision, and IEEE C57.16-1996 "IEEE Standard Requirements, Terminology, and Test Code for Dry-Type Air-Core Series-Connected Reactors", Section 5 Normal and Emergency Ratings will be identical. If needed, Short-term emergency ratings shall be determined, if necessary, on a case-by-case basis, using provisions in the above standards documents.

Shunt Reactive Devices

Shunt reactive device ratings will be established via nameplate ratings established by the manufacturer as described in IEEE C57.21-2008 "IEEE Standard Requirements, Terminology, and Test Code for Shunt Reactors Rated over 500 kVA", Section 5; and IEEE 18-2002 "IEEE Standard for Shunt Power Capacitors", Sections 4 and 5. Normal and Emergency Ratings will be identical. If needed, Short-term emergency ratings shall be determined, if necessary, on a case-by-case basis, using provisions in the above standards documents.

This section also applies to the shunt reactive components on FACTS and other advanced power electronics.

DC Ties

With the exception of Stegall, Tri-State currently has no DC ties. This section also applies to series reactive components as part of FACTS and other advanced power electronics devices. DC Tie ratings are determined by the manufacturer. Normal and Emergency Ratings are identical.

Underground Cables

Underground cables will be rated according to the manufacturer's design, in combination with the ambient in-situ conditions (soil resistivity, nearby UG parallel cables, ambient temperature, etc.). Short-term emergency ratings shall be determined on a case-by-case basis.

Substation Jumpers

Jumpers are rated using the same methodology as overhead conductors for normal and emergency ratings. A static thermal temperature of 100 degrees C shall be assumed for all strandings, tempers, and cores.

For facilities that terminate in a multiple breaker arrangement, such as in a ring bus, breaker-and-a-half, or double-breaker-double-bus configuration, the rating of the smallest series-connected jumper associated with the circuit will be used. Ratings of jumpers connected to shunt equipment (Potential Transformers, etc.) shall be applied to the shunt connected equipment only, not the line.

Substation Bus

Ratings of substation buswork shall be based on IEEE Standard 605-2008, "IEEE Guide for Design of Substation Rigid-Bus Structures" in Section 5. Unless directed otherwise, on a case-by-case basis, by Tri-State's substation engineering group, assumptions shall include Emissivity = 0.5, with Sun, and temperature rise above 40 degrees C ambient; and ampacities found in Annex B of the standard based on a maximum bus temperature of 70°C.

Ratings of substation Strain Bus shall follow the same criteria as Jumpers, described above. A maximum static thermal temperature of 100°C shall be assumed.

For facilities that terminate in a multiple breaker arrangement, such as in a ring bus, breaker-and-a-half, or double-breaker-double-bus configuration, the rating of the smallest series-connected bus associated with the circuit will be used.

Short-term emergency ratings shall be determined, using the provisions of the above cited Annex B for the appropriate bus shape and a maximum conductor of 110°C for the 30-minute short time emergency and 100°C for the four-hour emergency rating. This rating shall be considered appropriate for both copper and aluminum bus conductors to avoid separate calculations. In the case of a bus that has non-standard size, thickness, shape, or mechanical support, the short-time emergency ratings shall be determined on a case-by-case basis. Rigid station bus that is mechanically fixed at both ends, without expansion joints shall also be evaluated on a case-by-case basis due to forces exerted on, and possible damage to, station equipment using provisions in the above standard document.

As an example, 4-inch Schedule 80 tubular aluminum (53% Conductivity) using the same ambient conditions as noted above would have a normal rating of 2358 Amps, a 30 Minute Emergency Rating of 4257 Amps (180% of Normal rating), and a 4-hour rating of 3882 Amps (164% of Normal rating). Because of the variety of shapes and metals used in station bus, it is difficult to support a system-wide short time emergency rating above 118% for 30 Minutes and 109% for 4 Hours. This is based on values for flat rectangular copper bus bars, and is the most limiting of the metals and shapes generally used in station bus construction.

Copper tubular buses, both Schedule 40 and Schedule 80 could have a short time emergency rating of 127% for 30 Minutes and 114% for 4 Hours.

