

Working Paper
on a
Proposed Transmission Relay Loadability
Standard



North American Electric Reliability Council

Prepared by the
System Protection and Control Task Force
of the
NERC Planning Committee

Approved by the NERC Planning Committee
for Submittal to
NERC Standards Authorization Committee

December 7, 2005

Introduction

This “Working Paper on a Proposed Transmission Relay Loadability Standard” was prepared by the NERC Planning Committee’s System Protection and Control Task Force. It provides a proposed draft standard on transmission relay loadability using the NERC Standards Development Process format for NERC reliability standards.

The purpose of the proposed standard is to ensure that protection systems and settings shall not limit transmission loadability, nor contribute to cascading outages. This transmission relay loadability recommendation is based on NERC Blackout Recommendation 8a, Improve System Protection to Slow or Limit the Spread of Future Cascading Outages, as included in the NERC Board of Trustees approved February 10, 2004 document, “August 14, 2003 Blackout: NERC Actions to Prevent and Mitigate the Impacts of Future Cascading Blackouts,” and the U.S.-Canada Power System Outage Task Force Recommendation 21A, Make More Effective and Wider Use of System Protection Measures, as included in the task force’s April 2004 report, “Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations.”

The proposed transmission relay loadability standard attempts to codify the requirements and criteria used to implement the above NERC and U.S.-Canada Power System Outage Task Force relay recommendations.

The purpose of this working paper is to provide assistance to the NERC Standards Authorization Committee in its consideration of the proposed standard authorization request on transmission relay loadability approved by the NERC Planning Committee at its December 7, 2005 meeting. It may also be useful to any SAC-assigned SAR or standard drafting team.

Standard Development Roadmap

This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

Development Steps Completed:

1. Briefly list the major steps completed, such as appointment of a drafting team, each draft of the SAR or standard that was posted, consideration of comments posted, field testing, ballots, etc.
- 2.

Description of Current Draft:

This is the initial draft of the Transmission Relay Loadability Standard. It codifies the relay loadability criteria embodied in the NERC Recommendation 8a, *Improve System Protection to Slow or Limit the Spread of Future Cascading Outages*, and U.S.–Canada Power System Outage Task Force Recommendation 21A, *Make More Effective and Wider Use of System Protection Measures*.

Future Development Plan:

| Anticipated Actions | Anticipated Date |
|--|------------------|
| 1. Present this draft to the Planning Committee for approval for submission to the Standards Authorization Committee as part of a Standards Authorization Request. | December, 2005 |
| 2. | |
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Definitions of Terms

Emergency Ampere Rating: “The highest seasonal ampere circuit rating (that most closely approximates a 4-hour rating) that must be accommodated by relay settings to prevent incursion.” That rating will typically be the winter short-term (four-hour) emergency rating of the line and series elements. The line rating should be determined by the lowest ampere rated device in the line (conductor, airswitch, breaker, wavetrapped, series transformer, series capacitors, reactors, etc) or by the sag design limit of the transmission line for the selected conditions. The relay evaluation should use whatever ampere rating currently used that most closely approximates a 4-hour rating.

Operationally Significant Circuits: The Regional Reliability Organizations (RROs) are responsible for the determination of Operationally Significant Circuits, which include all of the following:

- All circuits that are elements of Flowgates in the Eastern Interconnection, Commercially Significant Constraints in the Texas Interconnection, or Rated Paths in the Western Interconnection. This includes both the monitored and outage element for Outage Transfer Distribution Factor (OTDF) sets.
- All circuits that are elements of system operating limits (SOLs) and interconnection reliability operating limits (IROLs), including both monitored and outage elements.
- All circuits that are directly related to off-site power supply to nuclear plants. Any circuit that adversely impacts voltages on the off-site power bus at a nuclear plant by its outage must be included, regardless of its proximity to the plant.
- Other circuits determined and agreed to by the reliability authority/coordinator and the RROs.

Transmission Protection System Owners (TPSOs): Entities that own and/or operate protective relaying systems applied to protect transmission facilities operated at 100 kV and above, including transformer banks with low-voltage terminals operated at 100 kV and above.

A. Introduction

1. **Title: Transmission Relay Loadability**
2. **Number:** PRC-___-1
3. **Purpose:** To ensure that protection systems and settings shall not limit transmission loadability, nor contribute to cascading outages.
4. **Applicability**
 - 4.1. This standard pertains to phase protection systems applied to:
 - 4.1.1 Transmission lines operated at 200 kV and above
 - 4.1.2 Transmission lines operated at 100 kV to 200 kV, identified by the Region as Operationally Significant Circuits.
 - 4.1.3 Transformers with low voltage terminals connected at 200 kV and above voltage levels
 - 4.1.4 Transformers with low voltage terminals connected at 100 kV to 200 kV, identified by the Region as Operationally Significant Circuits.
 - 4.2. Any protective functions which could trip with or without time delay, on normal or emergency load current, including but not limited to:
 - 4.2.1 Phase distance
 - 4.2.2 Out-of-step tripping
 - 4.2.3 Out-of-step blocking
 - 4.2.4 Switch-on-to-fault
 - 4.2.5 Overcurrent relays
 - 4.2.6 Communications aided protection schemes including but not limited to:
 - 4.2.6.1 Permissive overreach transfer trip (POTT)
 - 4.2.6.2 Permissive under-reach transfer trip (PUTT)
 - 4.2.6.3 Directional comparison blocking (DCB)
 - 4.3. The following protection systems are excluded from requirements of this standard:
 - 4.3.1 Relay elements that are only enabled when other relays or associated systems fail.
 - 4.3.1.1 Overcurrent elements that are only enabled during loss of potential conditions.
 - 4.3.1.2 Elements that are only enabled during a loss of communications.
 - 4.3.2 Protection systems intended for the detection of ground fault conditions.
 - 4.3.3 Protection systems intended for protection during stable power swings.
 - 4.3.4 Generator protection relays that are susceptible to load.
 - 4.3.5 Relays elements used only for special protection systems, applied and approved in accordance with NERC Reliability Standards PRC-012 through PRC-017.
 - 4.4. This standard applies to the following entities:

- 4.4.1** Regional Reliability Organizations.
- 4.4.2** Transmission Owners that are Transmission Protection System Owners (TPSOs).
- 4.4.3** Generation Owners that are TPSOs.
- 4.4.4** Distribution Providers that are TPSOs.

