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Facility Connection Requirements

Title: Facility Connection Requirements	Revision: C 07/28/14	Author: Manager-Reliability Compliance
Approval Signature(s) and date: Director of Engineering and Line Services		
Applicable NERC Standard(S): FAC-001, FAC-002		

Revision History

Revision	Date	Changes	Approved By
A	3/31/08	Formalized Documentation Process	McGarrah
B	3/22/11	Added Revision History Table	McGarrah
C	07/28/14	Periodic Review, Changed Approver to Gaines, Removed McGarrah, added Appendix G to associated documents, updated associated Appendices	Gaines

Associated Documents: Appendix A, B, C, D, E, F, G

Preface: This Facility Connection Requirement applies to any connection to the Empire District Electric Company (EDE) bulk electric system regardless of voltage occurring after April 1, 2005. Addition of facilities that are not directly connected to the bulk electric system of EDE, but has a measurable effect on EDE's facilities shall also be governed by this standard.

1.0 General Facility Connection Requirements:
Facility Connection with the Empire District Electric Company bulk electric transmission facilities may be permitted provided such connection complies with the procedures and requirements set forth herein:

1.1 Definitions:

1.1.1 Transmission Owner: Transmission Owner shall mean an entity that owns, leases or otherwise posses an interest in a portion of the Transmission System.

1.1.2 Transmission System: Transmission System shall mean the facilities owned, controlled or operated by the Transmission Owner operated at 34.5 kV and higher.

1.1.3 Facility Owner: Facility Owner shall mean a person or entity responsible for ownership, operation and maintenance of facilities connected with Transmission System. In this document, Facility Owner also represents the End User.

1.1.4 Facility Connection: Facility Connection shall mean the point where the Transmission Owner's and Facility Owner's facilities physically meet.

1.1.5 Generating Source: A Generating Source is defined to exist when ANY of the following conditions are met:

A. Facility Owner's facilities can produce sustained watt or var flow into Transmission Owner's facilities at the closed Facility Connection.

B. Facility Owner's facilities can energize Transmission Owner's facilities across the Facility Connection at sustained levels of fifty-one (51) volts or more during times when the Transmission Provider's source is de-energized.

C. Facility Owner's facilities can energize the Facility Connection with sustained voltage magnitude and frequency quantities that differ from Transmission Owner's values.

D. Facility Owner's facilities can contribute fault-current to Transmission Owner's facilities at the Facility Connection.

Note: Sustained shall mean in excess of one (1) second duration.

1.2 All applicable Local, State, and Federal statutes shall govern connection of Facility Owner's facilities with Transmission System. In addition, Facility Owner's facilities shall be installed in accordance with all provisions set forth in: this Facility Connection Requirements; National Electrical Safety Code (ANSIC2); National Electrical Code (NFPA70); or North American Electric Reliability Council (NERC); American National Standards Institute (ANSI); Institute of Electrical and Electronics Engineers (IEEE); or other Regulatory or Governing Body having jurisdiction. Any applicable statute, rule, order, provision, guide, or code of an organization, council, institute, regulatory, or governing body having jurisdiction over such matters shall further govern connection of Facility Owner's facilities with Transmission System. Facility Owner's facilities shall also be installed in accordance with any applicable facility connection requirements that a Transmission Owner may have provided such requirements are more stringent than these Facility Connection Requirements.

1.3 Facility Owner shall be responsible for all engineering studies, design, modeling data, and installation, required for connection with Transmission System.

1.4 Facility Owner shall be responsible for compliance with all permits, licenses, fee, rules, regulations, standards, agreements, ordinances, inspections, and other requirements imposed by Transmission Owner or any regulatory or governmental body having jurisdiction. There is no obligation on the part of the Transmission Owner to connect, or to remain connected whenever Facility Owner's facilities are out of compliance. In addition, Facility Owner shall be responsible for: and Transmission Owner shall require Facility Owner facilities or the Facility Connection between Facility Owner's facilities and Transmission Owner's facilities to be modified in accordance with all applicable statutes, rules, orders, provisions, guides, or codes of an organization, council, institute, regulatory or governing body having jurisdiction over such matters.

1.5 Because of risks and potential hazards inherent with operating Facility Owner's facilities connected with Transmission Owner's facilities, overall safety for life, quality of service and property is paramount. Transmission Owner shall disconnect Facility Owner's facilities anytime Facility Owner's facilities pose a dangerous condition, and such disconnection is appropriate to protect safety of Transmission Owner's employees, customers, general public, or to maintain integrity of the Transmission Owner's facilities.

1.6 Facility Owner shall provide the Transmission Owner a minimum, of two hundred and seventy (270) days written notice of its intent to connect facilities to the Transmission System. Failure to give such notice shall render Facility Owner liable for all damages to Transmission Owner's property, other customers' property, injury to persons, or any other damages resulting from unauthorized connection. Notice of intent shall include such information as:

1.6.1 Location

1.6.2 Connected kVA

1.6.3 Interconnection Voltage

1.6.4 Seasonal average and peak Watt capacity or demand

1.6.5 Seasonal average and peak Reactive capacity or demand

1.6.6 Connected Generation & Type: (synchronous, induction, converter)

1.6.7 Large Motors including Type (synchronous, induction, VFD)

1.6.8 Fault Current Limits

1.6.9 Power Quality Requirements

1.6.10 Reliability Requirements

1.6.11 Interconnection equipment current and voltage ratings

1.6.12 Other Requirements

Requests to install Facility Connection shall be submitted to:

The Empire District Electric Company
Director of Engineering
P.O. Box 127
Joplin, MO 64802

1.7 Within ninety (90) days of submitting a written request to connect facilities, but not less than one hundred twenty (120) days prior to facility connection, the Transmission Owner shall submit to Facility Owner preliminary general equipment requirements such as breaker(s), switches, supervisory control and data acquisition (SCADA), and existing Transmission Owner facility protection scheme, required for Facility Owner to proceed with Facility Connection design. In addition, Transmission Owner shall notify Facility Owner of costs to evaluate the proposed Facility Connection.

1.8 Within ninety (90) days of receipt of a complete copy of Facility Owner's detailed engineering studies, design specifications, proposed protective relaying schemes, and payment of costs for evaluation, Transmission Provider shall review, perform analysis, and notify Facility Owner of approval and/or conditions for acceptance. Should Transmission Owner be unable to evaluate Facility Owner's request to connect as submitted, Transmission Owner shall provide Facility Owner a written explanation of information required to complete the evaluation.