APPENDIX C: EQUIPMENT THERMAL AND EMERGENCY RATINGS

Tri-State Overhead Conductor Static Thermal Ratings
(Amperes)

Conductor Type	Maximum Conductor Temperature (Celsius)	Region 1 (NC WY)	Region 2 (SE WY/NE CO/ W NE)	Region 3 (W CO/ NW NM)	Region 4 (E CO/ NE NM)	Region 5 (S NM)
Falcon	50	1012	1000	972	932	824
1590 (ACSR)	75	1571	1575	1534	1554	1477
54/19 Stranding	100	1877	1878	1828	1862	1800
Pheasant	50	885	877	853	820	729
1272 (ASCR)	75	1362	1366	1331	1348	1281
54/19 Stranding	100	1623	1624	1581	1611	1557
Bittern	50	880	872	849	816	726
1272 (ASCR)	75	1358	1362	1327	1344	1278
45/7 Stranding	100	1625	1627	1584	1613	1559
Cardinal	50	745	740	721	694	619
954 (ACSR)	75	1134	1137	1108	1122	1066
54/7 Stranding	100	1347	1349	1313	1338	1293
Rail	50	740	735	716	690	616
954 (ACSR)	75	1130	1133	1104	1118	1062
45/7 Stranding	100	1346	1349	1313	1338	1293
Drake	50	676	671	655	631	564
795 (ACSR)	75	1030	1033	1006	1019	968
26/7 Stranding	100	1227	1229	1197	1219	1179
Grosbeak	50	591	586	572	551	495
636 (ACSR)	75	890	894	870	881	838
26/7 Stranding	100	1060	1061	1034	1053	1017
Dove	50	545	540	527	508	458
556.5 (ACSR)	75	818	820	798	809	769
26/7 Stranding	100	972	973	947	965	932
Hen						
477 (ACSS)	150	1099	1098	1069	1093	1065
30/7 Stranding						
Hawk	50	495	491	480	463	418
477 (ACSR)	65	663	664	649	653	615
26/7 Stranding	75	740	741	722	732	696
	100	879	880	856	873	843
Lark						
397.5 (ACSS)	200	1114	1108	1082	1105	1083
30/7 Stranding						
Ibis	50	442	438	429	414	375
397.5 (ACSR)	75	657	659	642	650	619
26/7 Stranding	100	781	781	759	774	748
Linnet	50	399	395	387	374	339
336.4 (ACSR)	75	590	591	576	583	555
26/7 Stranding	100	700	700	680	694	670
Partridge	50	345	343	336	324	295
266.8 (ACSR)	75	508	510	495	502	479
26/7 Stranding	100	602	601	584	597	576
Penguin	50	286	284	280	270	246
4/0 (ACSR)	75	405	406	394	400	382
6/1 Stranding	100	466	465	455	462	446
Quail	50	217	216	213	206	188
2/0 (ACSR)						
6/1 Stranding	100	352	352	342	350	337

Tri-State Overhead Conductor Emergency Ratings
(Percent of Static Rating)

Conductor Type	15 Min Percent Overload	30 Min Percent Overload
Falcon 1590 (ACSR) 54/19 Stranding	112	103
Pheasant 1272 (ASCR) 54/19 Stranding	109	102
Bittern 1272 (ASCR) 45/7 Stranding	108	102
Cardinal 954 (ACSR) 54/7 Stranding	107	101
Rail 954 (ACSR) 45/7 Stranding	106	101
Drake 795 (ACSR) 26/7 Stranding	106	101
Grosbeak 636 (ACSR) 26/7 Stranding	104	100
Dove 556.5 (ACSR) 26/7 Stranding	103	100
Hen 477 (ACSS) 30/7 Stranding	103	100
Hawk 477 (ACSR) 26/7 Stranding	103	100
Lark 397.5 (ACSS) 30/7 Stranding	102	100
Ibis 397.5 (ACSR) 26/7 Stranding	102	100
Linnet 336.4 (ACSR) 26/7 Stranding	101	100
Partridge 266.8 (ACSR) 26/7 Stranding	101	100
Penguin 4/0 (ACSR) 6/1 Stranding	101	100
Quail 2/0 (ACSR) 6/1 Stranding	100	100

Tri-State Terminal Equipment Emergency Ratings
(Percent of Nameplate Continuous Rating)

Terminal Equipment	30 Min Percent Overload	4 Hour Percent Overload
Power Transformers	125	110
Circuit Breakers	119	112
Current Transformers	170	119
Disconnect Switches	122	122
Wave Traps	129	100

APPENDIX D: REACTIVE POWER & VOLTAGE REGULATION REQUIREMENTS FOR GENERATION INTERCONNECTIONS

C. Tri-State's Steady State VAR, and Voltage Regulation Requirements:
Note - while these generally make reference to wind generation facilities, they shall apply to all generation interconnections, PV solar plants may be exempt if the requirement is not feasible.

