Southwest Power Pool
MINIMUM DESIGN STANDARDS TASK FORCE WORKING GROUP
MEETING
November 4, 2014
Teleconference
(10:00 am – 12:00 pm)

- MINUTES -

Agenda Item 1: Administrative Items
MDSTF Meeting

Item 1a: Call to Order and Introductions
Chair, Jeff Stebbins, called the meeting to order at 10:00 am and welcomed everyone. There were 25 teleconference participants. (Attendance List Attached).

Item 1b: Proxies
There were no proxies for this meeting.

Item 1c: Approve minutes of previous meetings
The minutes for the October 14th, 2014 meeting were not reviewed during this meeting but can be found on the MDSTF Exploder at SPP.ORG. (20141014 Meeting Minutes).

Item 1d: Approve agenda
The agenda is to continue generating the Minimum Design Standard.

Agenda Item 2: Review of Past Action Items
There are no past action items to address.

Agenda Item 3: SPCWG Meeting November 11-13
The Protection and Controls portion of the Minimum Design Standard will be reviewed during the next SPCWG meeting on November 13, 2014 at 8AM. All MDSTF members and their SME’s are encouraged to participate.

Agenda Item 4: Review of the Minimum Design Standard
Paul Sedlacek[WERE] requested adding the bus height and phase spacing and CCVT BILS to the substation section of the MDS. The group decided to use standards instead of those tables so that the MDS would not need to be revised if the tables were updated.

The group reviewed MDS comments from various PCWG members. Rob Christman[Lone Star Transmission] had comments concerning conductor operating temperature, rigid bus design, and terminal equipment ratings. Brenda Jessop[WERE] wanted to delete the normal amps rating from the table because the emergency rating is the rating under a contingency which matters most in planning and operations. John Krajewski[JK Energy Consulting] also expressed concerns regarding the 100-200 kV and 230 kV minimum normal amperage rating in the phase conductors section. Other comments included the need for seismic requirements and further research was required to verify SPP Criteria 12.2 covers bus conductors.

Based on the comments from PCWG, the remainder of the meeting was spent discussing conductor ratings and how it should be described in the MDS. Cary Frizzell was tasked with scheduling a meeting with Jeff Stebbins, Dave Parrish, Terri Gallup, Jay Caspary, and Antoine Lucas to discuss ratings of transmission lines (i.e. should we determine standards based on a SIL or use the value), topics that should be covered in the MDS vs. RFP, and the MISO MDS document. MISO created a Minimum Design Standard for their region which details their methodology in determining rating requirements for open transmission projects. MDSTF wanted to know if the expected MDS should be similar to the MISO document. The task force decided to keep the current ratings specified in the MDS until after meeting with SPP. (Minimum Design Standard Attached and MISO presentation attached)

**Agenda Item 5: Target Milestones**

**Item 5A:** Schedule for return of utility SME comments

MDSTF still needs SME comments from the following utilities: AEP, OGE, ITC, and WERE

Everyone requested the latest edition of the MDS be sent to the MDSTF Exploder.

**Item 5B:** Schedule for return of SPP Staff comments and future SPP reviews/approvals

PCWG, TWG, and ORWG all need to review and approve the MDS before it goes to MOPC. These working groups would like to review the MDS prior to the end of the year.

Both TWG and SPCTF (Order 1000) have scheduled MDS status updates during their next meetings. TWG will meeting November 18-19 and SPCTF will meet November 10-11. Jeff Stebbins/Dave Parrish will provide the update.

**Agenda Item 6: Revisions to “Applicability” section**

This item was deferred to the next meeting due to time constraints.

**Agenda Item 7: Revisions to “Scoping” section**

This item was deferred to the next meeting due to time constraints.

**Agenda Item 8: MISO Minimum Design Standard**
Jeff Stebbins provided the group with a presentation describing MISO’s initial efforts to define minimum design standards. Due to time constraints this item was briefly referred to in the meeting.

**Agenda Item 9: Discussion of Further Meetings**

SPCWG Meeting November 11-13, 2014. MDS P&C section review November 13 at 8AM.

Remaining Meetings through December (Meet every 2-3 weeks):

- Nov 10 (Doodle poll sent out for meeting time)

**Agenda Item 10: Closing Administrative Duties**

A doodle poll will be sent out for November 10th, 2014. We will continue reviewing the Minimum Design Standard. The meeting was adjourned.

Respectfully Submitted,

**Douglas Bowman**

**MDSTF Staff Secretary**
<table>
<thead>
<tr>
<th>Participant</th>
<th>Name</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Melanie Hill</td>
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<td>4</td>
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<td>6</td>
<td>Paul Sedlacek (Westar)</td>
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<td>Aaron Shipley</td>
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<td>8</td>
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<td>10</td>
<td>Kyle Drees (WERE)</td>
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<td>11</td>
<td>Jeff Stebbins (TCEC)</td>
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<tr>
<td>12</td>
<td>Nick Vanous</td>
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<td>13</td>
<td>Clarence D. Suppes - Sunflower</td>
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<tr>
<td>14</td>
<td>Garrett Graybill (OGE)</td>
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<tr>
<td>15</td>
<td>David Evans (SPS)</td>
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<td>16</td>
<td>jrdring</td>
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<tr>
<td>17</td>
<td>Garrett Graybill (OGE)</td>
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<tr>
<td>18</td>
<td>Thomas Maldonado</td>
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</tr>
<tr>
<td>19</td>
<td>Terri Gallup (AEP -PCWG Chair)</td>
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<td>Leland Jacobson (OPPD/PCWG)</td>
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<td>Jeff Brown</td>
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<tr>
<td>23</td>
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</tr>
<tr>
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</tr>
</tbody>
</table>
Minimum Transmission Design Standards

July 22, 2011

Minimum Design Standards | Design Best Practices and Performance Criteria
Task Force

Southwest Power Pool
### Introduction

#### Applicability

This document outlines the Minimum Design Standards, Design Best Practices and Performance Criteria (DBP&PCMDS) to be used when developing Study Estimates for the SPP footprint projects rated at voltages of 100 kV and greater. These DBP&PC have been incorporated into this Study Estimate Design Guide and are intended to promote consistency in Study Stage estimates.

Effective March 31, 2014, SPP Staff will be responsible for providing Study Estimates for projects applicable to the Transmission Owner Selection Process (Competitive Projects). For non-Competitive Projects, the incumbent Transmission Owner (TO)(s) will be responsible for providing Study Estimates. For the remainder of this document, the Study Estimate Provider (SEP) will refer to SPP Staff for Competitive Projects and incumbent TOs for non-Competitive Projects.

Recognizing the importance of well defined scopes when developing cost estimates, this document also contains scoping guidelines for the Conceptual and Study estimate phases. These guidelines will promote better understanding of the project definition as the project is developed and estimates are prepared for the applicable phase of the potential project.

Study Estimate assumptions will be detailed in the Standardized Cost Estimate Reporting Template (SCERT) as used by the SPP project cost tracking process.
Minimum Design Standards

**Best Practices**

Minimum Design Standards and Design Best Practices represent high-level, foundational principles on which sound designs are based. Minimum Design Standards and Design Best Practices facilitate the design of transmission facilities in a manner that is compliant with NERC, SPP, and TO requirements; are consistent with Good Utility Practice as defined in the SPP Open Access Transmission Tariff (SPP Tariff); are consistent with the most recent industry standards such as NESC, IEEE, ASCE, CIGRE, and ANSI at time of RFP submittal; and are cost-effective. Although not addressed here, construction and maintenance best practices must be considered during the design phase to optimize these costs and efficiencies.

Performance Criteria further define the engineering and design requirements needed to promote a more uniform cost and reliability structure of the transmission facilities and to ensure that the Qualified RFP Participants (QRPs) submit RFPs for and TOs construct project(s) within the parameters requested by SPP. Individual sections within this document contain both Minimum Design Standards and Design Best Practices and Performance Criteria.

Scope Management

A well developed and rigorously managed scoping document promotes consistent estimates and helps control costs. It also ensures that the SPP and any potential project builder have a clear understanding of the project being reviewed.

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1 The SPP Tariff defines Good Utility Practice as follows: “Good Utility Practice: Any of the practices, methods and acts engaged in or approved by a significant portion of the electric utility industry during the relevant time period, or any of the practices, methods and acts which, in the exercise of reasonable judgment in light of the facts known at the time the decision was made, could have been expected to accomplish the desired result at a reasonable cost consistent with good business practices, reliability, safety and expedition. Good Utility Practice is not intended to be limited to the optimum practice, method, or act to the exclusion of all others, but rather to be acceptable practices, methods, or acts generally accepted in the region, including those practices required by Federal Power Act section 215(a)(4).”
Minimum Transmission Design Standards

Transmission Lines

General

Where applicable, RUS guidelines should also be considered.

Environmental

Transmission lines shall be designed to meet all applicable environmental and regulatory requirements. Storm water management plans and structures must comply with all federal, state, and local regulations.

Electrical Clearances

Conductor-to-ground and conductor-to-conductor clearances. Design and working clearances shall meet the clearance requirements of the NESC. Clearance-to-ground and foreign objects shall have, plus an additional margin of 2 feet. These clearances shall be maintained during conditions of maximum operating temperature, and extreme ice, and dynamic loading such as galloping and ice drop.