1.9 Only written notice shall constitute acceptance by Transmission Owner. Written approval by Southwest Power Pool does not waive any requirements pertaining to Facility Owner's installation that may be governed directly by or other jurisdictional bodies. Southwest Power Pool's specifications and requirements are designed towards protecting the safety of life, quality of service and the Southwest Power Pool's property, and do not assume nor ensure proper protection of Facility Owner's facilities equipment during electrical faults.

1.10 When Transmission Owner is required to incur expenses necessary to make extensions or improvements of its lines or additions to its disconnecting devices, transformers, meters, breakers, relays, controls, data systems, or to make any other equipment modifications relating to its circuits, substations, or apparatus necessary to connect Facility Owner's facilities, and such expenses made are attributable to this application, then all costs incurred by Transmission Owner for Facility Connection shall be borne by Facility Owner as set forth in the connection agreement. Such costs are due and payable prior to Transmission Owner commencing construction, and are non-refundable in whole or in part at anytime.

1.11 Facility Owner, Transmission Owner, and Southwest Power Pool shall execute appropriate agreements for connected service prior to installation of any equipment.

1.12 Transmission Owner may require Facility Owner's facility design to include an appropriate automatic disconnecting device to be controlled by any or all of the following: overcurrent relays, automatic synchronizing relays, voltage relays, frequency relays, ground fault detection relays, or any other automatic relaying equipment necessary to ensure proper protection and safety of Transmission Owner employees, customers, equipment, and overall system integrity. The Transmission Owner reserves the right to review, inspect, and approve Facility Owner's design and shall not give approval to connect until any concerns relating to Facility Owner's design have been remedied. Refer to Appendix A, "Relay Standard for Connected Generating Facilities", and Appendix B, "Relay Standard for Connected Load Facilities."

1.13 If needed, Transmission Owner shall procure, install, and maintain all metering equipment required to measure energy exchanged between Facility Owner and Transmission Owner across the Facility Connection.

2.0 Transmission System Connection Requirements

2.1 Transmission System includes the bulk electric system operating at voltage levels of 34.5 kV and higher.

2.1.1 Transmission Facilities - General Requirements

A. New load delivery points connected to the transmission system must adhere to the process defined in SPP Open Access Transmission Tariff (OATT) Attachment AQ. (attached as Appendix C).

B. At a minimum Southwest Power Pool Regional Transmission Planning Criteria 3.0 (attached as Appendix D) should be followed for the studies associated with the transmission interconnection.

C. Any electrical structure or equipment utilized for high-voltage service shall be designed and installed according to Section 9 of the NESC (attached as Appendix E) and shall be connected to an earth-ground grid that measures no more than 0.6 ohms resistance to remote earth. Such value shall be measured with equipment and techniques approved by the Transmission Owner and shall be certified by a measuring contractor qualified for this service. The connectors and components of the grounding grid shall be adequate for the anticipated short-circuit current magnitude and duration.

D. Supervisory remote control data points shall be communicated via paths specified by the Transmission Owner to provide data required to reliably operate the transmission system. Electrical metering meeting the requirements set forth in SPP Criteria 7.9 (attached as Appendix F) shall be provided using devices and communications paths specified by the Transmission Owner. Such equipment shall be proven operational before electrical operation begins.

E. Surge protection equipment must be installed on each line terminal. Additional surge protection equipment may be installed to limit surges and impulses to be within the insulation characteristics of the interconnection equipment. The BIL of equipment and the characteristics of surge suppression devices will be coordinated during the design.

F. Load delivery points are required to operate at a monthly average power factor of between 100% and 95% lagging. Load shall operate in a manner to prevent voltage flicker to be in excess of the value provided by the Transmission Owner.

G. Harmonics at the interconnection point shall not exceed values recommended in IEEE 519 (attached as Appendix G).

H. Maintenance at the Facility Connection shall be coordinated with the Transmission Owner.

2.1.2 Transmission Facilities – 34.5 kV through 161 kV Requirements

A. Multiple remotely controllable line-sectionalizing switches or circuit breakers with protective relays may be required at Facility Connection.

B. Transformers capable of serving load greater than or equal to 14.0 MVA shall be controlled by a primary circuit switcher or circuit breaker with appropriate protective relaying.

C. Sectionalizing devices may require load breaking and/or fault interrupting capability. Fault interrupting capability must exceed the values determined from SPP Regional Transmission Planning Criteria 3.0 studies.

D. Protective relay schemes of Facility Owner shall be integrated to operate with protective relay schemes on Transmission Owner facilities and shall adhere to Appendix B if applicable. The required duty of the breaker will be determined by the protective relay scheme operating requirements.

E. Where applicable sync check relay will be installed to prevent closure of the connecting breaker if the phase angle of the two systems is more than 20 degrees.

F. Protective relaying shall include both primary and backup schemes.

2.1.3 Transmission Facilities – Greater than 161 kV

A. All requirements for lower-voltage connection shall apply. In addition, the following requirements shall apply:

B. Substation may be specified as a ring-bus or breaker-and-a-half configuration.

C. Control power shall be supplied from redundant DC supply systems.

D. Protective relaying shall include dual primary schemes.

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3.0 Generating Source Facility Connection Requirements

3.1 General Requirements

3.1.1 Generating Sources shall be three (3) phase to qualify for Facility Connection with Transmission System.

3.1.2 New Generating Sources must adhere to the process defined in the SPP OATT Attachment V.

3.1.3 Generation capacity in MW and MVARS must be provided as well as the voltage output of the generator and step-up transformers.

3.1.4 Generating Source shall not close or reclose automatically onto a de-energized Transmission Owner Facility Connection.

3.1.5 Disconnecting equipment shall have a visible break between Facility Owner and Transmission Owner facilities.

3.1.6 Facility Owner shall design the generating facility to maintain a composite power delivery at continuous rated power output at the Point of Interconnection at a power factor between 0.95 leading to 0.95 lagging. [This language matches the FERC Order 2003 Large Generator Interconnection Agreement.]

3.1.7 Supervisory Control and Data Acquisition (SCADA) may be required by Transmission Owner to connect Generating Source to Provider facilities.

3.1.8 Supervisory remote control data points shall be communicated via paths specified by the Transmission Owner to provide data required to reliably operate the transmission system. Electrical metering meeting the requirements set forth in SPP Criteria 7.9 (attached as Appendix F) shall be provided using devices and communications paths specified by the Transmission Owner. Such equipment shall be proven operational before electrical operation begins.

3.1.9 Connection to the Transmission System shall be at 60 Hz alternating current.

3.1.10 Any electrical structure or equipment utilized for high-voltage service shall be designed and installed according to Section 9 of the NESC (attached as Appendix E) and shall be connected to an earth-ground grid that measures no more than 0.6 ohms resistance to remote earth. Such value shall be measured with equipment and techniques approved by the Transmission Owner and shall be certified by a measuring contractor qualified for this service. The connectors and components of the grounding grid shall be adequate for the anticipated short-circuit current magnitude and duration.