8) All interconnections are subject to detailed study and may require mitigation in excess of minimums imposed by published standards, according to the best judgement of Tri-State engineers. <u>The IC's Large Generating Facilities (LGF) shall be capable of either producing or absorbing reactive power (VAR) as measured at the HV POI bus at an equivalent 0.95 pf, across the range of near 0% to 100% of facility MW rating</u>, with the magnitude of VAR calculated on the basis of nominal POI voltage (1.0 p.u. V). This would be the net MVAR able to be either produced or absorbed by the IF facility, depending upon the voltage regulating conditions at the POI (see next item).

9) The POI voltage range where the IC's LGF may be required to produce VAR is from 0.90 p.u. V through 1.04 p.u. V. In this range the IC facilities are being utilized to help support or raise the POI bus voltage.

10) The POI voltage range where the IC's LGF may be required to absorb VAR is from 1.02 p.u. V through 1.10 p.u. V. In this range the IC facilities are being utilized to help reduce the POI bus voltage.

11) Note that the POI voltage range where the IC's LGF may be required to either produce VAR or absorb VAR is 1.02 p.u. V through 1.04 p.u. V, with the typical target regulating voltage being 1.03 p.u. V.

12) The IC's LGF may supply reactive power from the generators, from the generators' inverter systems alone (if capable), or a combination of the generators, generators' inverter systems plus switched capacitor banks and/or reactors, or continuously variable STATCOM or SVC type systems. The IC's LGF is required to supply a portion of the reactive power (VAR) in a continuously variable fashion, such as supplied from either the generators, the generators' inverter systems, or a STATCOM or SVC system. The amount of continuously variable VAR shall be a value equivalent to a minimum of 0.95 pf produced or absorbed <u>at the generator terminal Low Voltage (LV) bus</u>, across the full range (0 to 100%) of rated MW output. The remainder of VAR required to meet the 0.95 pf net criteria at the HV POI bus may be achieved with switched capacitors and reactors, so long as the resultant step-change voltage is no greater than 3% of the POI operating bus voltage. This step change voltage magnitude shall be initially calculated based upon the minimum system (N-1) short circuit POI bus MVA level as supplied by the TP.

13) Under conditions when the IC's LGF is not producing any real power (near 0 MW, and typically less than 2 MVAR), the reactive power exchange at the POI shall be near 0 MVAR ("VAR neutral"). This condition assumes that the facility needs to remain energized to supply base-level station-service "house power" for the control facilities, maintain wind turbines on turning gear, etc., and that tripping open the IC transmission line supply is not a normal or acceptable means to create this VAR neutral condition. In this

non-generating mode, the IC Facility appears as a transmission connected load customer, and therefore must meet TP's requirements for load pf, which requires that the load pf be 0.95 or better.

14) All interconnections are subject to additional detailed study, utilizing more complex models and software such as PSCAD, EMTP, or similar, and may require mitigation in excess of minimums imposed by published standards, according to the best judgement of the TP's engineers.

D. Tri-State's Dynamic VAR and Low Voltage Ride-Through Requirements (consistent with FERC Order 661-A):

Note - while these requirements generally make reference to wind generation facilities, they shall apply to all types of generation interconnections. PV solar plants may be exempt if the requirement is not feasible.

6) The IC's LGF shall be able to meet the dynamic response Low Voltage Ride-Through (LVRT) requirements consistent with the latest WECC / NERC criteria. In particular, as per the Tri-State LGIP, Appendix H: Transmission Transfer Capability Assessment and FERC Order 661A for LVRT (applicable to Wind Generation Facilities).

7) Generating plants are required to remain in service during and after faults, three-phase or single line-to-ground (SLG) whichever is worse, with normal total clearing times in the range of approximately 4 to 9 cycles, SLG faults with delayed clearing, and subsequent post-fault voltage recovery to pre-fault voltage unless clearing the fault effectively disconnects the generator from the system. The clearing time requirement for a three-phase fault will be specific to the circuit breaker clearing times of the effected system to which the IC facilities are interconnecting. The maximum clearing time the generating plant shall be required to withstand for a fault shall be 9 cycles after which, if the fault remains following the location-specific normal clearing time for faults, the wind generating plant may disconnect from the transmission system. A wind generating plant shall remain interconnected during such a fault on the transmission system for a voltage level as low as zero volts, as measured at the Point of Interconnection (POI). To elaborate, before time 0.0, the voltage at the POI is the nominal voltage. At time 0.0, the voltage drops. The plant must stay online for at least 0.15 seconds regardless of voltage during the fault. Further, if the voltage returns to 90 percent of the nominal voltage within 3 seconds of the beginning of the voltage drop, the plant must continuously stay online. The Interconnection Customer may not disable low voltage ride-through equipment while the wind plant is in operation.