5. (Proposed) Effective Dates:

- 5.1.** For circuits described in 4.1.1 and 4.1.3 above — January 1, 2008
- 5.2.** For circuits described in 4.1.2 and 4.1.4 above — July 1, 2008

B. Requirements

R1. Protection system applications and settings shall not limit transmission use. All transmission relays shall be set to ensure that transmission facilities are not unnecessarily interrupted during system disturbances when operator action within the first 15 minutes could alleviate potentially damaging overloads or prevent cascading outages.

R1.1. The desired emergency loadability of a transmission line may be limited by the conductor thermal capability, maximum power transfer, or series capacitor emergency rating. Any one of the following may be used to determine the required phase protective relay loadability:

R1.1.1. Transmission line relays shall not operate at or below 150% of the Emergency Ampere Rating of a circuit ($I_{emergency}$), assuming a 0.85 per unit voltage and a power factor angle of 30 degrees.

$$Z_{relay30} = \frac{0.85 \times V_{L-L}}{\sqrt{3} \times 1.5 \times I_{emergency}}$$

Where:

$Z_{relay30}$ = Relay reach in primary Ohms at a 30 degree power factor angle

V_{L-L} = Rated line-to-line voltage

$I_{emergency}$ = Emergency Ampere Rating

R1.1.1.1. This calculation must be redone whenever $I_{emergency}$ changes.

R1.1.2. Utilize the 15-Minute Rating of the Transmission Line — The tripping relay should not operate at or below 1.15 times an established 15-minute Emergency Ampere Rating ($I_{emergency}$) of the line.

When evaluating a distance relay, assume a 0.85 per unit relay voltage and power factor angle of 30 degrees.

$$Z_{relay30} = \frac{0.85 \times V_{L-L}}{\sqrt{3} \times 1.5 \times I_{emergency}}$$

Where:

$Z_{relay30}$ = Relay reach in primary Ohms at a 30 degree power factor angle

V_{L-L} = Rated line-to-line voltage

$I_{emergency}$ = Emergency Ampere Rating

R1.1.2.1. This calculation must be redone whenever $I_{emergency}$ changes.

R1.1.2.2. Transmission operators shall be instructed to take immediate remedial steps, including dropping load, if the current on the circuit reaches $I_{emergency}$.

General loadability statement

Exception 1 parallel

R1.1.3. Maximum Power Transfer Limit Across a Transmission Line —

Transmission line tripping relays shall not operate at or below the maximum power transfer capability of the line.

Exception
2 parallel

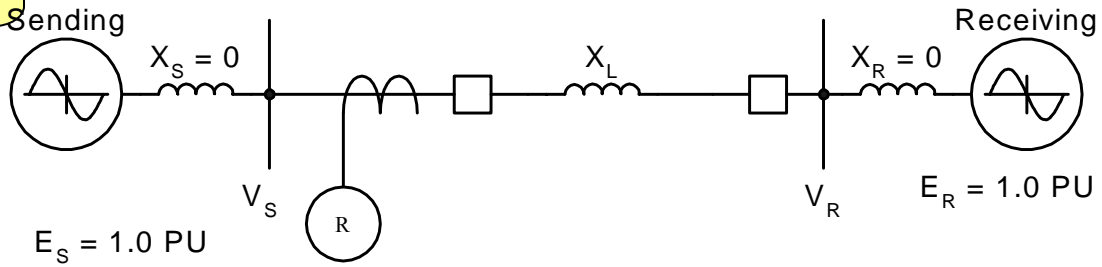


Figure 1 — Maximum Power Transfer

Where:

P = Power flow across the transmission line

$$P = \frac{V_S \times V_R \times \sin \delta}{X_L}$$

V_S = Phase-to-phase voltage at the sending bus

V_R = Phase-to-phase voltage at the receiving bus

δ = Voltage angle between V_S and V_R

X_L = Reactance of the transmission line in ohms

When evaluating a distance relay, assume a 0.85 per unit relay voltage and a power factor angle of 30 degrees.

$$Z_{relay30} = \frac{0.85 \times V_{L-L}}{\sqrt{3} \times 1.15 \times I_{max}}$$

Where:

$Z_{relay30}$ = Relay reach in primary Ohms at a 30 degree power factor angle

V_{L-L} = Rated line-to-line voltage

X_L = Reactance of the transmission line in ohms

I_{max} = Maximum power transfer capability in Amperes:

$$I_{max} = \frac{0.816 \times V_{L-L}}{X_L}$$

R1.1.3.1. This calculation shall be redone whenever the impedance of the circuit changes.

R1.1.4. Maximum Power Transfer Limit Across a Transmission Line Based on the Breaker Interrupting Ratings at Each End of the Line —

Transmission line relays shall not operate at or below the maximum power transfer capability of the circuit including the breaker ratings.

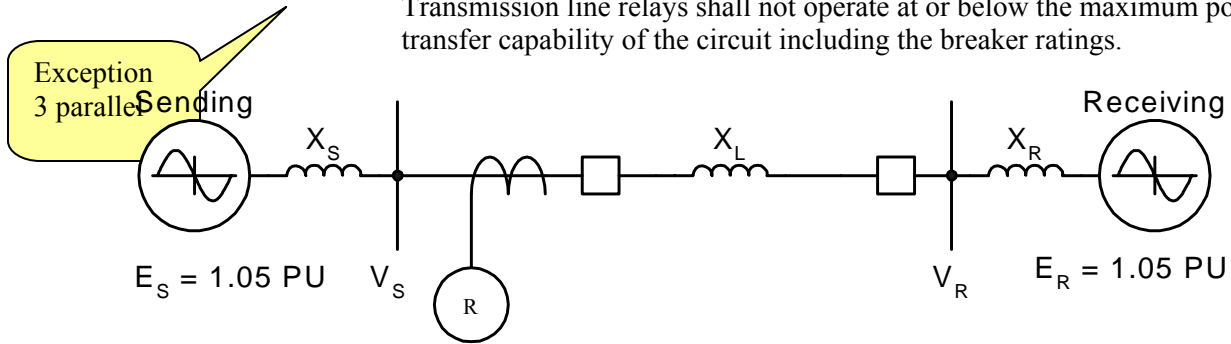


Figure 2 — Maximum Power Transfer Based on Breaker Interrupting Ratings

Where:

P = Power flow across the transmission line

$$P = \frac{(E_S \times E_R \times \sin \delta)}{(X_S + X_R + X_L)}$$

Where:

P_{max} = Maximum power that can be transferred across a system

E_S = Thévenin phase-to-phase voltage at the system sending bus

E_R = Thévenin phase-to-phase voltage at the system receiving bus

δ = Voltage angle between E_S and E_R

X_S = Calculated reactance in ohms of the sending bus (based on breaker interrupting duty)

X_R = Calculated reactance in ohms of the receiving bus (based on breaker interrupting duty)

X_L = Reactance of the transmission line in ohms

The tripping relay should not operate at or below a calculated I_{max} :

$$I_{max} = \frac{0.857 \times V_{L-L}}{\left[\frac{0.577 \times V_{L-L}}{I_{BRS}} + \frac{0.577 \times V_{L-L}}{I_{BRR}} + X_L \right]}$$

Where:

V_{L-L} = Rated line-to-line voltage

I_{max} = Maximum power transfer capability of the circuit including the breaker ratings

I_{BRS} = Interrupting rating of the breaker in amps on the sending bus

I_{BRR} = Interrupting rating of the breaker in amps on the receiving bus

X_L = Reactance of the transmission line in ohms

When evaluating a distance relay, assume a 0.85 per unit relay voltage and a power factor angle of 30 degrees.

$$Z_{relay30} = \frac{0.85 \times V_{L-L}}{\sqrt{3} \times 1.15 \times I_{max}}$$

Where:

$Z_{relay30}$ = Relay reach in primary Ohms at a 30 degree power factor angle

V_{L-L} = Rated line-to-line voltage

I_{max} = Maximum power transfer capability of the circuit including the breaker ratings

R1.1.4.1. This calculation shall be redone whenever the breakers are overdutied or replaced.

R1.2. The desired emergency loadability of a transmission line may be “limited” by source, generation capability, or system configuration. In such cases, any one of the following requirements may be used instead of R1 to determine the phase protective relay settings.

R1.2.1. System’s Site-Specific Calculated Maximum Power Transfer Limit — Transmission line relays shall not operate at or below the maximum power transfer capability of the line including the line source impedances.

Exception
4 parallel

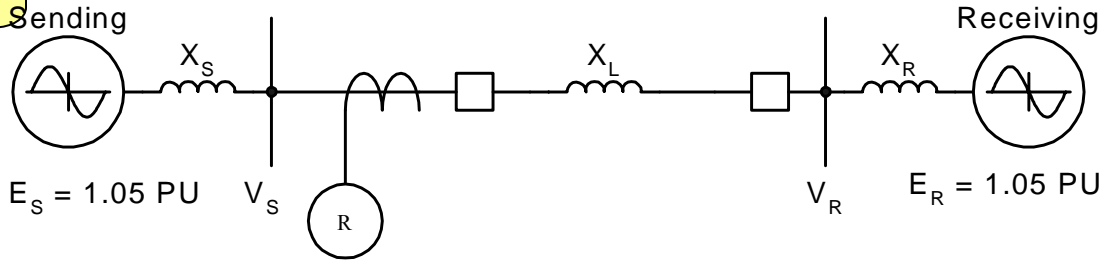


Figure 3 — Maximum Power Transfer Based on Breaker Interrupting Ratings

The tripping relay should not operate at or below a calculated I_{max} :

$$I_{max} = \frac{0.606 \times V_{L-L}}{(X_S + X_R + X_L)}$$

Where:

I_{max} = Maximum power transfer capability of the circuit including the line source impedances

X_S = Thévenin equivalent reactance in ohms of the sending bus

X_R = Thévenin equivalent reactance in ohms of the receiving bus

X_L = Reactance of the transmission line in ohms

When evaluating a distance relay, assume a 0.85 per unit relay voltage and a power factor angle of 30 degrees.

$$Z_{relay30} = \frac{0.85 \times V_{L-L}}{\sqrt{3} \times 1.15 \times I_{max}}$$

Where:

$Z_{relay30}$ = Relay reach in primary Ohms at a 30 degree power factor angle

V_{L-L} = Rated line-to-line voltage

I_{max} = Maximum power transfer capability of the circuit including the line source impedances

R1.2.1.1. This calculation shall be re-verified annually or whenever major system changes are made.

R1.2.2. Weak Source Systems — Transmission line relays applied at weak source terminals shall not operate at or below 1.15 times the maximum end-of-line three-phase fault current magnitude.

Exception
6 parallel

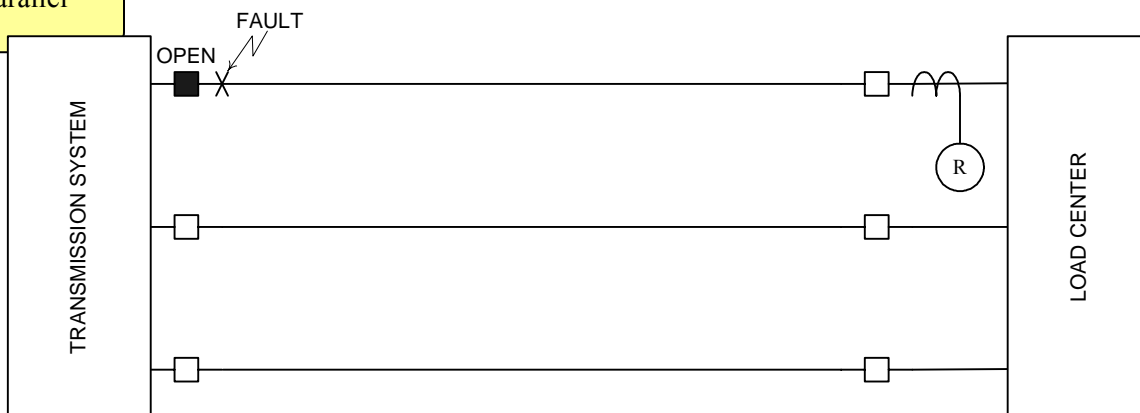


Figure 3 — Weak Source Systems

It is necessary to increase the line end fault current I_{fault} by $\sqrt{2}$ to reflect the maximum current that the terminal could see for maximum power transfer.