3.1.11 Surge protection equipment must be installed on each line terminal. Additional surge protection equipment may be installed to limit surges and impulses to be within the insulation characteristics of the interconnection equipment. The BIL of equipment and the characteristics of surge suppression devices will be coordinated during the design.

3.1.12 Harmonics at the interconnection point shall not exceed values recommended in IEEE 519 Section 10.4 & 11.5 (Appendix G).

3.1.13 Generating Source shall be connected using a WYE-DELTA Generator Step Up transformer and shall be connected Grounded-WYE to Transmission Owner's facilities.

3.1.14 Protective relay schemes of Facility Owner shall adhere to Appendix A and B and be integrated to operate with protective relay schemes on Transmission Owner facilities.

3.2 Generating Source Types

3.2.1 Synchronous Generating Sources

Synchronous Generating Sources shall utilize three-phase circuit breakers, which meet or exceed the following requirements:

A. Rated for 2.0 per unit voltage across open contacts.

B. Interrupt maximum available fault currents between Facility Owner's Generating Source and Transmission Owner's facilities.

C. Open for frequency and voltage deviations specified by Southwest Power Pool.

D. Utilize synchronism check within +/- 10 degrees and +/- 5 percent of nominal voltage on each side of the breaker prior to closing the breaker between Transmission Owner's and Facility Owner's facilities.

E. Provide ground fault detection and tripping for breaker anytime an ungrounded circuit configuration exists as the result of opening the Transmission Owner's source to the Facility Connection.

F. Continuously monitor breaker control power source.

3.2.2 Induction Generating Sources

Induction Generating Sources shall utilize three-phase circuit breakers, which meet or exceed the following requirements:

A. Shall utilize three phase circuit breakers that can interrupt maximum available fault currents between Facility Owner's Generating Source and Transmission Owner's facilities.

B. Southwest Power Pool shall specify frequency and voltage deviations to Facility Owner for which circuit breaker shall open.

C. Breaker control power source shall be continuously monitored.

3.2.3 Converter Generating Sources

Converter Generating Sources shall meet the following requirement:

A. Shall utilize three phase circuit breakers that can interrupt maximum available fault currents between Facility Owner's Generating Source and Transmission Owner's facilities.

B. Converter Generating Sources shall cease operation for frequency and voltage deviations specified by Southwest Power Pool.

C. Breaker control power source shall be continuously monitored.

3.3 Generating Source Facility Connections – 20,000 kVA and Greater

3.3.1 Generating Sources shall be operated and maintained under the direction of the Southwest Power Pool.

3.3.2 Generating Sources shall operate with excitation systems in automatic voltage-control mode.

3.3.3 Generating Sources shall maintain reactive power output as required by the Southwest Power Pool within the demonstrated reactive capability of the unit.

3.3.4 In addition to the protection described in 1.12, Generating Sources shall have reverse power, loss of field, differential generator current, differential transformer current, negative sequence current, and inadvertent energization of the generator protection systems.

4.0 Commissioning of the Facility Connection

4.1 Transmission Owner may measure and document the harmonics present at the Facility Connection before and after such connection is made.

4.2 Transmission Owner reserves the right, but does not assume the duty, to inspect, test, or check Facility Owner's equipment in any way deemed appropriate to confirm operation and verify system protection characteristics. Transmission Owner does not assume any responsibility in connection with such Facility Owner's equipment or the inspection thereof.

4.3 Metering equipment shall be verified by Transmission Owner or its designated agent.

5.0 Operating Requirements:

5.1 Facility Owner agrees to respond to Southwest Power Pool and Transmission Owner requests during normal and emergency conditions.

5.2 Facility Owner shall ensure competent personnel are available to operate, maintain, and repair connected generating equipment at all times when such equipment operates in parallel with Transmission Owner's facilities.

5.3 Facility Owner shall provide a 10 day notice to Southwest Power Pool and Transmission Owner for routine maintenance on interconnection equipment that requires de-energization.

5.4 Facility Owner interconnection equipment and equipment that could impact the transmission system shall be inspected and tested in accordance with manufacturer recommendations or standard industry practices.

5.5 Transmission Owner may require connected generating sources to have both normal and emergency paths for supervisory control, metering, or voice communications systems.

5.6 The Southwest Power Pool and Transmission Owner require coordination with the regional underfrequency load shedding. Wholesale service providers shall be required to provide the Southwest Power Pool and Transmission Owner with a documented manual load shed plan.

5.7 Facility Owner shall provide all available operating data upon request.

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APPENDIX A

Relay Standards for Connected Generating Facilities

A1.0 *NERC Planning Standards, Sec. I.C:*

"All facilities involved in the generation, transmission and use of electricity must be properly connected to the interconnected transmission systems to avoid degrading the reliability of the electric systems to which they are connected."

A2.0 Requirements for generating facilities defined under Southwest Power Pool Facility Connection Requirements:

A2.1 "Facility Owner's facility design shall include an appropriate automatic disconnecting device to be controlled by any or all of the following: overcurrent relays, automatic synchronizing relays, voltage relays, frequency relays, ground fault detection relays, or any other automatic relaying equipment necessary to ensure proper protection and safety of Transmission Owner employees, customers, equipment, and overall system integrity."

A2.2 "Protective relay schemes of Facility Owner shall be integrated to operate with protective relay schemes of Transmission Owner's facilities. Generating Sources shall:

A2.2.1 not supply sustained fault current to Transmission Owner facilities."

A2.2.2 open for frequency and voltage deviations specified by Transmission Owner."

A2.2.3 utilize synchronism check not to exceed +/- 10 degrees and voltage limits of +/- 5 percent of nominal on each side of the disconnecting device prior to connecting Facility Owner's and Transmission Owner's facilities."

A2.2.4 provide ground fault detection and tripping for disconnecting device whenever an ungrounded circuit configuration exists as the result of opening the Transmission Provider's source to the Facility Connection."

A2.2.5 continuously monitor disconnecting device control-power source."

A2.2.6 not reclose automatically."

A2.2.7 accept transferred-tripping initiated from Transmission Owner facilities"

A2.2.8 be capable of transferring data to and from Transmission Owner SCADA system.

A3.0 Outline of generating facility protective-relay features:

A3.1 Protective relay features shall include:

A3.1.1 alternate modes of operation for generating and non-generating conditions. Voltage, frequency, synchronism and backfeed requirements will differ between modes.

A3.1.2 tripping for all faults on Transmission Owner source while in generating mode. This protects Transmission Owner equipment from inadvertent energization and non-synchronous reclosure, and other Transmission Owner customers from unpredictable electrical quality.