8) This requirement does not apply to faults that would occur between the generator terminals and the POI.

9) Generating plants may be tripped after the fault period if this action is intended as part of a special protection system.

10) Wind generating plants may meet the LVRT requirements of this standard by the performance of the generators or by installing additional equipment (e.g., Static VAR Compensator) within the wind generating plant or by a combination of generator performance and additional equipment.

APPENDIX E: VOLTAGE FLICKER CRITERIA

Maximum Allowable Voltage Flicker on Bulk Transmission versus Sub-transmission and Distribution System Buses

These criteria address the maximum allowable steady-state voltage flicker that can be caused by starting a motor or by switching a reactive device. The pertinent reference is REA-Bulletin 160-3, dated October 1969.

Tri-State Steady-State System Voltage Flicker Criteria for Sub-transmission and Distribution Buses (All Bus Voltage Levels Less than 115kV)

Maximum Allowable Voltage Flicker (per unit)	**Allowable Switching Frequency**
0.0600	Voltage flicker of this magnitude cannot be exceeded, and is limited to 3 occurrences per day.
0.0333	Voltage flicker of this magnitude is limited to 15 occurrences per day.
0.0250	Voltage flicker of this magnitude is limited to 1 occurrence per minute.
0.0167	Voltage flicker of this magnitude is limited to 12 occurrences per minute.
0.0125	Voltage flicker of this magnitude is limited to 1 occurrence per second.
0.0083	Voltage flicker of this magnitude can occur at an unlimited frequency.

Note – Sub-transmission and Distribution System as measured on the low side of the substation power transformer.

Tri-State Steady-State System Voltage Flicker Criteria for Bulk Transmission Buses (All Bus Voltage Levels 115kV and Greater)

Maximum Allowable Voltage Flicker (per unit)	**Allowable Switching Frequency**
0.030	Voltage flicker (step-change voltage) as applicable for motors, switched shunt capacitors or reactors not controlled by Tri-State, as measured at the HV transmission reference bus.

APPENDIX F: RAS OR SPECIAL PROTECTION SCHEMES

Tri-State Remedial Action Schemes

This Appendix provides information and documentation about the purpose, analysis, operation, and coordination of Remedial Action Schemes (RAS), also called Special Protection Schemes, implemented by Tri-State. Currently, Tri-State does not own or implement a RAS or Special Protection Schemes in MRO's reliability jurisdiction. Therefore, Appendix E specifically addresses criteria and standards established by FERC and developed by NERC and WECC. The information contained in this Appendix are for reference only and subject to change.

A RAS is a control scheme designed to mitigate conditions that could violate defined performance criteria, in lieu of adding system improvements. Failure of a RAS to operate as designed can result in violation of the defined performance criteria resulting in possible negative impacts on the system. The failure of a RAS may impact not only the immediate transmission owner, but also other interconnected transmission owners as well as the Balancing Authority.

Three different types of RAS conditions are defined by WECC. These three types are as follows:

1. Local Area Protection Scheme (LAPS): a scheme whose failure to operate would NOT result in any of the following:
    - Violations of TPL – (001 thru 004) – WECC – 1 – CR - System Performance Criteria.
    - Maximum load loss ≥ 300 MW.
    - Maximum generation loss ≥ 1000 MW.

2. Wide Area Protection Scheme (WAPS): a scheme whose failure to operate WOULD result in any of the following:
    - Violations of TPL – (001 thru 004) – WECC – 1 – CR - System Performance Criteria.
    - Maximum load loss ≥ 300 MW.
    - Maximum generation loss ≥ 1000 MW.

3. Safety Net (SN): A RAS designed to remediate system performance following an extreme event that results in the loss of two or more Bulk Electric System elements (TPL-004-0 Category D event), or other extreme events. Extreme events are identified by Planners from TPL-004-1 (new TPL-001-2, Table 1).

The LAPS and WAPS must be designed so that a single component failure, when the LAPS or the WAPS is intended to operate, does not prevent any portion of the interconnected transmission system from meeting the performance requirements. Thus, all RAS are designed to have redundant components as well as communication paths, if used. An overview of the process in developing and implementing a RAS is shown in Figure E-1 below.