Sufficient space for OSHA working clearances shall be provided when establishing the geometrical relationships between structure and conductors.

Commented [TDP1]: This could become part of the criteria, but we’ll need help from the utilities affected by these guidelines. And are they guidelines or standards? What are they – comprehensive, or specific to one aspect of design. Are they enforceable?

Commented [MH2]: Need to research codes
Structure Design Loads

All structures types (deadends, tangents, and angles), materials, and foundations shall be designed to withstand the following combinations of gravity, wind, ice, conductor tension; and dynamic, construction, and maintenance loads. The magnitude of all weather-related loads, except for NESC or other legislated loads, shall be based on a 100 year mean return period as defined in that specify otherwise, are defined by the ASCE Manual of Practice (MOP) 74, unless otherwise specified. With the exception of the NESC or other legislated loads that specify otherwise, overload factors shall be a minimum of 1.0.

Loads with All Wires Intact
- NESC Grade B, Heavy Loading
- Other legislated loads, including NESC requirements
- Extreme wind applied at 90° to the conductor and structure
- Extreme wind applied at 45° to the conductor and structure
- Combined wind and ice loadings
- Extreme ice loading

Unbalanced Loads
- Longitudinal loads due to unbalanced ice conditions, considering 41/2” radial ice, no wind in one span, no ice fallen off of on adjacent span, with all wires intact at 32° Fahrenheit initial tension
- Longitudinal loads due to a broken ground wire or one phase position (the phase may consist of multiple sub-conductors)

Construction and Maintenance Loads
- Construction and maintenance loads shall be applied based on the recommendations of ASCE MOP 74.

Dynamic Loads
- Galloping
- Ice Drop

Structure and Foundation Design

Structures and foundations shall be designed to the requirements of the applicable publication:
- ASCE Standard No. 10, Design of Latticed Steel Transmission Structures
- ASCE Standard No. 48, Design of Steel Transmission Pole Structures
- ASCE Manual No. 91, Design of Guyed Electrical Transmission Structures
- ASCE Manual No. 91, Design of Guyed Electrical Transmission Structures
- ASCE Publication Guide for the Design and Use of Concrete Poles
A site specific geotechnical study shall be the basis of the foundation design parameters.

Deflection of structures shall be limited such that proper clearances are maintained.

### Insulation Coordination, Shielding, and Grounding

Insulation, grounding, and shielding shall be coordinated to ensure acceptable system performance.

**Metallic All** transmission line structures shall be grounded. Overhead static wires (shield wires) shall also be grounded, or a low impulse flashover path to ground shall be provided. Grounding practices shall be in accordance with the NESC, by a spark gap. Individual structure grounds must be coordinated with the structure insulation level and static wire shielding angles (with reference to the phase conductors) to limit momentary operations of the supported circuit(s) to the targeted rate.

### Phase Conductors

Phase conductors shall be sized to carry the amperage defined in the following table, the anticipated power flow of the circuit, or that specified in the RFP, whichever is largest. The values shall be considered as minimum continuous ratings for both normal and emergency operating conditions.

<table>
<thead>
<tr>
<th>Voltage (kV)</th>
<th>Normal Amps</th>
<th>Emergency Amps</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 - 200</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>230</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>345</td>
<td>3,000</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>3,000</td>
<td></td>
</tr>
<tr>
<td>765</td>
<td>4,000</td>
<td></td>
</tr>
</tbody>
</table>

Consideration shall be given to metallurgical (losses, impedance), mechanical and corona performance, electrical system stability (voltage and stability), and for the effects of the high electric fields when selecting the size of phase conductors.

Conductors shall be selected such that they will lose no more than 10 percent of their original strength during the first fifty years of service when operated at their emergency rating.

The conversion to **impacity** shall be based on IEEE Publication No. 738, *Standard for Calculating the Current-Temperature of Bare Overhead Conductors*, SPP Criteria 12.2.2, or other similar documented approaches.
**Communication**

**Optical Ground Wire**

Fiber shall be considered on all new transmission lines being constructed using OPGW, unless an underground fiber or ADSS feed is provided. Other forms of communication, such as microwave or tone, may be considered if compatible with the incumbent TO(s) equipment. Except where an underground fiber path will be provided, overhead ground wires shall be Optical Ground Wire (OPGW).—Where there are multiple static wires only one need be OPGW, except for voltages of 345 kV and higher where both shall be OPGW. The size shall be determined based on the anticipated fault currents generating from the terminal substations.

Adequate provisions should be made for OPGW repeater redundancy as well as power supply redundancy at each repeater.

**Reactive Compensation**

Project cost estimates should include reactive compensation as appropriate. (A project specific study is needed to define actual reactive compensation requirements.) The following table contains the suggested reactive compensation per mile of line:

<table>
<thead>
<tr>
<th>Voltage (kV)</th>
<th>Reactive Compensation (MVAR/mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-200</td>
<td>0.1</td>
</tr>
<tr>
<td>230</td>
<td>0.3</td>
</tr>
<tr>
<td>345</td>
<td>1</td>
</tr>
<tr>
<td>500</td>
<td>2</td>
</tr>
<tr>
<td>765</td>
<td>4.5</td>
</tr>
</tbody>
</table>

**Other Considerations**

Wind induced vibration

- The design shall allow for mitigation of wind induced vibration for structures and wire systems.
Transmission Substations

Substation Site Development

Transmission substations shall be sited and designed to minimize impact to the surrounding environment and to meet all applicable environmental and regulatory requirements. Each shall be developed to accommodate the intended electrical purpose and sufficient property shall be provided to accommodate predicted growth and expansion throughout the anticipated planning horizon and as defined in the RFP.

The design and development of the substation property shall be completed with due consideration to the existing terrain and geotechnical conditions. Storm water management plans and structures must comply with all federal, state, and local regulations. The substation pad shall be graded such that it is at or above the 100-year flood level. Alternate methods to protect equipment will be considered.

Electrical Clearances

All design and working clearances shall meet the requirements of the NESC. Additional vertical clearance to conductors and bus shall be provided in areas where foot and vehicular traffic may be present. Phase spacing shall meet IEEE C37.32 and NESC requirements.

Structure Design Loads

Structures and foundations shall be designed to withstand the following combinations of gravity, wind, ice, conductor tension, and fault loads. The magnitudes of all weather-related loads, except for NESC or other legislated loads shall be based on a 100 year mean return period as defined in ASCE Manual of Practice (MOP) 113. NOTE: The load combinations and overload factors defined in ASCE MOP 113 or a similar documented procedure shall be used.

Line Structures and Shield Wire Poles

- NESC Grade B, Heavy Loading
- Other legislated loads
- Extreme wind applied at 90 degrees to the conductor and structure
- Extreme wind applied at 45 degrees to the conductor and structure
- Combined wind and ice loadings
- Extreme ice loading, based on regional weather studies

Equipment Structures and Shield Poles without Shield Wires

- Extreme wind, no ice
- Combined wind and ice loadings
- Forces due to line tension, fault currents and thermal loads

In the above loading cases, wind loads shall be applied separately in three directions (two orthogonal directions and at 45 degrees, if applicable).
Structure and Foundation Design

Structure and foundation design shall be based on the following, as appropriate:

- ASCE Standard No. 10, Design of Latticed Steel Transmission Structures
- ASCE Standard No. 48, Design of Steel Transmission Pole Structures
- ASCE Standard No. 113, Substation Structure Design Guide
- AISC 360 Specification for Structural Steel Buildings
- ACI 318

A site specific geotechnical study shall be the basis of the foundation design parameters.

Deflection of structures shall be limited such that equipment function or operation is not impaired, and that proper clearances are maintained. NOTE: The load combinations, overload factors, and deflection limits defined in ASCE MOP 113 or a similar documented procedure shall be used.

Grounding and Shielding

The substation ground grid shall be designed in accordance with the latest version of IEEE Std. 80, Guide for Safety in AC Substation Grounding, using the fault currents defined in the Minimum Design Fault Current Levels section.

All bus and equipment shall be protected from direct lightning strikes using the Rolling Sphere Method. IEEE Std. 998, Guide for Direct Lightning Stroke Shielding of Substations.

Surge protection shall be applied on all line terminals with circuit breakers and on all oil- or gas-filled electrical equipment in the substation such as transformers, but excluding instrument transformers and power PTs.

Bus Design

Substation bus shall be designed in accordance with IEEE Std. 605, Guide for Bus Design in Air Insulated Substations.

Bus Configuration

Substations shall be designed using the bus configurations shown in the table below. Each shall be developed to accommodate predicted growth and expansion (e.g., converting ring bus to a breaker and a half as terminals are added) throughout the anticipated planning horizon and as defined in the RFP.

Interrupting devices shall be used for two or more terminal lines above 300 kV.
Rating of Bus Conductors

Bus conductors shall be sized to carry the amperage defined in the following table, the anticipated power flow of the circuit, or that specified in the RFP, whichever is largest. The values shall be considered as minimum continuous ratings for both normal and emergency operating conditions.