A3.1.3 acceptance of direct-trip signal from Transmission Owner source while in generating mode.

A3.1.4 closure of the interconnecting device through direct or indirect supervision of the protective relay for <u>all</u> modes of operation. This assures that the interconnection will be protected by a viable relay before closure.

A3.1.5 closure of the interconnecting device through permissive synchronism-checking supervision of the protective relay. Hot-source / dead-bus supervision should be utilized in the non-generating mode.

A3.1.6 waveform and event-capture of all opening and closing events.

A3.1.7 digital communication compatibility with Transmission Owner SCADA system.

A3.1.8 alarm capability to Transmission Owner dispatch for DC failure or relay failure.

A3.1.9 real-time telemetry capability of interconnection watt and var flows when generating.

A4.0 Required generic protective-relay functions:

A4.1 Inputs:

<> 3-phase AC potentials and currents
<> Close command
<> Trip command
<> Transferred-trip command
<> Synchronism-check permissive
<> Alternate-settings mode
<> Breaker trip-coil monitor
<> Breaker-indication contact

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A4.2 Algorithms:

<> Breaker state
<> Nondirectional overcurrent trip
<> Directional overcurrent trip
<> Negative-sequence overcurrent trip
<> 3-phase over- and under-voltage trip
<> 3-phase over- and under-frequency trip
<> Breaker failure-to-trip alternative protection scheme
<> Breaker trip-circuit "open" alarm
<> Malfunctioning or inoperative protective-relay alarm
<> Loss of control power alarm
<> Synchronism-check of breaker "close" command
<> Event-capture of each breaker operation
<> Waveform-capture of each breaker operation

A4.3 Outputs:

<> TRIP Command
<> CLOSE Command or synchronism-check permissive
<> LOCKOUT Command for failure-to-trip or malfunction
<> Alarms defined in section A4.2
<> Metering values for voltage and frequency
<> RS-232 or RS-485 communications port

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APPENDIX B
Relay Standards for Connected Load Facilities

B1.0 *NERC Planning Standards, Sec. I.C:*

"All facilities involved in the generation, transmission and use of electricity must be properly interconnected to the transmission systems to avoid degrading the reliability of the electric systems to which they are connected."

B2.0 Requirements for facilities defined under Southwest Power Pool Facility Connection Requirements:

B2.1 "Protective relay schemes of Facility Owner shall be integrated to operate with protective relay schemes of Transmission Owner facilities."

B2.2 Facility Owner equipment shall be capable of transferring data to and from Transmission Owner SCADA system.

B3.0 Outline of connection protective-device features:

B3.1 Connection with Transmission System shall be appropriate for the requirements of the electrical-system protective schemes. Such connection may utilize fuses, circuit-switchers or circuit-breakers with appropriate control schemes.

B3.2 Fuse ratings shall be in accordance with Transmission Owner standards.

B3.3 Protective-relay response shall not exceed transformer-damage specifications.

B3.4 Protective relay characteristics shall coordinate with Transmission Owner schemes.

B3.5 Digital communication protocol shall be compatible with Transmission Owner SCADA system.

B4.0 Required generic protective relay functions:

B4.1 Inputs:

<> 3-phase AC potentials and currents
<> Close command
<> Trip command
<> Breaker trip-coil monitor
<> Breaker-indication contact

B4.2 Algorithms:

<> Breaker state
<> Nondirectional overcurrent trip
<> Breaker failure-to-trip
<> Breaker trip-circuit "open" alarm
<> Malfunctioning or inoperative protective-relay alarm
<> Loss of control power alarm
<> Event-capture of each breaker operation

B4.3 Outputs:

<> TRIP Command
<> CLOSE Command or synchronism-check permissive
<> LOCKOUT Command for failure-to-trip or malfunction
<> Alarms defined in section B4.2
<> RS-232 or RS-485 communications port

ATTACHMENT AQ
DELIVERY POINT ADDITION PROCESS

1.0 Introduction: When it becomes necessary or desirable to make changes in delivery point facilities, to upgrade, retire, replace or establish a new delivery point, including metering or other facilities at such location, the provisions of this Attachment AQ shall apply. For the purposes of this Attachment, Host Transmission Owner is defined as the owner of that portion of the Transmission System to which such connection or modification is to be made.

2.0 Study Requests for Changes in Local Delivery Facilities: The Transmission Customer shall make requests for changes in local delivery facilities, including facility upgrades, retirements and replacements, or the establishment of any new delivery point in writing to (a) the Transmission Provider and the Host Transmission Owner as specified in Section 20 of the Network Operating Agreement or to (b) the Transmission Provider as specified in Section 8 of the Point to Point Transmission Service Agreement, as applicable. Such request shall contain as much information as is known or projected at the time of the request as set forth in "Sample Request for Change in Local Delivery Facilities" attached hereto as Addendum 1.

3.0 Studies: The Transmission Provider and Host Transmission Owner shall conduct all necessary studies associated with the delivery point change. Such studies shall be conducted at Transmission Customer's expense pursuant to the provisions of this section. In the event that such change in delivery point configuration results in significant impact on the Transmission System, Transmission Provider will coordinate the studies necessary to evaluate such addition or modification. Otherwise, the Host Transmission Owner will coordinate the studies.

3.1 Load Connection Study: Host Transmission Owner shall respond within ten (10) Business Days of receipt of such request and, if necessary, provide a Load Connection Study ("LCS") Agreement and a list of any additional information that Host Transmission Owner would require from the Transmission Customer to proceed with such study. Unless otherwise agreed, the LCS Agreement shall commit the Transmission Customer to pay Host Transmission Owner the actual cost to complete the study. The Host Transmission Owner may require an advance deposit equal to the estimated study cost or $25,000, whichever is less. In conducting the LCS, the Host Transmission Owner shall assess the feasibility of modifying an existing delivery point or establishing the new delivery point using power flow and short circuit analyses and any other analyses that may be appropriate. It shall also determine the details and estimated cost of facilities necessary for establishing the requested delivery point and any system additions/upgrades needed to address any problems identified in the LCS.

If the Transmission Customer fails to return an executed LCS Agreement within thirty (30) Calendar Days of receipt along with the required deposit, or at a later date as the Parties may mutually agree, Host Transmission Owner shall deem the study request to be withdrawn. The Transmission Customer may withdraw its study request at any time by written notice of such withdrawal to Host Transmission Owner. Host Transmission Owner shall complete the LCS and issue a Load Connection Report to the Transmission Customer and Transmission Provider within sixty (60) Calendar Days after receipt of an executed LCS Agreement, deposit and necessary data, or at a later date as the Parties may mutually agree.