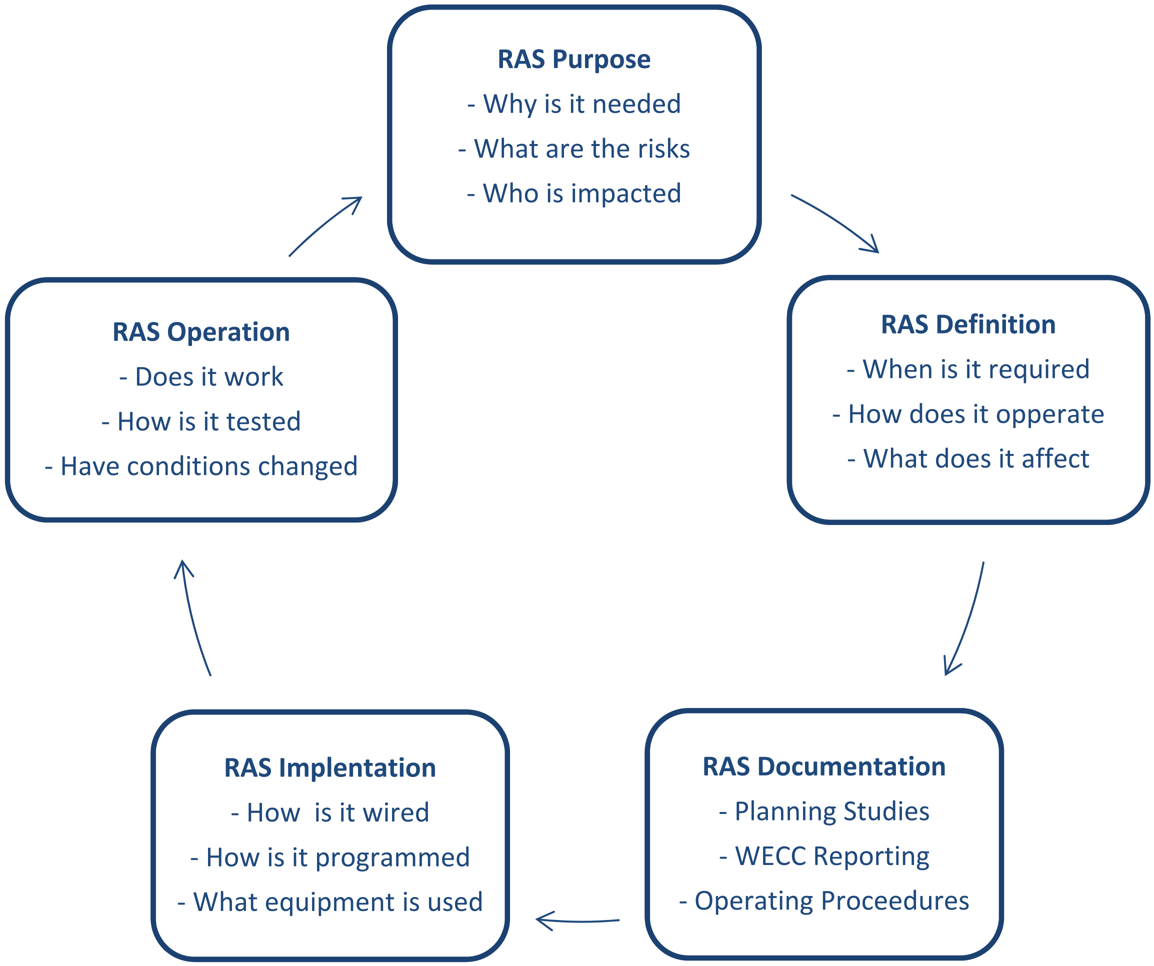

Figure E-1. RAS Overview

New RAS

Planning assessments are performed pursuant to NERC reliability standards. If the assessments show that reliability criteria are violated, then mitigation must be developed. If the performance criteria allows (such as for N-2 contingencies) or no system improvement can be proposed and implemented in a timely and cost-effective manner, then RAS development will be evaluated pursuant to the following criteria:

- The RAS must demonstrate that a single component failure, when the RAS was intended to operate, does not prevent the interconnected transmission system from meeting the performance requirements defined in NERC reliability standards .
- The RAS must demonstrate that the inadvertent operation of the RAS shall meet the performance requirements defined in NERC reliability standards.
- Demonstrate that the RAS will coordinate with other protection and control systems and any applicable Regional Reliability Organization emergency procedures.
- If the RAS is in the WECC region, then it must be classified as either a WAPS or LAPS.