$$I_{max} = \sqrt{2} \times 1.05 \times I_{fault}$$

$$I_{max} = 1.485 \times I_{fault}$$

Where:

I_{max} = Maximum power transfer capability of the circuit.

I_{fault} = The line-end three-phase fault current magnitude obtained from a short circuit study, reflecting sub-transient generator reactances.

When evaluating a distance relay, assume a 0.85 per unit relay voltage and a power factor angle of 30 degrees.

$$Z_{relay30} = \frac{0.85 \times V_{L-L}}{\sqrt{3} \times 1.15 \times I_{max}}$$

Where:

$Z_{relay30}$ = Relay reach in primary Ohms at a 30 degree power factor angle

V_{L-L} = Rated line-to-line voltage

I_{max} = Maximum power transfer capability of the circuit.

R1.2.2.1. This calculation shall be redone whenever the maximum end-of-line three-phase fault current changes significantly.

Exception
7 parallel

R1.2.3. Long Line Relay Loadability — The desired emergency loadability of a transmission line may be “limited” by the requirement to adequately protect the transmission line. In such cases, the following may be used instead of R1 to determine the phase protective relay settings. Transmission line distance relays applied to two-terminal line set no longer than 125% of the line impedance.

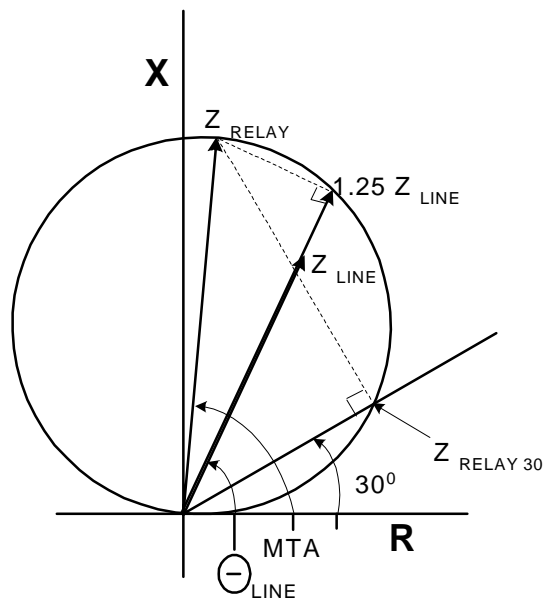


Figure 4 — Long Line relay Loadability

R1.2.3.1. The maximum torque angle (MTA) shall be set as close to 90 degrees as possible.

R1.2.3.2. The short-term emergency rating ($I_{emergency}$) of the line shall be equal to or less than:

$$I_{emergency} = \left(\frac{0.341 \times V_{L-L}}{Z_{line}} \right) \times \left(\frac{\cos(MTA - \Theta_{line})}{\cos(MTA - 30^\circ)} \right)$$

Where:

$I_{emergency}$ = Emergency current (including a 15% margin) that the circuit can carry at 0.85 per unit voltage at a 30 degree power factor angle before reaching the relay trip point

V_{L-L} = Rated line-to-line voltage

Z_{line} = Impedance of the line in ohms.

MTA = Maximum torque angle, the angle of maximum relay reach

Z_{relay} = Relay setting at the maximum torque angle

Θ_{line} = Line impedance angle

When evaluating a distance relay, assume a 0.85 per unit relay voltage and a power factor angle of 30 degrees.

$$Z_{relay30} = \frac{0.85 \times V_{L-L}}{\sqrt{3} \times 1.15 \times I_{emergency}}$$

Where:

$Z_{relay30}$ = Relay reach (trip point) in primary Ohms at a 30 degree power factor angle

V_{L-L} = Rated line-to-line voltage

$I_{emergency}$ = Emergency current (including a 15% margin) that the circuit can carry at 0.85 per unit voltage at a 30 degree power factor angle before reaching the relay trip point

- R1.2.3.3.** No planning contingency shall identify any conditions where a recoverable flow is greater than $I_{emergency}$.
- R1.2.3.4.** $I_{emergency}$ of the circuit shall be used in all planning and operational modeling for the short-term (15-minute or that most closely approximates a 15-minute) emergency rating.
- R1.2.3.5.** Transmission Operators shall be instructed to take immediate remedial steps, including dropping load, if the current reaches $I_{emergency}$.

Exception
8 parallel

R1.2.4. Three (or more) Terminal Lines and Lines with One or More Radial Taps — The desired emergency loadability of a transmission line may be “limited” by the requirement to adequately protect the transmission line. In such cases, the following may be used instead of R1 to determine the phase protective relay settings. Transmission line distance relays applied to multi-terminal line set no longer than 125% of the apparent impedance.