Upon completion of the LCS, the Transmission Customer shall reimburse Host Transmission Owner for the unpaid cost of the LCS if the cost of LCS exceeds the deposit. Host Transmission Owner shall refund to the Transmission Customer, with interest, any portion of the deposit that exceeds the cost of the LCS. The interest rate will be computed in accordance with 18 C.F.R. § 35.19a(a)(2).

3.2 Transmission System Study: Upon receipt of the Request for Change in Local Delivery Facilities, Transmission Provider shall perform a preliminary assessment of the impact of the requested delivery point configuration change on the Transmission System. On or before the 20th day of the succeeding month, Transmission Provider shall conclude its preliminary assessment of the impact of each requested delivery point configuration change on the Transmission System for all Requests for Change in Local Delivery Facilities received in the current calendar month and post its findings on the SPP website. For all requests for which the Transmission Provider finds no significant impact on the Transmission System, Host Transmission Owner will coordinate completion of such change in local delivery facilities, including all required studies. For all requests for which the Transmission Provider finds that there is significant impact on the Transmission System, it shall, within five (5) days of posting of the results of the preliminary assessment, deliver to the Transmission Customer a Delivery Point Network Study ("DPNS") Agreement and a request for any additional information that it requires from the Transmission Customer to proceed with such study. The study agreement shall commit the Transmission Customer to pay the Transmission Provider the actual cost to complete the study and to make an advance deposit equal to the estimated study cost or $25,000, whichever is less. The Transmission Customer shall execute and deliver the DPNS Agreement and required deposit to the Transmission Provider as soon as reasonably possible, but not later than thirty (30) Calendar Days following its receipt or at a later date as the Parties may mutually agree. Upon receipt of the executed study agreement, study data, and the required deposit, Transmission Provider shall perform the DPNS. During the conduct of the DPNS, Transmission Provider shall assess the impacts on the Transmission System caused by modifying an existing delivery point or establishing the new delivery point using power flow and short circuit analyses and any other analyses that may be appropriate.

If the Transmission Customer fails to return an executed DPNS Agreement within thirty (30) Calendar Days of receipt or at a later date as the Parties may mutually agree, Transmission Provider and Host Transmission Owner shall deem the study request to be withdrawn. The Transmission Customer may withdraw its study request at any time by written notice of such withdrawal to the Transmission Provider and the Host Transmission Owner.

Transmission Provider shall issue a study report to the Transmission Customer and Host Transmission Owner within sixty (60) Calendar Days of the receipt of an executed DPNS Agreement, or at a later date as the Parties may mutually agree. If Transmission Provider is unable to complete such study in the allotted time, Transmission Provider shall provide an explanation to the Transmission Customer and Host Transmission Owner regarding the cause(s) of such delay and a revised completion date and study cost estimate.

Upon completion of the DPNS, the Transmission Customer shall reimburse Transmission Provider for the unpaid cost of the DPNS if the cost of the study exceeds the deposit. Transmission Provider shall refund the Transmission Customer, with interest, any portion of the deposit that exceeds the cost of the DPNS. The interest rate will be computed in accordance with 18 C.F.R. § 35.19a(a)(2).

3.3 Modifications to Study Request: During the course of a LCS or DPNS, the Transmission Customer, Host Transmission Owner or Transmission Provider may identify desirable changes in the planned facilities that may improve the costs and/or benefits (including reliability) of the planned facilities. To the extent the revised plan and study schedule are acceptable to Host Transmission Owner, Transmission Customer, and if applicable, Transmission Provider, such acceptance not to be unreasonably withheld, Host

Transmission Owner and if applicable, Transmission Provider, shall, at Transmission Customer's Expense, proceed with any necessary restudy.

4.0 Engineering, Design and Construction of New Facilities: The Transmission Customer and Host Transmission Owner shall agree to and specify in writing each party's responsibility for engineering, design, construction, and cost of facilities described in the final Load Connection Report.

Addendum 1 to Attachment AQ

Sample Request for Change in Local Delivery Facilities

Pursuant to the Delivery Point Addition Process in Attachment AQ of the Tariff notice is hereby provided on ________________ (date of notice) to _______________(the Host Transmission Owner) and Transmission Provider that Transmission Customer requests certain changes in delivery point(s) under the agreement.

Responses marked with an asterisk (*) are required. Supply all details that are known or projected.

Requested Modification

1) Description of delivery point modification*
   a) Type of change requested (new delivery point, upgrade of an existing delivery point, retirement or abandonment of an existing delivery point, etc.) *
   b) Proposed in service date of the modification*
   c) Reason for the requested change (i.e. normal or unexpected load growth or load reduction, reliability needs or other reason) *
   d) Related transmission service agreement*
   e) Location of the delivery point change and identification of the facilities involved*
      i) Geographic location of the new delivery point or the delivery point to be modified*
      ii) The transmission facilities of the Host Transmission Owner involved in the change*
      iii) Voltage of the facilities involved*
      iv) Desired meter location*
      v) Expected impact on other delivery points, if any*

(1) Load transfer from another delivery point and, if so, estimated amount*

(2) Anticipated modifications to other delivery points due to this change, if any*

vi) Facilities of others that may be involved*

2) Facilities to be constructed

a) Facilities to be constructed or provided by the Host Transmission Owner

b) Facilities to be constructed or provided by the Transmission Customer

3) Technical Aspects of a new delivery point

a) Location

i) Located near structure number

ii) 911 address

iii) State, County and ¼ of ¼ Section number

iv) GPS Coordinates

b) Technical aspects

i) Anticipated service voltage

ii) Number of wires (3 or 4 wire connection)

iii) Service voltage

iv) Meter

(1) Type

(2) Voltage

(3) Supplied by

(4) Owned by

(5) PTs and CTs required

(6) Communications configuration

v) Anticipated starting load

vi) Transformer size and voltages

vii) Transmission line conductor size and impedance rating

viii) Type and location of protective devices

4) Other pertinent information

Attachments:

1) Ten year load forecast for the delivery point being added or modified and any associated changes in the load forecast for other delivery points.

2) One-line diagram showing existing and proposed facilities pertaining to the request.

Requestor Contact:

Name: ______________________________

Title: _______________________________

Mailing Address: ______________________

Email Address: ________________________

Voice Phone No.: ______________________

By: ____________________________________
(Representative of Transmission Customer)

Title: __________________________________

Date: __________________________________

3.0 REGIONAL TRANSMISSION PLANNING

3.1 Concepts

The interconnected transmission system shall be capable of performing reliably under a wide variety of expected system conditions while continuing to operate within equipment and electric system thermal, voltage, and stability limits. The transmission system shall be planned to withstand all single element contingencies and maintenance outages over the load conditions of all seasonal models as developed by MDWG. Extreme event contingencies which measure the robustness of the electric systems should be evaluated for risks and consequences. The *NERC Reliability Standards* define specific requirements that provide a high degree of reliability for the bulk electric system. SPP provides additional coordinated regional transmission planning requirements to promote reliability through this Criterion and related “Coordinated Planning Procedures” in the *SPP Open Access Transmission Tariff.*

3.2 Definitions

All capitalized terms shall have their meaning as contemplated in the SPP OATT, unless defined below.