After a RAS has been identified that satisfies the conditions defined above, transmission or generation elements, and related protection and telemetry systems are selected to implement the RAS. Documentation is then developed that defines the conditions under which the RAS will operate and the anticipated effects of the RAS after successful operation. If the proposed RAS impacts other transmission owners or requires the use of other entities' transmission or generation elements, then the appropriate coordination and operations agreements must be secured and documented.

Documentation

Documentation for the RAS shall include the following:

- The reporting entity.
- The name of the RAS as identified by the reporting party.
- Identification of a WECC RAS as a WAPS, LAPS or Safety Net.
- Identify if the RAS will be classified as a Major WECC RAS.
- The written operating procedures required for the scheme, if applicable.
- The design objectives of the scheme including contingencies and system conditions.
- Data required describing operation and the actions taken by the scheme in response to disturbance conditions.
- Data required for adequate modeling and information on system elements such as detection logic on relay settings or telemetry that control operation of the scheme.

- Identify the date in which the RAS was placed into service.
- The entities that own and control the scheme.
- The most recent assessment of the RAS design, coordination, need, and effectiveness including the group assessing the scheme and the date performed.

Annual Assessment

Assessments of the RAS shall be performed on an annual basis and reported to the Regional Reliability Organization / Reliability Assurer. The annual RAS assessment shall include the following:

- Review of the scheme purpose and impact to ensure proper classification, necessity, and intended or unintended adverse impacts on reliability.
- Technical studies performed, including years studied, system conditions, contingencies analyzed, date studies were completed, and the results of the studies including regional and NERC compliance.
- Review of any coordination between the studied RAS and other protection and control schemes.
- Corrective action plan and related documentation if the RAS is found to be non-compliant or has coordination issues with other schemes.

The information developed above shall be incorporated into the WECC Remedial Action Scheme Database (PRC-012 through 014, WECC-CRT-2, Attachment A), and the WECC RAS Initial or Periodic Assessment Summary (PRC-012 through 014 WECC-CRT-2, Attachment B).

The RAS shall be designed and reviewed by the appropriate responsible entities and departments and reviewed by Engineering, Operations, System Protection, and System Planning. After development and in-house approval of new or modified RAS, the RAS shall be submitted to the Reliability Assurer for its review.

Existing RAS information shall be reviewed for accuracy and the Transmission Owner shall report any changes, modifications, or removal of its RAS to the Reliability Assurer in the form of a RAS database spreadsheet by December 31 of each calendar year. Each RAS shall be assessed for operation, coordination, and effective compliance at least once every five years and report the assessment to the Reliability Assurer as defined in the WECC criterion “PRC-012 through PRC-014, WECC-CRT-2” or the “Midwest Reliability Organization Procedure For NERC PRC-012.”

Upon implementation of the RAS, requirements defined in NERC standard PRC-015-0 shall be met which include the following:

- The Transmission Owner shall maintain a list of and provide data for existing RAS as specified in NERC standard PRC-013-0.

- The Transmission Owner shall have evidence that it has reviewed new or functionally modified RAS in accordance with the Reliability Assurer procedures as defined in NERC standard PRC-012-0.
- The Transmission Owner shall provide documentation of RAS data and the results of studies that show compliance of new or functionally modified RAS with NERC reliability standards and regional criteria to the affected Reliability Assurer and NERC upon request.

A record of all misoperations shall be maintained in accordance with NERC PRC-016-0.1. In the event of a misoperation, corrective actions shall be taken to avoid future misoperations and documented. Documentation and analysis of any RAS misoperation and the corrective actions taken shall be made available to the Reliability Assurer and NERC upon request.

Defined Tri-State Remedial Action Schemes

Tri-State owns the RAS as noted in Table 1 – Tri-State WECC Remedial Action Schemes. These schemes are included in the WECC Remedial Action Scheme database and are reported to WECC as defined in PRC-012 through 014, WECC-CRT-2. Tri-State has no RAS in the MRO at this time.

Table 1. Tri-State WECC Remedial Action Schemes

ID	Scheme Name	Class	Description
1	Nucla RAS	LAPS	Trips the Montrose-Nucla 115 kV line for overload conditions caused by TOT 2A and Nucla generation levels
2	Walsenburg RAS	LAPS	Trips the Gladstone-Walsenburg 230 kV line for overloading conditions for the loss of Comanche-Walsenburg 230 kV line
3	Gladstone (Bravo Dome) RAS	LAPS	Trips Interruptible Load at Bravo Dome and Bravo Dome West for the loss of Gladstone-Walsenburg 230 kV line
4	PEGS RAS	LAPS	Trips PEGS generation for the loss of Escalante-Ambrosia Lake 230 kV and Escalante-Blue Water 115 kV lines
5	Fraser RAS	LAPS	Trips the 138/115 kV transformer at Fraser for overloading caused by various outages

Each RAS description, design objectives, and operation description are described as follows:

1 - Nucla RAS

The Nucla RAS is located in southwest Colorado and is classified as a Local Area Protection Scheme. The RAS is solely owned, operated, and maintained by Tri-State and has been identified as a Major WECC RAS (11). The original in service date for the RAS was 1990 with additional modifications made in 2008.