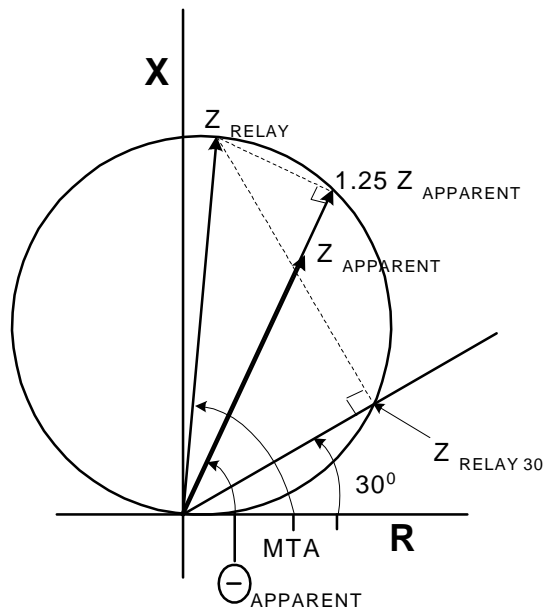


Figure 5 — Three (or more) Terminal Lines and Lines with One or More Radial Taps

R1.2.4.1. The maximum torque angle (MTA) shall be set as close to 90 degrees as possible.

R1.2.4.2. The short-term emergency rating ($I_{emergency}$) of the line shall be equal to or less than:

$$I_{emergency} = \left(\frac{0.341 \times V_{L-L}}{Z_{apparent}} \right) \times \left(\frac{\cos(MTA - \Theta_{apparent})}{\cos(MTA - 30^\circ)} \right)$$

Where:

$I_{emergency}$ = Emergency current (including a 15% margin) that the circuit can carry at 0.85 voltage at a 30 degree power factor angle before reaching the trip point

V_{L-L} = Rated line-to-line voltage

$Z_{apparent}$ = Apparent line impedance in ohms as seen from the line terminal. This apparent impedance is the impedance calculated (using in-feed where applicable) by the TPSO for a fault at the most electrically distant line terminal for system conditions normally used in their protective relaying setting practices.

MTA = Maximum torque angle, the angle of maximum relay reach

$\Theta_{apparent}$ = Apparent line impedance angle as seen from the line terminal

When evaluating a distance relay, assume a 0.85 per unit relay voltage and a power factor angle of 30 degrees.

$$Z_{relay30} = \frac{0.85 \times V_{L-L}}{\sqrt{3} \times 1.15 \times I_{emergency}}$$

Where:

$Z_{relay30}$ = Relay reach (trip point) in primary Ohms at a 30 degree power factor angle

V_{L-L} = Rated line-to-line voltage

$I_{emergency}$ = Emergency current (including a 15% margin) that the circuit can carry at 0.85 voltage at a 30 degree power factor angle before reaching the trip point

- R1.2.4.3.** No planning contingency shall identify any conditions where a recoverable flow is greater than $I_{emergency}$.
- R1.2.4.4.** $I_{emergency}$ of the circuit shall be used in all planning and operational modeling for the short-term (15-minute or that most closely approximates a 15-minute) emergency rating.
- R1.2.4.5.** Transmission Operators shall be instructed to take immediate remedial steps, including dropping load, if the current reaches $I_{emergency}$.

R1.2.5. Generation Remote to Load — Transmission line relays applied on transmission lines connected to generation stations remote to load shall not operate at or below 1.15 times twice the generation capability.

Exception
9 parallel

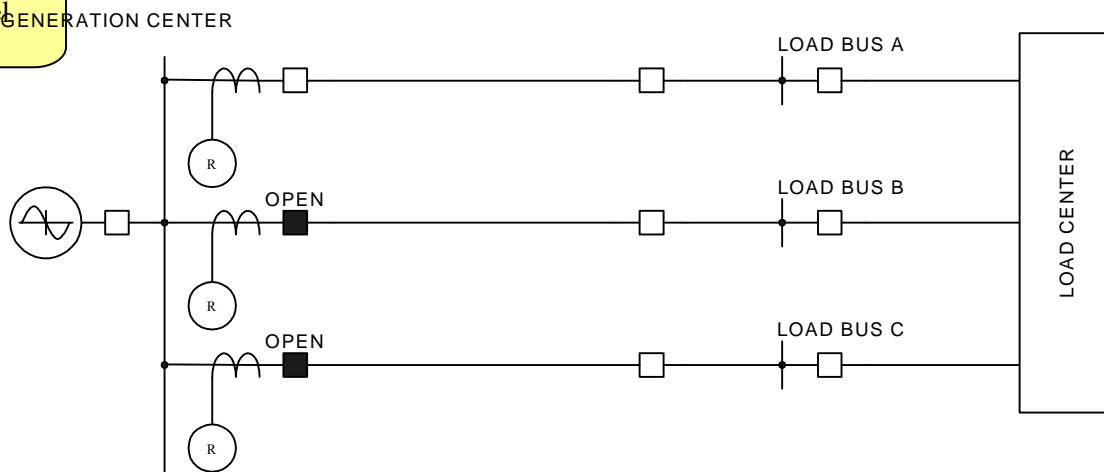


Figure 6 — Generation Connected to System – Multiple Lines

- R1.2.5.1.** The TSPO shall determine the maximum current flow from the generation center to the load center under any system condition. In the case of multiple lines, this includes situations where all the other lines that connect the generator to the system are out of service.
- R1.2.5.2.** The reliability coordinator / reliability authority must concur with this maximum flow.
- R1.2.5.3.** This calculation shall be reviewed whenever the generation sources change.
- R1.2.5.4.** The total generation output is defined as two times¹ the aggregate of the nameplate ratings of the generators in MVA converted to amps at the relay location at 100% voltage:

$$MVA_{\max} = 2 \times \sum_1^N \frac{MW_{\text{nameplate}}}{PF_{\text{nameplate}}}$$

$$I_{\max} = \frac{MVA_{\max}}{\sqrt{3} \times V_{L-L}}$$

Where:

MVA_{\max} = Twice the aggregate of the nameplate ratings of the generators in MVA.

¹ This has a basis in the PSRC paper titled: "Performance of Generator Protection During Major System Disturbances", IEEE Paper No. TPWRD-00370-2003, Working Group J6 of the Rotating Machinery Protection Subcommittee, Power System Relaying Committee, 2003. Specifically, page 8 of this paper states: "...distance relays [used for system backup phase fault protection] should be set to carry more than 200% of the MVA rating of the generator at its rated power factor."