<table>
<thead>
<tr>
<th>Voltage (kV)</th>
<th>Number of Terminals</th>
<th>Substation Arrangement</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 - 200</td>
<td>One or Two</td>
<td>Single Bus</td>
</tr>
<tr>
<td></td>
<td>Three to Six</td>
<td>Ring Bus</td>
</tr>
<tr>
<td></td>
<td>More than Six</td>
<td>Breaker-and-a-half</td>
</tr>
<tr>
<td>201 - 765</td>
<td>One to Four</td>
<td>Ring Bus</td>
</tr>
<tr>
<td></td>
<td>More than Four</td>
<td>Breaker-and-a-half</td>
</tr>
</tbody>
</table>

Consideration shall be given to metallurgical (losses, impedance), mechanical and corona performance, electrical system stability (voltage and stability), and for the effects of the high electric fields when selecting the size of bus conductors.

Conductors shall be selected such that they will lose no more than 10 percent of their original strength during the first fifty years of service when operated at their emergency rating.

The conversion to ampacity shall be based on **IEEE Publication No. 738, Standard for Calculating the Current-Temperature of Bare Overhead Conductors**, SPP Criteria 12.2.2, or other similar documented approaches.

The jumpers to bus equipment shall be rated to the same criteria as bus conductor.

Substation Equipment

All substation equipment should be specified such that audible sound levels at the edge of the substation property are appropriate to the facility’s location. Refer to IEEE 656 and IEEE C57 for guidance.
Basic Insulation Levels (BIL)

Substation insulators, power transformer bushings, potential transformer bushings, current transformer bushings, and power PTs shall meet the minimum BIL levels shown in the tables below. When placed in areas of heavy contamination (coastal, agricultural, and industrial), extra-creep insulators, special coatings to extra-creep porcelain insulators, or polymer insulators shall be used.

### Substation Insulators

<table>
<thead>
<tr>
<th>Nominal System L-L Voltage (kV)</th>
<th>BIL (kV Crest)</th>
<th>BIL (kV Crest) Heavy Contaminated Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>115 - 138</td>
<td>550</td>
<td>650 (Extra Creep)</td>
</tr>
<tr>
<td>161</td>
<td>650</td>
<td>750 (Extra Creep)</td>
</tr>
<tr>
<td>230</td>
<td>900</td>
<td>900 (Extra Creep)</td>
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<tr>
<td>345</td>
<td>1050</td>
<td>1300 (Extra Creep)</td>
</tr>
<tr>
<td>500</td>
<td>1550</td>
<td>1800 (Standard Creep)</td>
</tr>
<tr>
<td>765</td>
<td>2050</td>
<td>2050 (Standard Creep)</td>
</tr>
</tbody>
</table>

### Power Transformers, Potential Transformers and Current Transformers

<table>
<thead>
<tr>
<th>Nominal System L-L Voltage (kV)</th>
<th>Power Transformer Winding BIL (kV Crest)</th>
<th>Power PTs (kV Crest)</th>
<th>PT and CT BIL (kV Crest)</th>
<th>Circuit Breaker BIL (kV Crest)</th>
</tr>
</thead>
<tbody>
<tr>
<td>115</td>
<td>450</td>
<td>550</td>
<td>550</td>
<td>550</td>
</tr>
<tr>
<td>138</td>
<td>650 / 550</td>
<td>650</td>
<td>650</td>
<td>650</td>
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<td>161</td>
<td>650</td>
<td>650</td>
<td>650</td>
<td>650</td>
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<td>230</td>
<td>825 / 750</td>
<td>900</td>
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<td>1300</td>
<td>1300</td>
</tr>
<tr>
<td>500</td>
<td>1550 / 1425</td>
<td>N/A</td>
<td>1550 / 1800</td>
<td>1800</td>
</tr>
<tr>
<td>765</td>
<td>2050</td>
<td>N/A</td>
<td>2050</td>
<td>2050</td>
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</table>
Minimum Design Fault Current Levels

Substation equipment, bus, and ground grids shall be designed to withstand the larger of the actual available symmetrical fault current to accommodate predicted growth and expansion throughout the anticipated planning horizon. Design values will be determined from system models provided by SPP.

Minimum Rating of Terminal Equipment

The minimum current carrying capability of substation terminal equipment shall meet or exceed the values shown below.

<table>
<thead>
<tr>
<th>Voltage (kV)</th>
<th>Amps</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 - 200</td>
<td>1,200</td>
</tr>
<tr>
<td>230</td>
<td>1,200</td>
</tr>
<tr>
<td>345</td>
<td>3,000</td>
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<tr>
<td>500</td>
<td>3,000</td>
</tr>
<tr>
<td>765</td>
<td>4,000</td>
</tr>
</tbody>
</table>

Substation Service

Two source of AC substation service, preferred and backup shall be provided. This shall be accomplished by using the tertiary winding of an autotransformer, power PTs connected to the bus, distribution lines or a generator. Distribution lines shall not be used as a primary source unless no feasible alternative exists. Generators in no case shall be used as a primary source.

Control Enclosures

Control enclosures shall be designed in accordance with the applicable sections of the latest editions of the following:

- ASCE 7 Minimum Design Loads for Buildings and Other Structures
- AISC 360 Specification for Structural Steel Buildings
- AISI Specification for the Design of Cold-Formed Steel Structural Members
- ACI 530/530.1, Building Code Requirements and Specification for Masonry Structures and Related Commentaries
- ACI 318, Building Code Requirements for Structural Concrete and Commentary

Design loads and load combinations shall be based on the requirements of the International Building Code or as directed by the jurisdiction having authority. Weather loads shall be based on a 50 year mean return period.

Commented [TDP24]: Eliminated the original ratings (40 and 50kA) and replaced with this recommendation.

Commented [MH25]: PCWG Comment by Rob Christman, NextEra Energy Transmission: This term should be defined to specify which equipment is included. If bus conductors are included (because they are part of the terminal), then this paragraph conflicts with the previous paragraph that specifies the ratings of bus conductors.

Commented [MH26]: PCWG Comment by Rob Christman, NextEra Energy Transmission: This value is less than the 2000A minimum specified for transmission line and bus conductors. Is that intentional?

Commented [MH27]: PCWG Comment by Rob Christman, NextEra Energy Transmission: This value is less than the 2000A minimum specified for transmission line and bus conductors. Is that intentional?

Commented [TDP29]: Increased from 50 year.
Wall and roof insulation shall be supplied in accordance with the latest edition of the *International Energy Conservation Code* for the applicable Climate Zone.

**Oil Containment**

Secondary oil containment shall be provided around oil-filled electrical equipment and storage tanks in accordance with the requirements found in 40 CFR 112 of the United States EPA and local NERC requirements.
Transmission Protection and Control Design

General

Substation protection and control equipment must adhere to NERC Reliability Standards and SPP Criteria, and be compatible with the incumbent TO standards. It is the responsibility of the successful QRP to contact the incumbent TO(s) to ensure proper coordination of both coordination of the communication channel and the relay systems.

Communication Systems

Power Line Carrier (PLC) equipment or fiber shall be specified as the communication medium in pilot protection schemes. PLC equipment shall be used on existing transmission lines greater than five miles in length. Fiber protection schemes shall be considered on all new transmission lines being constructed using OPGW, unless an underground fiber or ADSS feed is provided. Compatible relays of the same manufacturer, shall be installed at both ends. Other forms of communication, such as microwave or tone, may be considered if compatible with the incumbent TO(s) equipment.

Voltage and Current Sensing Devices

For primary and secondary protection schemes, independent current transformers (CTs) shall be used for primary and backup protection schemes in addition to independent secondary windings of the same voltage source (CCVTs) shall be used.

DC Systems

For substations greater than 300 kV redundant battery systems shall be installed. DC systems shall be designed in accordance with NERC standards and SPP Criteria.
Primary and Secondary Protection Schemes

Primary and secondary protection schemes shall be required for all lines and be capable of detecting all types of faults on the line. The primary scheme shall provide high-speed, simultaneous tripping of all line terminals at speeds that will provide fault clearing times for system stability as defined in the most recent version of the NERC Transmission Planning and Reliability Standards (TPL-001 through TPL-004).

The following criteria shall be used to determine if one or two high speed protection systems are required on a line. While it is possible that the minimum protective relay system and redundancy requirements outlined below could change as NERC Planning and Reliability Standards evolve, it will be the responsibility of the project builder to assess the protection systems and make any necessary modifications to comply with these changes.

Line Applications:

765 / 500 kV

At least two high speed pilot schemes using a dual battery design, and dual direct transfer trip (DTT) using PLC and/or fiber are required. Protection communications require fully redundant paths. Power Line Carrier requires Mode 1 coupling (three phase coupling). Automatic checkback features shall be installed on PLC-based protection schemes using directional comparison blocking (DCB) to ensure the communication channel is working properly at all substations.

345 kV

Dual high speed pilot schemes using a dual battery design and one direct transfer trip (DTT) system using PLC and/or fiber are required. Dual DTT systems are required for direct equipment protection (transformers, reactors, capacitors) or if remote breaker failure protection cannot be provided with relay settings. Protection communications require fully redundant paths. Power Line Carrier requires single or two phase coupling. Automatic checkback features shall be installed on PLC-based protection schemes using directional comparison blocking (DCB) to ensure the communication channel is working properly at all substations.