Bulk Electric System – Bulk Electric System shall have the definition as provided in the NERC Glossary of Terms Used In Reliability Standards, as may be amended from time to time.

NERC – The North American Electric Reliability Corporation, or its successor organization, which is an organization of all segments of the electric industry that recommends, sets, oversees, and implements policies and standards to ensure the continued reliability of North America’s bulk electric system.

Nominal Voltage – The root-mean-square, phase-to-phase voltage by which the system is designated and to which certain operating characteristics of the system are related. Examples of nominal voltages are 500 kV, 345 kV, 230 kV, 161 kV, 138 kV, 115 kV and 69 kV. SPP shall evaluate contingencies on the transmission system for all system elements with a Nominal Voltage of 60 kV or greater.

Planned Project – A transmission project, driven by system needs and the recommended solution among considered alternatives, which is a specific commitment requirements, SPP requires that the power flow models conform to the following standards:

- Normal Operations - Initiating incident may result in two or more (multiple) components out of service. Both non-fault and fault initiated events should be evaluated for severity of impact.

- Transmission Project Inclusion – All Planned Projects shall be included in the power flow models if the expected in-service date is prior to (i) November 1, for all winter peak cases, and (ii) June 1, for all summer peak cases.
- Compliance with NERC Table 1 – Category C System Performance Standards - All

MDWG power flow models shall be tested to verify compliance with the System Performance Standards from NERC Table 1 – Category C, subject to the following clarifications:

  - Thermal Limits within Applicable Rating - Applicable Rating shall be defined as the Emergency Rating per SPP Criteria 12, Section 12.2.b. The thermal limit shall be 100% of the Applicable Rating.
  - Voltage Limits Within Applicable Rating – Applicable Rating shall have the meaning of Nominal Voltage per Criteria 3. Voltage limits shall be set at plus five percent to minus ten percent (+5%/-10%) of Applicable Rating for systems operating at 60 kV or above on load serving buses.
- System Stability - Stability of the Transmission System (angular and voltage) shall be maintained. Cascading outages shall not occur.
  - Modeling of Projected Firm Transfers - All contracted firm (non-recallable reserved) transfers shall be maintained. All firm customer demands shall be maintained.
- Loss of Demand - Planned outages of customer demand or generation (as noted in NERC Reliability Standards Table I Transmission System Standards – Normal and Emergency Conditions) may occur, and contracted firm (non-recallable reserved) transfers may be curtailed.
- Mitigation Plans – Mitigation plans shall be submitted to SPP to verify effectiveness. Mitigation plans may include Transmission Operating

Directives or additional system elements. A mitigation plan is deemed effective if it shall return all system voltages and line and equipment ratings to within the Applicable Rating as defined above. SPP shall document the corrective plans necessary to mitigate effects of those events.

3.4.1.4 **Extreme Event (TPL-004)** – An extreme event shall have the meaning consistent with Category D of NERC Reliability Standards Table 1, Transmission System Standards – Normal and Emergency Conditions. SPP shall run contingency studies as provided by the transmission owners under the following conditions:

- Initiating event(s) shall result in multiple elements out of service.
- SPP shall document the measures and procedures to mitigate or eliminate the extent and effects of those events and may at their discretion recommend such measures and procedures where extreme contingency events could lead to uncontrolled cascading outages or system instability.

3.4.2 Study Requirements

System contingency studies should be based on system simulation models that should incorporate:

- Evaluation of reactive power resources
- Existing protection systems
- Any existing backup or redundancy protection systems
- All projected firm transfers (including rollover rights of long-term firm transactions)
- All existing and Planned Projects

These studies shall assist to determine that existing transmission protection schemes are sufficient to meet the system performance levels as defined in appropriate Category of NERC Reliability Standards Table I, Transmission System Standards – Normal and Emergency Conditions. Studies shall consider all contingencies applicable to the appropriate Category and document the selection rationale. Studies shall be conducted or reviewed annually, shall cover seasonal or expected critical system conditions for near (current or next year) and intermediate (two to five year recommended) planning horizons, and address both intra- and interregional reliability. Detailed analyses of the systems will not be conducted annually if changes to system conditions do not warrant such analyses.

The longer-term (beyond five years) simulations will identify concerns that may surface in the period beyond the more certain intermediate year period. Focus of simulations for the longer term will be on marginal system conditions evident from the intermediate year cases. Cases beyond the five-year horizon will be evaluated as needed to address identified marginal conditions.

3.4.3 **Mitigation Plans** – When simulations indicate an inability of the systems
to respond as prescribed by this Criterion, responsible entities must provide a written summary of their mitigation plans, including a schedule for implementation, to achieve the required system performance throughout the planning horizon. Mitigation plan summaries should discuss expected required in-service dates of facilities, should consider lead-times necessary to implement plans, and will be reviewed for continuing need in subsequent annual assessments.

3.4.4 **Transmission Operating Directives** – A Transmission Operating Directive qualifies as a valid mitigation measure when the Transmission Operating Directive is effective as written.

3.4.5 **Reporting Requirements** – Entities responsible for the reliability of interconnected transmission systems shall report annually on the performance of their systems in connection with NERC *Reliability Standards* to the SPP Region. The SPP will annually provide a summary of intra- and interregional studies to the NERC. Regional and interregional reliability assessments shall include the results of the system simulation testing as stated in the NERC Reliability Standards.

3.5 Interconnection Review Process

Southwest Power Pool Criteria 3.3.2 and the Regional Open Access Transmission Tariff both require members to contact the SPP and the Transmission Working Group whenever new transmission facilities that impact the interconnected operation are in the conceptual planning stage so that the optimal integration of any new facilities can be identified. Under this criterion an interconnection involves two or more SPP members or an SPP member and a non-member. A project that creates a non-radial, non-generation interconnection at 69 kV or above or that removes an interconnection at 230 kV or above shall be reviewed for impacts in accordance with Appendix 11. A Transmission Service Provider shall be subject to provisions of this criterion.