N = Number of generators connected to the generation bus

$MW_{nameplate}$ = Nameplate ratings of the generators in MW

$PF_{nameplate}$ = Nameplate power factor ratings of the generators

I_{genmax} = Current in Amperes associated with the aggregate of the nameplate ratings of the generators in MVA at the relay location at 100% voltage.

V_{L-L} = Rated line-to-line voltage

When evaluating a distance relay, assume a 0.85 per unit relay voltage and a power factor angle of 30 degrees.

$$Z_{relay30} = \frac{0.85 \times V_{L-L}}{\sqrt{3} \times 1.15 \times I_{genmax}}$$

Where:

$Z_{relay30}$ = Relay trip point at a 30 degree power factor angle

V_{L-L} = Rated line-to-line voltage

I_{genmax} = Current in Amperes associated with the aggregate of the nameplate ratings of the generators in MVA at the relay location at 100% voltage.

R1.2.6. Load Remote to Generation — Transmission line relays applied on transmission lines connected at the load end, remote to generation station shall not operate at or below 1.15 times the maximum current flow from the load to the generation source under any system configuration.

Exception
10 parallel

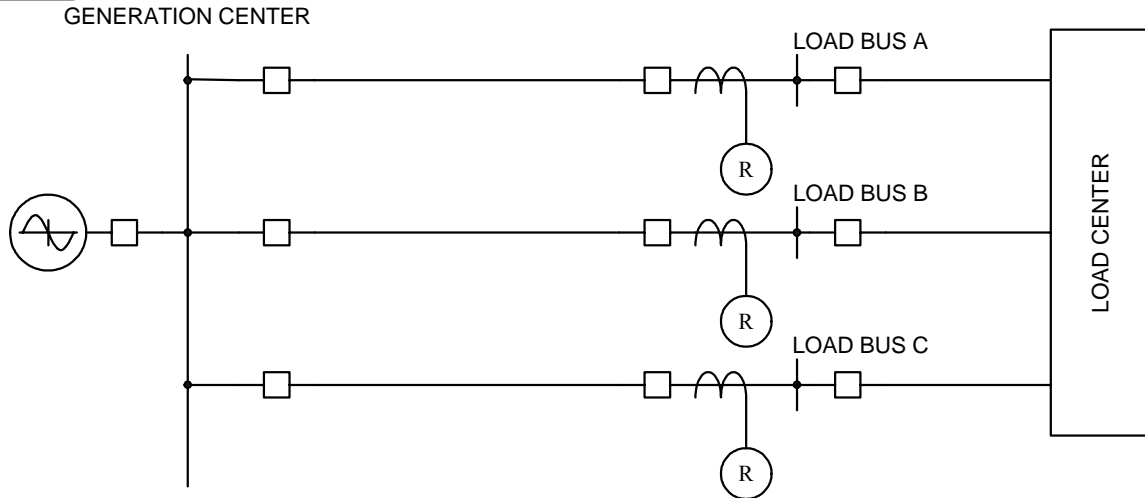


Figure 7 — Load Remote to Generation

The TSPSO shall determine the maximum current flow from the load center to the generation center under any system condition. In the case of multiple lines, this includes situations where all the other lines that connect the generator to the system are out of service.

When evaluating a distance relay, assume a 0.85 per unit relay voltage and a power factor angle of 30 degrees.

$$Z_{relay30} = \frac{0.85 \times V_{L-L}}{\sqrt{3} \times 1.15 \times I_{max}}$$

Where:

$Z_{relay30}$ = Relay reach in primary Ohms at a 30 degree power factor angle

V_{L-L} = Rated line-to-line voltage

I_{max} = Maximum current flow in Amperes determined by the TSPSO

R1.2.6.1. The reliability coordinator must concur with this maximum flow.

R1.2.7. Transmission to Remote Cohesive Load Center — Transmission line relays applied on the bulk system-end of transmission lines that serve load remote to the system shall not operate at or below 1.15 times the maximum current flow from the system to the load under any system configuration.

Exception
11 parallel



Figure 8 — Transmission to Remote Cohesive Load Center

The TSP0 shall determine the maximum current flow from the bulk system to the load center under any system condition. In the case of multiple lines, this includes situations where all the other lines that connect the generator to the system are out of service.

When evaluating a distance relay, assume a 0.85 per unit relay voltage and a power factor angle of 30 degrees.

$$Z_{relay30} = \frac{0.85 \times V_{L-L}}{\sqrt{3} \times 1.15 \times I_{max}}$$

Where:

$Z_{relay30}$ = Relay reach in primary Ohms at a 30 degree power factor angle

V_{L-L} = Rated line-to-line voltage

I_{max} = Maximum current flow in Amperes determined by the TSP0

R1.2.7.1. The reliability coordinator must concur with this maximum flow.

R1.2.8. Cohesive Load Center Remote to Transmission System — Transmission line relays applied on the load-end of transmission lines that serve load remote to the bulk system shall not operate at or below 1.15 times the maximum current flow from the load to the system under any system configuration.

Exception
12 parallel

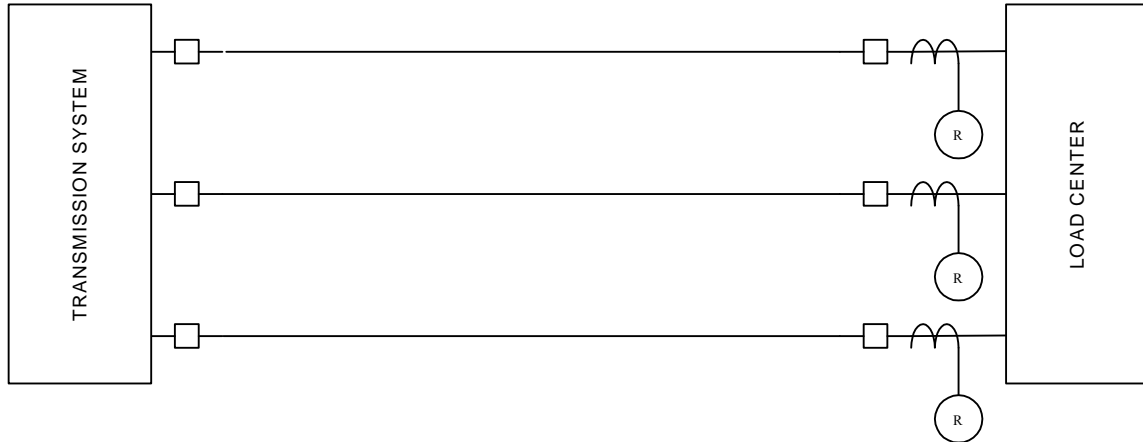


Figure 9 — Cohesive Load Center Remote to Transmission System

Additional requirements:

The TSPO shall determine the maximum current flow from the load center to the bulk system under any system condition. In the case of multiple lines, this includes situations where all the other lines that connect the generator to the system are out of service.