Below 300 kV

A minimum of one high speed pilot scheme using PLC and/or fiber is required. Single phase couple for PLC is acceptable. DTT system is required if remote breaker failure protection cannot be provided with relay settings. Pilot schemes may be required for proper relay coordination or system dynamic performance requirements. When dual high speed systems are needed, fully redundant communication paths shall be used (PLC shall require two phase coupling). Dual DTT systems are required for direct equipment protection (transformers, reactors, capacitors). Automatic checkback features shall be installed on PLC-based protection schemes using directional comparison blocking (DCB) to ensure the communication channel is working properly at all substations. Where pilot scheme(s) are required, DTT is also required (for equipment and breaker failure protection) unless a utility stability study can show that high speed clearing is not required.
Transformer Applications:

**765 - 300/500 kV**

Transformer protection shall be designed with a dual station battery configuration, with the protection divided into two systems. Each system must provide differential protection schemes and have independent lockout relays. At least one system must provide: protection for internal differential (single phase application), highside and lowside lead differential, backup overcurrents, and sudden pressure. Transformer protection for three (3) single phase banks shall be designed with a dual station battery configuration, with the protection divided into two systems. The first system shall be an overall differential protection scheme. The second system shall provide protection for other needs such as internal differential, highside and lowside lead differential, backup overcurrents, sudden pressure and loss of cooling protection. The two protection systems shall be separated as much as is practicable.

**30045 kV - 100 kV**

The transformer protection shall be divided into two systems, an overall differential protection scheme, and a second system providing protection for other needs such as internal differential, highside and lowside lead differential, backup overcurrents, **and** sudden pressure, **and** loss of cooling protection.

Bus Applications:

**765 - 300 kV**

Bus protection shall be designed using a dual station battery configuration with the protection divided into two systems. Each system must provide differential protection schemes and have independent lockout relays.

**765 / 500 kV**

Bus protection shall be designed using a dual station battery configuration. Low impedance bus differential protection shall be used with the protection divided into two systems with their own dedicated lockout relay.

**Commented [MH32]:** Should we explicitly include breaker failure protection here?
345 / 230 kV

Low-impedance bus differential protection shall be used with the protection divided into two systems with their own dedicated lockout relay.

300 kV – 100 kV

Bus protection shall be designed with the protection divided into two systems. Each system must provide differential protection schemes and have independent lockout relays. Current summation (unrestrained differential) shall be used in new stations with the protection scheme divided into two systems with their own dedicated lockout relay. To improve reliability at these voltages, bus one-shot capabilities shall be provided when a capacitor bank is installed on the bus and its protection is not accounted for in the bus differential scheme. If bus fault levels are greater than 20kA, then high impedance or low impedance protection solutions must be used.

Other Substation Equipment

For substation devices, such as capacitor banks, Static VAR Compensators, reactors, appropriate protection systems shall be incorporated with due consideration of redundancy and flexibility to facilitate system operations and maintenance.

Sync Potential and Sync Scopes

Sync potential sources (wire wound PTs or CCVTs) and synchronizing equipment sync scopes shall be installed where required.

Disturbance Monitoring Equipment (DME) and Fault Recorders

DME shall be installed in accordance with the SPP criteria 7.0 on all new 230kV and above substations.

Fault Recorders

Fault Recorders shall be installed on all new 230kV and above substations.
Metering
Intertie metering shall be installed. Refer to SPP criteria 7.0 and the Interconnect Agreement with the incumbent TO(s).

Phase Measurement Units (PMUs)
PMUs, or Intelligent Electronic Devices (IEDs) capable of providing PMU measurements, shall be installed in all new 230 kV and above substations.

SCADA and RTUs
SCADA and RTUs, with the ability to retrieve fault records, shall be installed in all substations.

Commented [MH33]: Need to discuss
Commented [MH34]: Should this be included in the DME section
Commented [MH35]: Define communication protocols. Specifically DNP and ICCP
Scoping Requirements

This section describes the Scoping Requirements to be used by SPP when developing Conceptual Estimates and SEP's when developing Study Estimates for transmission facilities for the SPP footprint.

**Conceptual Estimate Scope Requirements**
*(Developed by SPP)*

**Transmission Line Projects**
- Description of project
- Approximate termination points of each transmission line (Point A to Point B)/Voltage
- Estimated Line Length
- Line Ampacity
- Need Date

**Transmission Substation Projects**
- Description of project
- Voltage
- Need Date
- Transformer requirements

**Study Estimate Scope Requirements**
*(Developed by the SEP)*

The Study Estimate Scope document should include the Conceptual Estimate Scope requirements in addition to the information listed below.

**Transmission Line Projects**
- Structures
  - Structure types - specify lattice structures, poles (wood, steel, concrete, etc.)
  - Number of storm structures, dead ends, running corners, tangents
  - Foundation information
- Number of circuits
- Conductor size, type and number/phase
- Static wire (EHS/OPGW)
- Protection control and communications
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- Type of terrain
- Switch requirements
- Legal requirements (e.g. CCN process)
- Geotechnical assumptions
- Special material requirements
- Preliminary line route (rough location when practical)
- Access road requirements
- Design criteria
  - Weather loading
  - Live line maintenance
  - Unbalanced structural loads
- Distribution/Joint Use requirements
- Right-of-Way
  - Right-of-Way acquisition
  - Right-of-Way clearing requirements
  - Right-of-Way width
- Permitting Concerns
  - Traffic control requirements
  - FAA Requirements
- Environmental Concerns
  - Environmental Study Requirements
  - Wetland Requirements/Mitigation
  - Threatened and Endangered Species Mitigation
  - Cultural/Historical Resource Requirements

Transmission Substation Projects

- Preliminary one-line diagram
- All major equipment, including rehab of existing equipment to meet the SPP project scope, i.e. Transformers, Breakers, Control panels, Switches, CTs, PTs, CCVTs
- BIL ratings
- Contamination requirements
- Mobile substation requirements
- Required substation property/fence expansions (indicating anticipated arrangement of proposed facilities and any resulting expansion needed)
Southwest Power Pool, Inc.

- Control enclosure expansions (indicating anticipated panel layout and any resulting expansion needed)
- Fiber optic requirements
- Remote end requirements
- Metering requirements
- Reactive Compensation requirements
- Wetland/T&E/Community Approval/Unusual site prep requirements.
- SCADA requirements
- Protection control and communications
Purpose and Objective

• **Purpose of Presentation**
  – To present a proposal for determining the following minimum design requirements for Open Transmission Projects
    • Ratings
    • Impedances
    • Bus Configurations

• **Objective of Presentation**
  – To solicit feedback on proposed methods for establishing minimum design requirements for Open Transmission Projects.
Background Information

• Per Order 1000 compliance for ROFR elimination, New Transmission Facilities associated with MEPs and MVPs approved in MTEP 14 and beyond may be competitively bid.
• In the past, the Transmission Owners have specified the design attributes of specific transmission facilities per the TOA and/or tariff.
• In the future, the Transmission Owners will continue to specify the design attributes for specific transmission facilities not subject to competitive bidding.
• However, for specific transmission facilities subject to competitive bidding, MISO must specify minimum design requirements since the specific Transmission Owner will not be known until bid award.
• This presentation provides a proposal for how MISO will accomplish this task.
Organization of Presentation

- Minimum Transmission Line Ratings
- Maximum Transmission Line Impedances
- Substation Bus Configurations and Position Assignments
- Minimum Substation Bus and Equipment Ratings
Minimum Transmission Line Ratings
Minimum Transmission Line Ratings

• Considerations
  – Voltage and Stability Loadability
  – Terminal Equipment Rating Classes
  – Transmission Owner Rating Standards
  – Duration Requirements for Emergency Ratings
Minimum Transmission Line Ratings
Voltage and Stability Loadability Constraints

• Three general limitations on transmission line loading:
  – Thermal
  – Voltage Drop
  – Angular Stability

• Voltage and stability loadability addresses voltage drop and angular stability.

• An upper bound on minimum ratings for EHV lines will be based on maximum expected voltage and stability loadability.
Minimum Transmission Line Ratings
St. Clair Curve

• The St. Clair curve expresses loadability as a percentage of Surge Impedance Loading (SIL) for various line lengths.
• The St. Clair curve was developed in 1953 based on practical considerations and empirical data.
• The curve has been refined and validated over the years by computational techniques, and is a good guideline for establishing ratings as a function of line length and voltage class assuming:
  – Voltage Drop Limitation of 5% (loadability driver for shorter lines)
  – Angular Stability Margin of 35% (loadability driver for longer lines).
• For EHV lines, MISO will use the St. Clair Curve to establish upper bounds on specified minimum ratings, and these upper bounds will apply both to normal and emergency ratings.
### Minimum Transmission Line Ratings
#### Upper Bounds on EHV Ratings

<table>
<thead>
<tr>
<th>Line Length (Miles)</th>
<th>% of SIL from St. Clair Curve</th>
<th>345 kV SIL (MW)</th>
<th>500 kV SIL (MW)</th>
<th>765 kV SIL (MW)</th>
<th>345 kV Min Rating Upper Bound (MVA)</th>
<th>500 kV Min Rating Upper Bound (MVA)</th>
<th>765 kV Min Rating Upper Bound (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;50</td>
<td>300%</td>
<td>450</td>
<td>1,000</td>
<td>2,400</td>
<td>1,350</td>
<td>3,000</td>
<td><strong>4,800</strong></td>
</tr>
<tr>
<td>50-100</td>
<td>200%</td>
<td>450</td>
<td>1,000</td>
<td>2,400</td>
<td>900</td>
<td>2,000</td>
<td>4,800</td>
</tr>
<tr>
<td>100-150</td>
<td>150%</td>
<td>450</td>
<td>1,000</td>
<td>2,400</td>
<td>675</td>
<td>1,500</td>
<td>3,600</td>
</tr>
<tr>
<td>150-200</td>
<td>130%</td>
<td>450</td>
<td>1,000</td>
<td>2,400</td>
<td>585</td>
<td>1,300</td>
<td>3,120</td>
</tr>
<tr>
<td>&gt;200</td>
<td>100%</td>
<td>450</td>
<td>1,000</td>
<td>2,400</td>
<td>450</td>
<td>1,000</td>
<td>2,400</td>
</tr>
</tbody>
</table>

**Note:** Upper bounds on minimum 765 kV Ratings will not exceed 2.0 SIL regardless of line length.
Minimum Transmission Line Ratings
Standard Terminal Equipment Rating Classes

• Principle 1:
  – Terminal equipment thermal ratings generally follow industry standards, but there are several rating classes available.
  – Therefore, minimum line ratings should align to some degree with industry standard terminal equipment rating classes to allow for the terminal equipment capability to be fully utilized if needed.