Appendix 11 – Interconnection Review Process Details

This appendix shall be subject to review and approval of the Transmission Working Group. Given the limited amount of time during a regular Transmission Working Group meeting, and given the need for timely responses, the majority of the interconnection review process will take place outside of a regular meeting. A Transmission Assessment Report will be prepared by the parties to the proposed interconnection and presented to the TWG for review. Once received, the Transmission Working Group will review the information provided in the assessment of impacts on the interconnected system. This appendix details the technical requirements which shall be the minimum necessary.

Coordination

1. The party proposing the interconnection shall appoint a person who will serve as the primary contact with SPP staff and with the Transmission Working Group.
2. If the proposal for interconnection comes from the SPP, then SPP shall appoint its primary contact.
3. The primary contact shall ensure that all affected parties are identified, shall provide a proposed timeline for the studies shall ensure that all affected parties are notified of and kept informed of progress, and provided the opportunity to review all study results prior to submission to the Transmission Working Group. The rationale for determining affected parties shall be included.
4. The primary contact shall coordinate any joint studies that may be necessary and shall report the results to all affected parties.
5. All affected parties shall cooperate in joint planning efforts.
6. All affected parties will work together to develop an estimated timeline for the completion of the study.
7. SPP shall coordinate activities that affect other regions pursuant to an applicable seams agreement.

Prior To The Review

Affected parties shall jointly develop and evaluate both the proposed interconnection and any mitigation plans. The primary contact shall submit a request for review of the interconnection request to the Transmission Working Group through the group's Secretary. The request for review shall include the following:

1. A list of all affected parties and the contact person at each affected party. The rationale for determining affected parties shall be included.
2. A brief summary of the results of planning studies. Each affected party shall provide a copy of its own planning criteria as documentation of the need of mitigations that exceed regional requirements.
3. A detailed description of the project including: in-service date; design information; ratings of the interconnection; a geographic map of the interconnection area; electrical one-line diagrams of the facilities being connected.
4. A summary of the results of power flow, short circuit, and dynamic analyses specifically addressing compliance to NERC Reliability Standards, SPP Criteria, other regional requirements, and affected party planning criteria.
5. Appropriate program files and program automation files to allow SPP staff to reproduce the studies performed.
6. Details of any required mitigation plans including identification of the parties responsible for mitigation. The detailed description of mitigation plans shall include such information as detailed in Item 3 above.

7. Any comments of the affected parties.

Technical Study Requirements

The following are minimum requirements for power flow analysis:

1. Impact analysis shall be performed using an N-1 contingency assessment of all single elements in the entire first-tier area of the combined areas which the proposed interconnection connects. This area maybe expanded or reduced as mutually agreed upon. The rationale for expansion or reduction of the study area shall be documented and agreed upon by all affected areas.
2. N-1 contingency assessment shall not be limited to a breaker-to-breaker outage assessment, but such assessment may also be included.
3. A review of impacts shall utilize all applicable Scenario Cases developed by the SPP extending to the planning horizon year.
4. If, at any time, impacts are identified affecting a nuclear power plant, it shall be included separately as an affected party.
5. Affected parties shall report adverse impacts and required mitigations.

The TWG may request additional studies at its discretion. The rationale for requesting additional studies shall be provided to all affected parties. If the proposed interconnection was previously evaluated by SPP and included in the most recent STEP, the power flow analysis described here does not need to be repeated.

The following are minimum requirements for short circuit analysis:

1. The model(s) assessed shall be determined by the affected parties. The rationale for the model(s) assessed shall be included
2. Assessment shall consist of 3-phase and phase-to-ground faults applied at the buses of the proposed interconnection plus all first-tier buses to the interconnection.
3. Additional buses may be studied as mutually agreed upon and documentation for including such additional buses shall be included.
4. Assessments shall document the before and after fault currents on all monitored busses.
5. Affected parties shall report adverse impacts and the required mitigation.

The following are minimum requirements for dynamics analysis:

1. The model(s) assessed shall be determined by the affected parties. The rationale for the model(s) assessed shall be included. If no dynamics analysis is performed the rationale for not performing such studies shall be provided.
2. The assessments performed shall be determined by the affected parties. The rationale for the assessments shall be included.
3. Assessments shall document the before and after dynamic performance on all monitored busses.
4. Affected parties shall report adverse impacts and the required mitigation.
5. If the interconnection is to be made at 345 kV or higher voltage, an assessment of reactive power impacts and management shall be made and provided for review. This assessment may include but is not limited to power flow, transient network analysis, or electromagnetics transients studies, insulation coordination studies and dynamics studies clearly indicating any required levels of shunt compensation.

Dispute Resolution

All disputes between SPP members shall be resolved using the procedures of Section 3.13 of the SPP Bylaws.

Review and Ballot by the Transmission Working Group

1. The Transmission Working Group Secretary shall review the request for interconnection for completeness.
2. Any deficiencies shall be reported to the primary contact.
3. Once a complete request is received, it shall be forwarded to the Transmission Working Group for a 14 day review and comment period.
4. The primary contact shall be responsible for coordinating any response necessary to comments and questions raised by the Transmission Working Group.
5. The Transmission Working Group shall schedule a ballot to accept or to reject the interconnection request.
6. Any action taken by the Transmission Working Group will be included in the minutes.

Transmission Interconnection Review Data Checklist

1. Primary contact and all affected parties' contact information.
2. Overview of the proposed interconnection and its need.
3. Estimated or proposed in-service date.
4. List of all studies run by season.
    a. Power flow studies minimum requirements met.
    b. Short circuit studies minimum requirements met.
    c. Dynamics studies minimum requirements met.
5. Affected parties planning criteria, if applicable.
6. A detailed description of the proposed interconnection.
    a. In-service date
    b. Design information
    c. Ratings of the interconnection
    d. A geographic map of the interconnection area
    e. Electrical one-line diagrams of the facilities being connected.
7. Appropriate program files and program automation files to allow SPP staff to reproduce the studies performed.
8. Details of any required mitigation plans including identification of the affected parties responsible for mitigation.
    a. In-service date
    b. Design information
    c. Ratings of the facilities
    d. A geographic map of the facility area
    e. Electrical one-line diagrams of the facilities being connected.
9. Comments of affected parties covering agreement or points of disagreement of the proposed interconnection, if any.

The Transmission Working Group shall review and modify this appendix as needed but not less frequently than once every 3 years.

Section 9. Grounding methods for electric supply and communications facilities

090. Purpose

The purpose of Section 9 of this Code is to provide practical methods of grounding, as one of the means of safeguarding employees and the public from injury that may be caused by electrical potential.

091. Scope

Section 9 of this Code covers methods of protective grounding of supply and communication conductors and equipment. The rules requiring grounding are in other parts of this Code. For rules requiring conductors or equipment to be effectively grounded, methods described in this section shall be used and the definition of effectively grounded shall be met.