Design Objectives:

System planning studies performed have identified that the Montrose-Nucla and Nucla-Cahone 115 kV lines may exceed their thermal ratings depending on the status of the following:

- Nucla generation output.
- TOT 2A schedules.
- Montrose – Hesperus 345 kV line.
- Curecanti – Lost Canyon 230 kV line.
- Shiprock and Waterflow phase shifting transformers.

Conditions have been identified that can cause flows on either or both of the lines to exceed thermal ratings during periods of high North-to-South TOT 2A schedules. In order to mitigate the overload of the Nucla-Cahone 115 kV line, the Nucla RAS was developed.

Operation:

The Nucla RAS is a fully redundant protection scheme that operates for conditions and contingencies that result in overloading the Montrose-Nucla 115 kV and or Nucla-Cahone 115 kV lines. The RAS will open the Nucla terminal of the Montrose – Nucla 115 kV line which mitigates the overloading condition.

2 - Walsenburg RAS

The Walsenburg RAS is located in southeast Colorado and is classified as a Local Area Protection Scheme and is primarily owned, operated, and maintained by Tri-State with operational and procedural input from XCEL-PSCO and PNM . The original in-service date for the RAS was 2008.

Design Objectives:

Planning studies and TPL assessments have identified that the loss of the Comanche-Walsenburg 230 kV line causes the West Station Tap-Stem Beach 115 kV line to exceed its thermal rating and system voltages in the Walsenburg area fall to unacceptable levels. In order to mitigate the overload and voltage criteria violations, the Walsenburg RAS was developed.

Operation:

The Walsenburg RAS is a fully redundant protection scheme that trips the Walsenburg-Gladstone 230 kV line 5 seconds after the loss of the Comanche-Walsenburg 230 kV line. Tripping the Walsenburg-Gladstone 230 kV line results in acceptable voltage and thermal loading limits for the transmission system.

3 – Gladstone RAS

The Gladstone RAS is located in northeast New Mexico and is classified as a Local Area Protection Scheme and is owned, operated, and maintained by Tri-State with operational and procedural input from network customers. The original in-service date for the RAS was 2009.

Design Objectives:

Planning studies and TPL assessments identified voltage and dynamic stability conditions that occur in northeast New Mexico for the loss of the Walsenburg-Gladstone 230 kV line. Static Var Systems (SVSs) have been installed at Clapham substation to provide system stability for the area including the motor load at Bravo Dome. However, for the loss of the Walsenburg-Gladstone 230 kV line, the load at Bravo Dome must be reduced to 52 MW and the Gladstone – Hess line must be opened in order to meet system voltage criteria. The loads being interrupted have agreed by contract to this scheme in lieu of installing required network upgrades and are considered Interruptible, not Firm Demand.

Operation:

The Gladstone RAS is a fully redundant protection scheme that trips load and reduces the maximum level at Bravo Dome to 52 MW for the loss of the Walsenburg-Gladstone 230 kV line and trips the Gladstone-Hess 115 kV line. Tripping loads served from Gladstone results in acceptable voltage for the northeast New Mexico area.

4 – PEGS RAS

The PEGS RAS is located in northwest New Mexico and is classified as a Local Area Protection Scheme. The RAS is owned, operated, and maintained by Tri-State with operational and procedural input from PNM. The original in service date for the RAS was 2010.

Design Objectives:

Planning studies and other system assessments have identified that the Escalante – Ciniza 115 kV line is overloaded if the Escalante – Ambrosia Lake 230 kV and the Escalante – Blue Water 115 kV lines are open when PEGS is generating. When this condition occurs, the Escalante – Ciniza 115 kV line is overloaded. In order to mitigate the over-loading conditions, the Generator at PEGS is tripped off-line, which mitigates the overloading on the Escalante – Ciniza 115 kV line.

Operation:

The PEGS RAS is a fully redundant protection scheme that trips the PEGS generator in the event the Escalante – Ambrosia Lake 230 kV and the Escalante – Blue Water 115 kV lines are both open. Tripping generation at PEGS results in mitigating the overloading conditions on the Escalante – Ciniza 115 kV line.