• Principle 2:
  – When thermal ratings dictate design requirements, it is prudent to have the most expensive component of a facility represent the limiting factor.
  – For transmission lines, this is typically the conductor, and conductor ratings generally do not align with terminal equipment standard rating classes.
  – Therefore, while minimum line ratings should align with terminal equipment rating classes, the limiting factor should generally be the conductor rating.
Minimum Transmission Line Ratings
Terminal Equipment Rating Alignment Example

• Assume terminal equipment items (breakers, switches, wave traps, etc.) are available with ratings of 2,000 A and 3,000 A.
• Assume conductors are available with ratings of 1,950 A; 2050 A; 2910 A; and 3,350 A.
• There are eight potential combinations of terminal equipment and conductor ratings.
• To meet the principles of aligning line ratings with terminal equipment standards and also maintaining the conductor as the limiting factor, the available choices are narrowed to two:
  – 1,950 A conductor and 2,000 A terminal equipment
  – 2,910 A conductor and 3,000 A terminal equipment
Minimum Transmission Line Ratings
Terminal Equipment Rating Considerations

• In determining minimum ratings for transmission lines, MISO will target a minimum rating value that is just below a standard terminal equipment rating.
• MISO proposes to apply 90% to the industry standard terminal equipment rating classes to establish minimum emergency rating targets.
• MISO also proposes to set minimum normal rating targets at 75% of the corresponding minimum emergency rating target.
• This methodology in conjunction with the upper bounds established based on line voltage and line length will significantly narrow the choices that must be made in determining minimum line ratings.
# Minimum Transmission Line Ratings

## TERC Emergency Rating Targets

<table>
<thead>
<tr>
<th>Typical Standard Terminal Equipment Rating Classes</th>
<th>115 kV (MVA @ 90% of TERC)</th>
<th>138 kV (MVA @ 90% of TERC)</th>
<th>161 kV (MVA @ 90% of TERC)</th>
<th>230 kV (MVA @ 90% of TERC)</th>
<th>345 kV (MVA @ 90% of TERC)</th>
<th>500 kV (MVA @ 90% of TERC)</th>
<th>765 kV (MVA @ 90% of TERC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200 A</td>
<td>215</td>
<td>258</td>
<td>301</td>
<td>430</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000 A</td>
<td>358</td>
<td>430</td>
<td>502</td>
<td>717</td>
<td>1,075</td>
<td>1,559</td>
<td>2,385</td>
</tr>
<tr>
<td>3000 A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,613</td>
<td>2,338</td>
<td>3,578</td>
</tr>
<tr>
<td>4000 A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4,770</td>
</tr>
</tbody>
</table>

**Note 1:** Rating targets apply to emergency ratings  
**Note 2:** TERC = Terminal Equipment Rating Class
EHV Minimum Ratings Table

- An EHV minimum line ratings table will be established based on the TERC Emergency Rating Targets table and the Upper Bounds on EHV Ratings table.
- Available minimum ratings will be established by voltage class and line length.
- If only one choice is available, it becomes the minimum emergency rating value.
- If multiple choices are available, more analysis will be required.
- MISO will also specify minimum SIL values for EHV lines as well that must be maintained within the proposed line design.
- Minimum normal ratings will be set at 75% of minimum emergency ratings.
## EHV Minimum Emergency Ratings Table

<table>
<thead>
<tr>
<th>Length (Miles)</th>
<th>345 kV &amp; 2000 A TERC</th>
<th>345 kV &amp; 3000 A TERC</th>
<th>500 kV &amp; 2000 A TERC</th>
<th>500 kV &amp; 3000 A TERC</th>
<th>765 kV &amp; 2000 A TERC</th>
<th>765 kV &amp; 3000 A TERC</th>
<th>765 kV &amp; 4000 A TERC</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;50</td>
<td>1,075</td>
<td>1,350</td>
<td>1,559</td>
<td>2,338</td>
<td>2,385</td>
<td>3,578</td>
<td>4,770</td>
</tr>
<tr>
<td>50-100</td>
<td>900</td>
<td>900</td>
<td>1,559</td>
<td>2,000</td>
<td>2,385</td>
<td>3,578</td>
<td>4,770</td>
</tr>
<tr>
<td>100-150</td>
<td>675</td>
<td>675</td>
<td>1,500</td>
<td>1,500</td>
<td>2,385</td>
<td>3,578</td>
<td>3,600</td>
</tr>
<tr>
<td>150-200</td>
<td>585</td>
<td>585</td>
<td>1,300</td>
<td>1,300</td>
<td>2,385</td>
<td>3,120</td>
<td>3,120</td>
</tr>
<tr>
<td>&gt;200</td>
<td>450</td>
<td>450</td>
<td>1,000</td>
<td>1,000</td>
<td>2,385</td>
<td>2,400</td>
<td>2,400</td>
</tr>
</tbody>
</table>

Minimum SIL Design Values Required for EHV Lines (with no series or shunt compensation):

- **345 kV**: 450 MW
- **500 kV**: 1,000 MW
- **765 kV**: 2,400 MW
HV Minimum Ratings Table

• An HV minimum line ratings table will be established based on the TERC Emergency Rating Targets table.

• Available minimum ratings will be established by voltage class.

• Minimum normal ratings will be set at 75% of minimum emergency ratings.
## HV Minimum Emergency Ratings Table

<table>
<thead>
<tr>
<th>Terminal Equipment Rating Class</th>
<th>115 kV (MVA)</th>
<th>138 kV (MVA)</th>
<th>161 kV (MVA)</th>
<th>230 kV (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200 A</td>
<td>215</td>
<td>258</td>
<td>301</td>
<td>430</td>
</tr>
<tr>
<td>2000 A</td>
<td>358</td>
<td>430</td>
<td>502</td>
<td>717</td>
</tr>
<tr>
<td>Typical SIL (MW)</td>
<td>50</td>
<td>60</td>
<td>75</td>
<td>150</td>
</tr>
<tr>
<td>1200 A (% of SIL)</td>
<td>430</td>
<td>430</td>
<td>401</td>
<td>287</td>
</tr>
<tr>
<td>2000 A (% of SIL)</td>
<td>717</td>
<td>717</td>
<td>669</td>
<td>478</td>
</tr>
</tbody>
</table>

**NOTE:** Since 2000 A loading is above 6.0 SIL for voltages below 200 kV, the default minimum limit for facilities below 200 kV will be based on the 1200 A rating class unless the line is very short in length (e.g., less than 10 miles) and/or there is significant load tapped off of the line such that the expected loading on the majority of the line is much lower than 2000 A.
Determining Minimum Line Ratings When Multiple Choices are Available

• Multiple minimum line rating targets are available for the following:
  – 115 kV to 161 kV transmission lines < 10 miles
  – 230 KV transmission lines
  – 345 kV transmission lines < 50 Miles
  – 500 kV transmission lines < 100 Miles
  – 765 kV transmission lines < 200 Miles

• A two step process will be used to determine the appropriate minimum line rating.
Determining Minimum Line Ratings
Step One of Two

• When multiple minimum rating targets are available, MISO will first determine answers to the following questions:
  – Is the transmission line internal to a single incumbent Transmission Owner footprint?
  – Does the incumbent Transmission Owner have a line rating standard for the voltage class in question?

• If the answer to both questions is “Yes”, MISO will select the minimum emergency rating target that is closest to the incumbent Transmission Owner standard rating, but not higher.
Determining Minimum Line Ratings  
Step Two of Two

- If one or more of the answers to the questions in Step 1 is “No”, then MISO will initially model the lower minimum rating target within the production cost models as the minimum rating.
- If the lower minimum rating does not provide for adequate congestion relief (acceptable B/C ratio, etc.) or the higher minimum rating would represent a significantly better project (higher B/C ratio and/or higher Value, etc.), then the higher minimum rating will be selected.
- Otherwise, the lower minimum rating will be selected.
Emergency Rating Duration Requirements

• MISO proposed to use 4 hours as the default minimum emergency rating duration.