When evaluating a distance relay, assume a 0.85 per unit relay voltage and a power factor angle of 30 degrees.

$$Z_{relay30} = \frac{0.85 \times V_{L-L}}{\sqrt{3} \times 1.15 \times I_{max}}$$

Where:

$Z_{relay30}$ = Relay reach in primary Ohms at a 30 degree power factor angle

V_{L-L} = Rated line-to-line voltage

I_{max} = Maximum current flow in Amperes determined by the TPSO

R1.2.8.1. The reliability coordinator must concur with this maximum flow.

Exception
14 parallel

R1.2.9. Transformer Overcurrent Protection — Transformers have short term loadability capability. Relays applied to protect transformers must provide emergency loadability. One of the following shall be used to determine the phase protective relay loadability:

R1.2.9.1. If the TPSO uses transformer fault protection relays, they shall be reviewed to verify that the relay is not set to operate at or below the greater of:

- 150% of the applicable maximum transformer nameplate rating²
- 115% of the highest operator established emergency transformer rating

R1.2.9.2. If the TPSO uses relays for overload protection for excessive load conditions (in addition to planned system operator action) that operates below the level stated above, one of the following conditions must apply:

- The relays are set to allow the transformer to be operated at an overload level of at least 150% of the maximum applicable nameplate rating, or 115% of the highest operator established emergency transformer rating, whichever is greater. The protection must allow this overload for at least 15 minutes to allow for the operator to take controlled action to relieve the overload.
- The relays are supervised by either a top oil or simulated winding hot spot element. The setting should be no less than 100° C for the top oil or 140° C³ for the winding hot spot.

² Loading conditions on the order of magnitude of 150% (50% overload) of the maximum applicable nameplate rating of the transformer can normally be sustained for several minutes without damage or appreciable loss of life to the transformer. See ANSI/IEEE Standard C57.92, Table 3.

³ IEEE standard C57.115, Table 3, specifies that transformers are to be designed to withstand a winding hot spot temperature of 180 degrees C, and cautions that bubble formation may occur above 140 degrees C.

Special
Exception
parallel

R1.2.10. TPSO-Established Maximum Loading Capability – Other system situations may exist which present practical limitations on the load which a circuit may carry. In such cases, the TPSO may utilize such limitations when determining the required relay loadability.

R1.2.10.1. The TPSO shall submit documentation for RRO review such that the Region can verify the limitation and approve its use.

R1.2.10.2. The reliability coordinator must concur with this maximum flow.

R1.2.10.3. No planning contingency shall identify any conditions where a recoverable flow is greater than this maximum flow.

R1.2.10.4. The maximum flow of the circuit shall be used in all planning and operational modeling for the short-term (15-minute or that most closely approximates a 15-minute) emergency rating.

R1.2.10.5. Transmission Operators shall be instructed to take immediate remedial steps, including dropping load, if the current reaches this maximum flow.

R1.3. Series Capacitor and Pilot Relaying

R1.3.1. Special Considerations for Series-Compensated Lines — For series compensated lines, transmission line relays shall not operate at or below the maximum power transfer capability of the line (I_{max}), determined as the greater of:

Exception
5 parallel

- 115% of the highest emergency rating of the series capacitor. When evaluating a distance relay, assume a 0.85 per unit relay voltage and a power factor angle of 30 degrees.
- I_{max} (where I_{max} is calculated under R1.1.3, R1.1.4, or R1.2.1, using the full line inductive reactance). When evaluating a distance relay, assume a 0.85 per unit relay voltage and a power factor angle of 30 degrees.

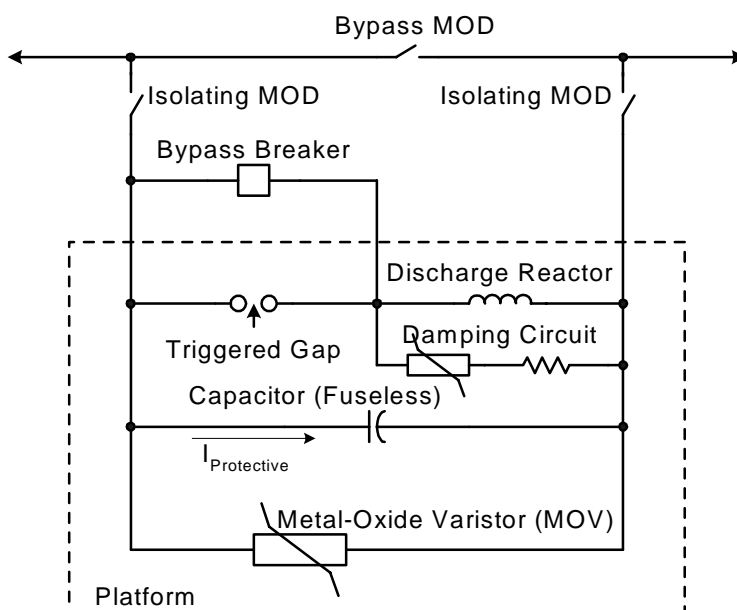


Figure 10 — Series Capacitor Components

When evaluating a distance relay, assume a 0.85 per unit relay voltage and a power factor angle of 30 degrees.

$$Z_{relay30} = \frac{0.85 \times V_{L-L}}{\sqrt{3} \times 1.15 \times I_{max}}$$

Where:

$Z_{relay30}$ = Relay reach in primary Ohms at a 30 degree power factor angle

V_{L-L} = Rated line-to-line voltage

I_{max} = Maximum power transfer capability in Amperes

R1.3.1.1. If I_{max} is based on the breaker ratings, this calculation shall be redone whenever the breakers are overdutied or replaced.