5 – Fraser RAS

The Fraser RAS is located in northern Colorado and is classified as a Local Area Protection Scheme. The RAS is owned, operated, and maintained by Tri-State. The original in-service date for the RAS was 1997.

Design Objectives:

Planning studies and other system assessments have identified that the Fraser 138/115 kV transformer overloads for certain contingencies following the loss of the Blue River-Gore Pass 230 kV line. In order to mitigate the over-loading conditions, the Fraser 138/115 kV transformer is opened which mitigates the overloading condition.

Operation:

The Fraser RAS is a special protection scheme that trips the 138/115 kV transformer in the event the transformer exceeds 120 MVA for 60 seconds. Tripping is performed using breaker 162 at Fraser which mitigates the overload condition.

<u>Tri-State also has equipment that participates in the WECC NE/SE Separation scheme. See WECC RAS-1 description for complete information.</u>

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APPENDIX H: TRANSMISSION TRANSFER CAPABILITY ASSESSMENT

Transmission Transfer Capability Assessment Practices

Tri-State has the capability of moving electric power throughout the region using the transfer capability of its transmission lines. Transfer capability is a measure of the ability of interconnected electric systems to reliably move power from one area to another. The transfer capability of a bulk transfer path is the total megawatt flow capability along a path. Currently, Tri-State has capacity rights in six bulk transfer paths, and uses this capacity for bulk power transfers. A bulk transfer path may, or may not, be an actual boundary determined by an electrical limitation. This electric limitation may be internal to one control area, and can be monitored by system operators to assist in dispatching electricity. Ratings have been established for those paths, and are recognized by WECC. The WECC Path Rating Catalog identifies many transmission paths including the operating restrictions and limitations for each. These limitations and restrictions have been determined by joint studies performed by WECC Members. The WECC facility rating document, "Procedures for Regional Planning Project Review and Rating Transmission Facilities", presents a methodology for rating the transmission facilities and bulk transfer paths. Each of these two documents is available through WECC. The bulk transfer paths in Tri-State's area are:

Path Name	Facilities Comprising Path
TOT 1A	Craig-Bonanza 345 kV
Colorado - Utah	Hayden-Artesia 138 kV
	Meeker-Rangely 138 kV
TOT 2A	Hesperus-San Juan 345 kV
SW Colo. – New Mexico	Hesperus-Glade Tap 115 kV
	Lost Canyon-Shiprock 230 kV

TOT 3	Archer-Ault 230 kV
SE Wyo. – Colo.	Laramie River-Ault 345 kV
	Laramie River-Story 345 kV
	Cheyenne-Owl Creek 115 kV
	Sidney-Sterling 115 kV
	Sidney-Spring Canyon 230 kV
	Terry Ranch Road-Ault 230 kV
TOT 4B	CarrDraw-Buffalo 230 kV
Northwest Wyoming	Sheridan- Tongue River 230 kV
	Spence-Thermopolis 230 kV
	Alcova-Raderville 115 kV
	Casper-Midwest 230 kV
	Riverton-Thermopolis 230 kV
	Riverton-230/115 kV transformers

<u>Path Name</u>	<u>Facilities Comprising Path</u>
TOT 5	North Park-Terry Ranch Road 230 kV
West Colo. – East Colo.	Craig-Ault 345 kV
	Hayden-Gore Pass 230 kV
	Hayden-Gore Pass 138 kV
	N. Gunnison-Salid (Poncha Jct.) 115 kV
	Curecanti-Poncha 230 kV
	Basalt-Malta 230 kV
	Hopkins-Malta 115 kV

NM 1	West Mesa-Arroyo 345 kV
Central NM	Springerville-Luna 345 kV
– Southern NM	Greenlee-Hidalgo 345 kV
	Belen-Bernardo 115 kV
NM 2	Four Corners-West Mesa 345 kV
Into Central NM	San Juan-BA 345 kV
	San Juan-Ojo 345 kV
Transformers	McKinley/YahTaHey 345/115 kV
	Bisti-Ambrosia 230 kV
	Walsenburg-Gladstone 230kV
	Less these flows:
	Belen-Bernardo 115 kV
	West Mesa-Arroyo 345

The potential impact of DC Tie Schedules in both directions must be considered as well. There are DC-ties located at Stegall and Sidney buses. Bulk transfer path ratings must be kept within limits established by approved studies. For more information on bulk transfer ratings listed above, contact information is listed with each accepted bulk transfer path rating in the WECC Path Rating Catalog.