• However, under specific operating circumstances, MISO reserves the right to increase this duration up to 12 hours if needed for any specific facility associated with an specific project.
Example 1

• A new 500 kV transmission circuit internal to an incumbent Transmission Owner system is determined to be the best solution to a set of congestion issues.
• The straight line distance between the two terminating substations is 62.5 miles, thus it is expected that the line length will be in the 50 to 100 mile range.
• The required design SIL for the line is specified as 1,000 MW.
• The EHV Minimum Emergency Line Ratings table indicates two available choices for minimum emergency line ratings:
  – 1,559 MW (2000 A terminal equipment)
  – 2,000 MW (3000 A terminal equipment)
Example 1 - Continued

• The incumbent Transmission Owner currently maintains a 500 kV emergency rating standard of 2,598 MVA for all new 500 kV transmission circuits.
• Therefore, the minimum emergency rating will be set at 2,000 MVA, which is the closest rating to the incumbent Transmission Owner standard without exceeding the incumbent Transmission Owner standard.
• The minimum normal emergency rating will be set at 1,500 MVA (75% of 2,000 MVA).
Example 2

- A new 345 kV transmission circuit interconnecting two incumbent Transmission Owner systems is determined to be the best solution to a set of congestion issues.
- The straight line distance between the two terminating substations is 49.3 miles, thus it is expected that the line length will be in the 50 to 100 mile range.
- The required design SIL for the line is specified as 450 MW.
- The EHV Minimum Emergency Line Ratings table indicates the minimum emergency rating must be 900 MVA.
- The minimum normal rating is set at 675 MVA (75% of 900 MVA).
Example 3

- A new 765 kV transmission circuit within a single incumbent Transmission Owner system is determined to be the best solution to a set of congestion issues.
- The straight line distance between the two terminating substations is 32.6 miles, thus it is expected that the line length will be less than 50 miles.
- The required design SIL for the line is specified as 2,400 MW.
- The EHV Minimum Emergency Line Ratings table indicates three available choices for minimum emergency line ratings:
  - 2,385 MVA (2000 A terminal equipment)
  - 3,578 MVA (3000 A terminal equipment)
  - 4,770 MVA (4000 A terminal equipment)
Example 3 - Continued

• The incumbent Transmission Owner does not have a standard rating for 765 kV transmission lines.
• Therefore, an emergency rating of 2,385 MVA is initially modeled in the economic models and is sufficient to remove all congestion.
• Therefore, the minimum emergency rating target will be set at 2,385 MVA.
• The minimum normal rating is set at 1,789 MVA (75% of 2,385 MVA).
Example 4

- A new 230 kV transmission circuit must be constructed as part of a much larger MEP.
- The new 230 kV transmission circuit will be constructed between two different incumbent Transmission Owner systems.
- The straight line distance between the two terminating substations is 17 miles, thus it is expected that the line length will be less than 50 miles.
- The HV Minimum Emergency Line Ratings table indicates two available choices for minimum emergency line ratings:
  - 430 MVA (1200 A terminal equipment)
  - 717 MVA (2000 A terminal equipment)
Example 4 - Continued

- Since the line involves multiple incumbent Transmission Owners, Step 1 is skipped and an emergency rating of 430 MVA is initially modeled.
- An emergency rating of 430 MVA does not provide for enough congestion relief in conjunction with other facilities to produce an acceptable B/C ratio.
- Therefore, a new minimum emergency rating of 717 MVA is modeled and the estimated cost of the project is adjusted accordingly.
- The new rating provides enough additional benefit to just the project with an acceptable B/C ratio.
Example 4 - Continued

- Therefore, the minimum emergency rating target will be set at 717 MVA.
- The minimum normal rating is set at 538 MVA (75% of 717 MVA).
Maximum Transmission Line Impedances
Overall Background and Approach

• The tariff specifically provides MISO with the ability to specify maximum impedances for transmission lines if there is a planning driver.
• MISO proposes to specify a maximum impedance for all proposed transmission circuits subject to competitive bidding as follows:
  – If production cost modeling indicates that the effectiveness of a project is subject to a maximum impedance, then one will be specified. This scenario is not expected to occur very often.
  – As a default, MISO will specify a maximum impedance for all EHV lines that will maintain acceptable stability margins given the specification of an emergency rating since this tends to be the loadability driver for longer lines.
Maximum Impedance as a Function of the Angular Stability Margin

• As stated earlier, the St. Clair curve has been validated assuming an angular stability margin of 35%, where the angular stability margin for a specified rating is defined as follows:

  – Angular Stability Margin = \[
  \frac{\text{Pmax} - \text{Rating}}{\text{Pmax}}
  \]

  – \text{Pmax} = \frac{|\text{Vs}| \cdot |\text{Vr}| \cdot \sin(\delta)}{|\text{Zl}|}

  where
  
  \begin{align*}
  \text{Vs} &= \text{Sending end voltage} \\
  \text{Vr} &= \text{Receiving end voltage} \\
  \delta &= \text{Angular displacement between Vs and Vr} \\
  \text{Zl} &= \text{Line impedance}
  \end{align*}
Maximum Impedance as a Function of the Angular Stability Margin

- The maximum impedance to achieve a specific angular stability margin would be set equal to the following in per unit assuming $|V_s| = |V_r| = 1.0$ and $\delta = 90^\circ$:

  $$|Z_{\text{max}}| = \frac{1 - \text{Angular Stability Margin}}{\text{Rating}}$$

- An angular stability margin of 35% is typical and is used in the validation of the St. Clair curve.
- An angular stability margin of 35% will be used to set maximum impedances for 345 kV and 500 kV lines.
- For 765 kV lines, an angular stability margin of 50% will be used since the equivalent system impedances at the line terminals are often not negligible when determining angular stability loadability for the 765 kV voltage class.
Maximum Impedance as a Function of the Angular Stability Margin

Using the line rating as the Base MVA, the maximum impedances in per unit for 345 kV, 500 kV, and 765 kV transmission lines are as follows:

- 345 kV: $|Z_{max}| = 1 - 0.35 = 0.65$ per unit
- 500 kV: $|Z_{max}| = 1 - 0.35 = 0.65$ per unit
- 765 kV: $|Z_{max}| = 1 - 0.50 = 0.50$ per unit
## EHV Default Maximum Impedance Table

<table>
<thead>
<tr>
<th>345 kV Min Rating (MVA)</th>
<th>345 kV Zmax (Ohms)</th>
<th>500 kV Min Rating (MVA)</th>
<th>500 kV Zmax (Ohms)</th>
<th>765 kV Min Rating (MVA)</th>
<th>765 kV Zmax (Ohms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>172</td>
<td>1,000</td>
<td>163</td>
<td>2,385</td>
<td>123</td>
</tr>
<tr>
<td>585</td>
<td>132</td>
<td>1,300</td>
<td>125</td>
<td>2,400</td>
<td>122</td>
</tr>
<tr>
<td>675</td>
<td>115</td>
<td>1,500</td>
<td>108</td>
<td>3,120</td>
<td>94</td>
</tr>
<tr>
<td>900</td>
<td>86</td>
<td>1,559</td>
<td>104</td>
<td>3,578</td>
<td>82</td>
</tr>
<tr>
<td>1,075</td>
<td>72</td>
<td>2,000</td>
<td>81</td>
<td>3,600</td>
<td>81</td>
</tr>
<tr>
<td>1,350</td>
<td>57</td>
<td>2,338</td>
<td>70</td>
<td>4,770</td>
<td>61</td>
</tr>
</tbody>
</table>
Substation
Bus Configurations
and
Position Assignments
Bus Configurations and Position Assignments
General Background

• In the past, the TOA and tariff have stipulated that facility design decisions are assigned solely to the Transmission Owners.
• For future projects where ROFR is eliminated, concerns have been raised by Transmission Owners and other stakeholders that MISO may need to specify limitations for bus configurations and capabilities.
• Therefore, based on approved tariff language, MISO will specify limitations and/or requirements regarding bus configurations and bus capabilities when there is a "planning driver".
• The presentation today provides examples of situations where MISO may do additional planning and/or operational studies to determine if constraints on bus configurations or position assignments are needed to ensure reliability and operational flexibility.
A single bus fault (NERC TPL 001-4: P2-2) would require tripping of breakers A, B, C, D, and E; which in turn would open five transmission circuits.

Other contingencies causing five open transmission circuits with a straight bus include P2-3 (internal breaker fault) and P4 (breaker failure).

Routine circuit breaker maintenance requires an open transmission circuit unless a transfer breaker is employed.