R1.3.1.2. If I_{max} is based on the line source impedances, this calculation shall be re-verified annually or whenever major system changes are made.

R1.3.2. Impedance-Based Pilot Relaying Schemes — Transmission line relays applied in communications aided tripping schemes shall meet the requirements of R1.1.1 through R1.2.4 unless all of the following requirements are met:

Exception
13 parallel

R1.3.2.1. The overreaching impedance elements are used only as part of the pilot scheme.

R1.3.2.2. The scheme is of the permissive overreaching transfer trip type, requiring relays at all terminals to sense an internal fault as a condition for tripping any terminal.

R1.3.2.3. The permissive overreaching transfer trip scheme has not been modified to include weak infeed logic or other logic which could allow a terminal to trip even if the (closed) remote terminal does not sense an internal fault condition with its own forward-reaching elements. Unmodified directional comparison unblocking schemes are equivalent to permissive overreaching transfer trip in this context. This generally does not apply to directional comparison blocking schemes.

R1.3.2.4. The TPSO shall furnish calculations which establish that the loadability of the scheme as a whole meets the NERC loadability requirement for the protected line.

R2. Determination of Operationally Significant Circuits — The Regional Reliability Organization shall determine Operationally Significant Circuits between 100 kV and 200 kV for the purposes of evaluating protection system loadability for their region.

R2.1. The Regional Reliability Organization shall develop and maintain a methodology for determining Operationally Significant Circuits

R2.2. Documentation of the RRO methodology for determining Operationally Significant Circuits shall be provided to NERC annually and upon request within 30 days.

R2.3. The RRO shall annually identify Operationally Significant Circuits between 100 kV and 200 kV.

R3. TPSO Reporting Requirements — TPSOs shall provide applicable documentation of Transmission Relay Loadability to the RROs annually and upon request within 30 days:

R3.1. Provide self-certification of relays that comply with R1.1.

R3.2. Documentation of relays conformance with R1.2.

R3.3. Documentation of relays conformance with R1.1 or R1.2 for relays systems identified in R1.3.

Documentation of procedures used for determining and maintaining compliance, and records relating to relay loadability of all applicable circuits shall be subject to audit by the RRO or NERC.

R4. RRO Reporting Requirements — RROs shall review the compliance of TPSOs with R1 and R3. RROs provide a summary report with all applicable documentation to NERC annually and upon request within 30 days.

C. Measures

- M1.** TPSO's relay applications and settings are in compliance with transmission loadability criteria in R1.
- M2.** Documentation of the methodology for RRO determination of Operationally Significant Circuits is in compliance with R2.
- M3.** TPSOs provide applicable documentation of Transmission Relay Loadability to the RROs
 - M3.1** Self-certification of relays that comply with R1.1.
 - M3.2** Documentation of relays compliance with R1.2.
 - M3.3** Documentation of relays compliance with R1.1 or R1.2 for relays systems identified in R1.3.
- M4.** RROs summary report complies with R4.

D. Compliance

1. Compliance Monitoring Process

1.1. Compliance Monitoring Responsibility

- 1.1.1** For PRC-XXX-1 R1, the RRO
- 1.1.2** For PRC-XXX-1 R2, the NERC
- 1.1.3** For PRC-XXX-1 R3, the RRO
- 1.1.4** For PRC-XXX-1 R4, the NERC

1.2. Compliance Monitoring Period and Reset Timeframe

One calendar year

1.3. Data Retention

The TPSO shall retain current documentation and any changes to it for three years.

The Regional Reliability Organization shall retain current documentation and any changes to it for three years.

The Compliance Monitor will retain its audit data for three years.

1.4. Additional Compliance Information

Not applicable

2. Levels of Non-Compliance

2.1. Level 1:

- 2.1.1 M1 — Through RRO review, TPSO's relay applications and settings are found to be not in compliance with transmission loadability criteria in R1 due to a calculation error.
- 2.1.2 M2 — Complete RRO documentation of Operationally Significant Circuits not provided according to schedule.
- 2.1.3 M3 — TPSO documentation of Transmission Relay Loadability not provided according to schedule.
- 2.1.4 M4 — RRO documentation submittal to NERC not provided according to schedule.

2.2. Level 2:

- 2.2.1 M1 — If during a disturbance analysis, TPSO's relay applications and settings are found to be not in compliance with transmission loadability criteria in R1 due to a calculation error, but does not cause or contribute to the disturbance.
- 2.2.2 M2 — RRO documentation of Operationally Significant Circuits provided, but incomplete.
- 2.2.3 M3 — TPSO documentation of Transmission Relay Loadability provided, but incomplete.
- 2.2.4 M4 — RRO documentation submittal to NERC provided, but incomplete.

2.3. Level 3:

- 2.3.1 M1 — TPSO's relay applications and settings are not in compliance with transmission loadability criteria in R1.
- 2.3.2 M2 — RRO documentation of Operationally Significant Circuits not provided.
- 2.3.3 M3 — TPSO documentation of Transmission Relay Loadability not provided.
- 2.3.4 M4 — RRO documentation submittal to NERC not provided.

2.4. Level 4:

- 2.4.1 M1 — TPSO's relay applications and settings are not in compliance with transmission loadability criteria in R1, and cause or is contributory to a reportable disturbance as defined in Standard EOP-004-1 — Disturbance Reporting.
- 2.4.2 M2 — Not applicable
- 2.4.3 M3 — Not applicable
- 2.4.4 M4 — Not applicable

E. Regional Differences

- 1. None

Version History

| Version | Date | Action | Change Tracking |
|---------|------|--------|-----------------|
|---------|------|--------|-----------------|