In developing MEPs or MVPs, MISO will assess on a case by case basis the potential impact on reliability, operational flexibility, and future standards compliance of a straight bus to determine if it would be desirable to disallow this bus configuration for a specific New Substation Facility associated with a specific Open Transmission Project.
Scenario 1

- Assume Lines 1 and 2 connect to a remote generation plant, Lines 3 and 4 connect to a common remote load area, and Transformer 5 connects to a local load area.
- Assume also that Beaker A is out for maintenance during off peak conditions.
- A fault and subsequent outage occurs on Transformer 5 (NERC TPL 001-4: P1-3 contingency) resulting in one open branch (TX 5) and a bus split (Lines 1 and 2 disconnected from Lines 3 and 4) due to Breakers A, D, and E all being in an open position.
- This scenario effectively results in an N-5 condition since Lines 1 and 2 are isolated from Lines 3 and 4.
- In developing MEPs or MVPs, MISO will assess on a case by case basis the potential impact on reliability, operational flexibility, and future standards compliance of scenarios such as this to determine if it would be desirable to i) disallow this bus configuration in a TPR or ii) specify position assignment constraints in a TPR that would mitigate or prevent a scenario such as this one.
Ring Bus Configuration Analysis Example
Scenario 2

- Assume Lines 1 and 2 connect to a remote generation plant while Lines 3, 4, and 5 connect to a common remote load area.
- Assume also that Line 3 is out for maintenance during off peak conditions and that breakers A and C, and their line side disconnects, must be open since there is no line sectionalizing switch on Line 3.
- A fault and subsequent outage on Line 5 (NERC TPL 001-4: P1-2 contingency) results in three branch outages (Line 3 and 5 out with Line 4 open) due to Breakers A, C, D and E all being in an open position.
- This scenario **effectively** results in an N-5 condition since Lines 1 and 2 are from the same bus.
- In developing MEPs or MVPs, MISO will assess on a case by case basis the potential impact on reliability, operational flexibility, and future standards compliance of scenarios such as this to determine if it would be desirable to i) disallow this bus configuration in a TPR, ii) specify position assignment constraints in the TPR that would mitigate or prevent a scenario such as this one, and/or iii) require line sectionalizing switches in the TPR for ring buses if allowed.
Ring Bus Configuration Analysis Example
Scenario 3

- Assume breaker B is out for maintenance during off peak conditions.
- A forced outage occurs on Lines 3 and 5 due to a NERC TPL 001-4 P6 contingency (two overlapping singles) or a NERC TPL 001-4 P7 contingency (common structure).
- This scenario will result in an N-5 condition since Lines 3 and 5 are out and Lines 1, 2 and 3 are open (i.e., all five breakers will be open).
- In developing MEPs or MVPs, MISO will assess on a case by case basis the potential impact on reliability, operational flexibility, and future standards compliance of scenarios such as this to determine if it would be desirable to disallow the ring bus configuration.
Assume Lines 1, 2, and 3 connect to remote generation in the west and, Lines 4, 5, and 6 connect to remote load in the east.
Assume also that Beaker A is out for maintenance during off peak conditions.
Assume also that the western generation is baseload and loading at the substation is consistent on a year round basis.
The loading on circuit breaker F for this situation will be equal to the sum of the loads flowing in on Lines 1, 2, and 3 from the western generation or the loads flowing out on Lines 4, 5, and 6 to the eastern load.
This creates a potential loading issue on circuit breaker F which must carry the load of three lines, and possibly on circuit breakers D and E which must each carry the load of two transmission lines.
In developing MEPs or MVPs, MISO will assess on a case by case basis the potential impact on station equipment loading of scenarios such as this to determine if it would be desirable to i) disallow the ring bus configuration or ii) establish position assignment constraints.
Breaker-and-a-Half & Double-Breaker Bus Configurations

- It is important to note that a breaker-and-a-half or double breaker bus configuration requires a minimum of three connections between the two main buses
  - Double buses connected together via only one connection are really straight buses
  - Double buses connected together via only two connections are really ring buses

- A pure breaker-and-a-half bus configuration requires an even number of positions with a minimum of six.

- A pure double breaker configuration can have an even or odd number of positions with a minimum of three.

- Often time a double bus configuration represents a combination of a breaker-and-a-half and double-breaker bus. For example, a four position combination bus may have two double-breaker positions and two breaker-and-a-half positions in a common three breaker string.
Breaker-and-a-Half Bus Configuration
Scenario 1

- Assume breaker A is out for maintenance during off peak conditions.
- If Lines 1 and 2 tie to the same general area, it is likely that the flow direction on the two lines will be the same.
- This could create a loading issue on breaker C which must carry the load of two transmission lines (would not be an issue if the flow directions were opposite and breaker C carried the net difference).
- In addition a TPL-001-4 P2-2 contingency on Line 2 would also disconnect Line 1 from the substation, and if both lines are from the same general area (source lines from the same generation area or sink lines to the same load area), this could complicate the impact of a single contingency.
- In developing MEPs or MVPs, MISO will assess on a case by case basis the potential impact on station equipment loading, reliability, and operational flexibility of scenarios such as this to determine if it would be desirable to specify position assignment constraints for the bus configuration.
Assume a bus fault occurs on the north bus during on peak conditions.
If Lines 1 and 2 tie to the same general area, it is likely that the flow direction on the two lines will the same. The same is true for Lines 3 and 4 or Lines 5 and 6.
This could create a loading issue on breakers C, F, and/or I which must carry the load of two transmission lines.
In developing MEPs or MVPs, MISO will assess on a case by case basis the potential impact on station equipment loading of scenarios such as this to determine if it would be desirable to specify position assignment constraints for the bus configuration.
Minimum Substation
Bus and Equipment
Ratings
Types of Substation Bus and Equipment Minimum Ratings to be Specified

- Power Transformer Minimum Load Ratings
- Terminal Equipment Minimum Load Ratings
- Circuit Breaker Assembly Minimum Load Ratings
- Bus Minimum Load Ratings
Power Transformer Minimum Ratings

- Power transformer minimum ratings will be determined in a manner similar to how line ratings are determined with the following exceptions:
  - There will be no voltage and stability loadability analysis, but the maximum transformer impedance will be specified to allow for a 35% angular stability margin at the minimum transformer rating.
  - Instead of using industry standard terminal equipment rating classes, power transformer minimum rating targets will be driven by industry standard nameplate transformer ratings.
  - Transformer Owner standards regarding transformer ratings will be used if all lines terminating at the New Substation Facility are owned by the same Transmission Owner and the Transmission Owner has such a standard.
  - Minimum normal ratings will be set equal to minimum emergency ratings.
## Power Transformer Minimum Ratings

### Industry Standard Available Choices

<table>
<thead>
<tr>
<th>X Winding</th>
<th>H Winding 230 kV</th>
<th>H Winding 345 kV</th>
<th>H Winding 500 kV</th>
<th>H Winding 765 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-200 kV</td>
<td>10,11,12,13,14</td>
<td>5,6,7,8,9</td>
<td>5,6,7,8,9</td>
<td>5,6,7</td>
</tr>
<tr>
<td>230 kV</td>
<td>N/A</td>
<td>3,4,5,6,7</td>
<td>3,4</td>
<td>3,4</td>
</tr>
<tr>
<td>345 kV</td>
<td>N/A</td>
<td>N/A</td>
<td>3,4</td>
<td>1,2</td>
</tr>
<tr>
<td>500 kV</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>1,2</td>
</tr>
</tbody>
</table>

**Available Ratings:**

1 = 2,250 MVA  
2 = 1,500 MVA  
3 = 840 MVA  
4 = 750 MVA  
5 = 700 MVA*  
6 = 672 MVA*  
7 = 600 MVA  
8 = 560 MVA*  
9 = 500 MVA  
10 = 448 MVA*  
11 = 400 MVA  
12 = 336 MVA*  
13 – 300 MVA  
14 = 224 MVA*

*NOTE: It is acceptable to maintain an off-site spare that is the next lower size. For example, a 500 MVA off-site spare is acceptable for a 560 MVA transformer minimum emergency rating.*
Power Transformer Minimum Ratings

Example 1

• A New Substation Facility connects between an existing 345 kV transmission line and an existing double circuit 138 kV transmission line.
• All interconnecting transmission lines are owned by the same Transmission Owner
• The Transmission Owner maintains a standard rating for all new 345-138 kV transformer of 560 MVA.
• The minimum emergency rating for the power transformer will be specified as 560 MVA (and this is the rating that would be modeled in the planning process).
Power Transformer Minimum Ratings
Example 2

• A New Substation Facility connects between an existing 765 kV transmission line and an existing double circuit 345 kV transmission line.
• The 765 kV transmission line and 345 kV transmission line are owned by different Transmission Owners.
• A 1,500 MVA standard rating is modeled in the economic studies and is sufficient to address all congestion.
• The minimum emergency rating for the power transformer would be specified as 1,500 MVA.
Terminal Equipment Minimum Ratings

• The terminal equipment minimum ratings will be set equal to the minimum ratings applied to the terminating line or power transformer.

• It is not expected that a New Substation Facility associated with an MEP or MVP would terminate a generator, but to the extent it does, the terminal equipment minimum normal and emergency rating will be set equal to the MVA nameplate rating of the installed generator.

• Special situations such as HVDC converters, series capacitors and reactors, phase angle regulators, and similar branch types will be handled on a case-by-case basis.
Circuit Breaker Assembly Definitions

• **Straight Buses**
  – When a straight bus is used, circuit breakers and associated series equipment are in series with the branch and thus are considered terminal equipment.
  – Therefore, circuit breaker assemblies are not applicable to straight bus configurations.

• **Ring Buses**
  – For a ring bus, a breaker assembly is defined as all series equipment between the two points where branches in adjacent positions connect to the ring bus.
  – This includes circuit breakers, disconnect switches, bus conductor, lead conductors, connectors, current transformers, current transformer secondary burdens, and other applicable series load carrying equipment.

• **Double Buses (Breaker-and-a-Half and/or Double-Breaker)**
  – For a double bus configuration, a breaker assembly is defined as all series equipment between the two points where branches in adjacent positions connect to the bus if the middle breaker in a breaker-and-a-half configurations, or between one of the main buses and the point where the branch in the adjacent position connects to the bus work if an outer breaker in a breaker-and-a-half configuration or a double-breaker configuration.
  – This includes circuit breakers, disconnect switches, bus conductor, lead conductors, connectors, current transformers, current transformer secondary burdens, and other applicable series load carrying equipment.
Circuit Breaker Assembly
Ring Bus Illustration

Breaker A Assembly

Breaker B Assembly

Breaker C Assembly

Breaker D Assembly
Circuit Breaker Assembly
Double Bus Illustration

Breaker A Assembly

Breaker B Assembly

Breaker C Assembly

Breaker D Assembly

Breaker E Assembly

Breaker F Assembly

Breaker G Assembly
Circuit Breaker Assembly
Minimum Ratings

• For a ring bus, the minimum emergency ratings of a circuit breaker assembly will be set equal to the smallest industry standard terminal equipment rating class that is equal to or greater than the minimum emergency ratings of all positions within the ring bus and the minimum normal rating will be set at 75% of the minimum emergency rating.

• For a double bus, the minimum ratings of a circuit breaker assembly will be set equal to the smallest industry standard terminal equipment rating class that is equal to or greater than the minimum ratings of all positions in a common breaker string between the two main buses and the minimum normal rating will be set at 75% of the minimum emergency rating.

• Circuit breaker assembly minimum rating targets are established based on terminal equipment rating classes because the circuit breaker is generally the most expensive component in a circuit breaker assembly, and should thus be the limiting factor.
Circuit Breaker Assembly
Minimum Ratings – Example 1

• Assume a TPR allows for a ring bus in a New Substation Facility that includes a 345 kV bus terminating three transmission circuits and one transformer.

• Assume the following minimum emergency ratings apply to the branches that terminate on the 345 kV bus:
  – Circuit 1: 1,350 MVA
  – Circuit 2: 1,350 MVA
  – Circuit 3: 900 MVA
  – Transformer 1: 560 MVA

• The lower bound for the emergency ratings is 1,350 MVA or 2,259 A at 345 kV.

• Therefore, minimum circuit ratings will be set as follows:
  – Minimum Emergency Rating: 3,000 A (1,792 MVA)
  – Minimum Normal Rating: 2,250 A (1,344 MVA)
Circuit Breaker Assembly
Minimum Ratings – Example 2

• Assume a TPR allows for a breaker-and-a-half bus in a New Substation Facility that includes a 765 kV bus terminating six transmission circuits.
• Assume the following minimum emergency ratings apply to the branches that terminate on the 765 kV bus:
  – Breaker String A: Circuit 1 = 3,578 MVA, Circuit 2 = 3,578 MVA
  – Breaker String B: Circuit 3 = 4,770 MVA, Circuit 4 = 3,578 MVA
  – Breaker String C: Circuit 5 = 3,578 MVA, Circuit 6 = 2,400 MVA
• The lower bound for the emergency ratings is as follows:
  – Breaker String A: 3,578 MVA
  – Breaker String B: 4,770 MVA
  – Breaker String C: 3,578 MVA
• Therefore, minimum circuit ratings will be set as follows:
  – Minimum Emergency Ratings (String A and C): 3,000 A (3,975 MVA)
  – Minimum Emergency Ratings (String B): 4,000 A (5,300 MVA)
  – Minimum Normal Ratings (String A and C): 2,250 A (2,981 MVA)
  – Minimum Normal Ratings (String B): 3,000 A (3,975 MVA)
Circuit Breaker Assembly
Minimum Ratings – Final Comments

• MISO will always reserve the right to increase minimum breaker assembly ratings if necessary, such as situations where loading patterns are variable and position assignments cannot always be made to accommodate the default minimum rating methodology.

• However, in no case will MISO recommend a minimum emergency rating for a breaker assembly that exceeds commercially available ratings for circuit breakers and other equipment of the voltage class in question.
Main Bus Minimum Ratings

• Main buses include:
  – Straight buses
  – One of two buses used in double bus configurations

• A separate but similar methodology is proposed to specify minimum emergency ratings for straight buses and buses used in double bus configurations based on the concept of Bus MVA Transfer
Main Bus Minimum Ratings

Bus MVA Transfer

The bus MVA transfer is the amount of MVA transferred into and out of a bus and is determined via the following formula:

\[
\text{Bus MVA Transfer} = \sum \{|S_i|\} / 2
\]

where

\[i = \text{Index of all generators, branches, shunts, and tie breakers connected to the bus}\]

\[S_i = \text{Magnitude of MVA for connected facility } i\]
The Bus MVA Transfer is calculated by summing the magnitudes of the MVAs for each bus connection, regardless of MW or MVAR flow direction, and then dividing by 2.

\[
\text{Bus MVA Transfer} = \frac{(427.1 + 879.5 + 590.1 + 498.3 + 551.3 + 31.3 + 36.2 + 96 + 600)}{2}
\]

\[
\text{Bus MVA Transfer} = 1,854.9 \text{ MVA}
\]

This is a conservative approximation for the theoretical worst case load for all bus segments regardless of position assignments.
Main Bus Minimum Ratings
Straight Bus Methodology

• The straight bus minimum emergency ratings will be set at the greater of the following:
  – 150% of the highest emergency rating for all branches, tie breakers, generators, and shunts terminating at the straight bus.
  – 150% of the highest bus MVA transfer projected for the long-term planning horizon based on power flow cases and contingency sets evaluated in the bottom-up planning process.

• The 150% factor applied to the highest emergency rating or calculated Bus MVA Transfer ensures a margin for future load growth and a safety margin for unanticipated scenarios or extreme events.

• Normal ratings are determined in the same manner, but Bus MVA Transfer is determined for N-0 conditions only.
Main Bus Minimum Ratings
Straight Bus Example

• Assume a straight bus terminates four 230 kV transmission lines with a minimum emergency rating of 430 MVA and one 500-230 kV transformer with an emergency rating of 840 MVA.

• Assume that the highest emergency Bus MVA Transfer is calculated in the long-term planning horizon to be 995 MVA.

• Assume that the highest normal Bus MVA Transfer is calculated in the long-term planning horizon to be 740 MVA.

• The minimum emergency bus rating would be specified as follows:
  – 150% of Highest Emergency Rating = 1.5 * 840 MVA = 1,260 MVA
  – 150% of Highest Emergency Bus MVA Transfer = 1.5 * 995 MVA = 1,493 MVA
  – Minimum Emergency Rating for Straight Bus = 1,493 MVA

• The minimum normal bus rating would be specified as follows:
  – 150% of Highest Normal Rating = 1.5 * 840 MVA = 1,260 MVA
  – 150% of Highest Normal Bus MVA Transfer = 1.5 * 740 MVA = 1,110 MVA
  – Minimum Normal Rating for Straight Bus = 1,260 MVA
Main Bus Minimum Ratings
Double Bus Methodology

• The double bus minimum emergency ratings will be set at the greater of the following:
  – 150% of the highest emergency rating for all branches and generators terminating at any position in the double bus configuration.
  – 100% of the highest Bus MVA transfer projected for the long-term planning horizon based on power flow cases and contingency sets evaluated in the bottom-up planning process with both buses in service.
  – 150% of the highest Bus MVA transfer projected for the long-term planning horizon based on power flow cases evaluated in the bottom-up planning process with one main bus out of service and no other contingencies.

• The 150% factor applied to the highest emergency rating or calculated Bus MVA Transfer with one bus out ensures a margin for future load growth and a safety margin for unanticipated scenarios or extreme events.

• The 100% factor applied to the highest Bus MVA transfer with both buses in service accounts for the fact that there will be distribution between the two buses, thus the 150% factor is not needed.

• Normal ratings are determined in the same manner, but Bus MVA Transfer is determined for N-0 conditions only and the one-bus out contingency is not included.
Main Bus Minimum Ratings

Double Bus Example

• Assume a double-bus / breaker-and-a-half configuration terminates six 345 kV transmission lines with a minimum emergency rating of 1,350 MVA each.

• Assume that the highest emergency Bus MVA Transfer is calculated in the long-term planning horizon to be 2,215 MVA.

• Assume that the highest normal Bus MVA Transfer is calculated in the long-term planning horizon to be 1,215 MVA.

• The minimum emergency bus rating would be specified as follows:
  – 150% of Highest Emergency Rating = 1.5 * 1,350 MVA = 2,025 MVA
  – 100% of Highest Emergency Bus MVA Transfer = 1.0 * 2,215 MVA = 2,215 MVA
  – 150% of Highest Normal Bus MVA Transfer = 1.5 * 1,215 MVA = 1,823 MVA
  – Minimum Emergency Rating for Straight Bus = 2,215 MVA

• The minimum normal bus rating would be specified as follows:
  – 150% of Highest Normal Rating = 1.5 * 0.75 * 1,350 MVA = 1,519 MVA
  – 100% of Highest Normal Bus MVA Transfer = 1.0 * 1,215 MVA = 1,215 MVA
  – Minimum Normal Rating for Straight Bus = 1,519 MVA
Next Steps
Next Steps

• Please provide written comments and feedback to MISO by November 7, 2014.

• MISO will return to the PSC in December to review feedback and present proposed BPM language to the PSC regarding minimum design requirements.

• MISO Contact:
  – mtackett@misoenergy.org