These rules do not cover the grounded return of electric railways nor those lightning protection wires that are normally independent of supply or communication wires or equipment.

092. Point of connection of grounding conductor

A. Direct-current systems that are required to be grounded

1. 750 V and below

   Connection shall be made only at supply stations. In three-wire dc systems, the connection shall be made to the neutral.

2. Over 750 V

   Connection shall be made at both the supply and load stations. The connection shall be made to the neutral of the system. The ground or grounding electrode may be external to or remotely located from each of the stations.

   One of the two stations may have its grounding connection made through surge arresters provided the other station neutral is effectively grounded as described above.

   EXCEPTION: Where the stations are not geographically separated as in back-to-back converter stations, the neutral of the system should be connected to ground at one point only.

B. Alternating current systems that are required to be grounded

1. 750 V and below

   The point of the grounding connection on a wye-connected three-phase four-wire system, or on a single-phase three-wire system, shall be the neutral conductor. On other one-, two-, or three-phase systems with an associated lighting circuit or circuits, the point of grounding connection shall be on the common circuit conductor associated with the lighting circuits.

   The point of grounding connection on a three-phase three-wire system, whether derived from a delta-connected or an ungrounded wye-connected transformer installation not used for lighting, may be any of the circuit conductors, or it may be a separately derived neutral.

   The grounding connections shall be made at the source, and at the line side of all service equipment.

2. Over 750 V

   a. Nonshielded (bare or covered conductors or insulated nonshielded cables)

Grounding connection shall be made at the neutral of the source. Additional connections may be made, if desired, along the length of the neutral, where this is one of the system conductors.

b. Shielded

(1) Surge-arrester cable-shielding interconnection

Cable-shielding grounds shall be bonded to surge-arrester grounds, where provided, at points where underground cables are connected to overhead lines.

(2) Cable without insulating jacket

Connection shall be made to the neutral of the source transformer and at cable termination points.

(3) Cable with insulating jacket

Additional bonding and connections between the cable insulation shielding or sheaths and the system ground are recommended. Where multi-grounded shielding cannot be used for electrolysis or sheath-current reasons, the shielding sheaths and splice-enclosure devices shall be insulated for the voltage that may appear on them during normal operation.

Bonding transformers or reactors may be substituted for direct ground connection at one end of the cable.

3. Separate grounding conductor

If a separate grounding conductor is used as an adjunct to a cable run underground, it shall be connected either directly or through the system neutral to the source transformers, source transformer accessories, and cable accessories where these are to be grounded. This grounding conductor shall be located in the same direct burial or conduit run as the circuit conductors. If run in duct of magnetic material, the grounding conductor shall be run in the same duct as the circuit conductors.

EXCEPTION: The grounding conductor for a circuit that is installed in a magnetic duct need not be in the same duct if the duct containing the circuit is bonded to the separate grounding conductor at both ends.

C. Messenger wires and guys

1. Messenger wires

Messenger wires required to be grounded shall be connected to grounding conductors at poles or structures at maximum intervals as listed below:

a. Where messenger wires are adequate for system grounding conductors (Rules 93C1, 93C2, and 93C5), four connections in each 1.6 km (1 mi).

b. Where messenger wires are not adequate for system grounding conductors, eight connections in each 1.6 km (1 mi), exclusive of service grounds.

2. Guys

Guys that are required to be grounded shall be connected to one or more of the following:

a. A grounded metallic supporting structure.

b. An effective ground on a nonmetallic supporting structure.

c. A line conductor that has at least four ground connections in each mile of line in addition to the ground connections at individual services.

3. Common grounding of messengers and guys on the same supporting structure

a. Where messengers and guys on the same supporting structure are required to be grounded, they shall be bonded together and grounded by connection to:

(1) One grounding conductor that is grounded at that structure, or to

(2) Separate grounding conductors or grounded messengers that are bonded together and grounded at that structure, or to

(3) One or more grounded line conductors or grounded messengers that are (a) bonded together at this structure or elsewhere and (b) multi-grounded elsewhere at intervals as specified in Rules 92C1 and 92C2.

b. At common crossing structures, messengers and guys that are required to be grounded shall be bonded together at that structure and grounded in accordance with Rule 92C3a.

EXCEPTION: This rule does not apply to guys that are connected to an effectively grounded overhead static wire.

D. Current in grounding conductor

Ground connection points shall be so arranged that under normal circumstances there will be no objectionable flow of current over the grounding conductor. If an objectionable flow of current occurs over a grounding conductor due to the use of multi-grounds, one or more of the following should be used:

1. Determine the source of the objectionable ground conductor current and take action necessary to reduce the current to an acceptable level at its source.
2. Abandon one or more grounds.
3. Change location of grounds.
4. Interrupt the continuity of the grounding conductor between ground connections.
5. Subject to the approval of the administrative authority, take other effective means to limit the current.

The system ground of the source transformer shall not be removed.

Under normal system conditions a grounding conductor current will be considered objectionable if the electrical or communication system's owner/operator deems such current to be objectionable, or if the presence and/or electrical characteristics of the grounding conductor current is in violation of rules and regulations governing the electrical system, as set forth by the authority having jurisdiction to promulgate such rules.

The temporary currents set up under abnormal conditions while the grounding conductors are performing their intended protective functions are not considered objectionable. The conductor shall have the capability of conducting anticipated fault current without thermal overloading or excessive voltage buildup. Refer to Rule 93C.

NOTE: Some amount of current will always be present on the grounding conductors of an operating ac electrical system.

E. Fences

Fences that are required to be grounded by other parts of this Code shall be designed to limit touch, step, and transferred voltages in accordance with industry practices.

NOTE: IEEE Std 80™-2000 [B34] is one source that may be utilized to provide guidance in meeting these requirements.[12]

The grounding connections shall be made either to the grounding system of the enclosed equipment or to a separate ground.

1. Fences shall be grounded at each side of a gate or other opening.
2. Gates shall be bonded to the grounding conductor, jumper, or fence.
3. A buried bonding jumper shall be used to bond across a gate or other opening in the fence, unless a nonconducting fence section is used.
4. If barbed wire strands are used above the fence fabric, the barbed wire strands shall be bonded to the grounding conductor, jumper, or fence.
5. When fence posts are of conducting material, the grounding conductor shall be connected to the fence post or posts, as required, with suitable connecting means.

[12] The numbers in brackets correspond to those of the bibliography in Appendix E.

6. When fence posts are of nonconducting material, suitable bonding connection shall be made to the fence mesh strands and the barbed wire strands at each grounding conductor point.

093. Grounding conductor and means of connection

A. Composition of grounding conductors

In all cases, the grounding conductor shall be made of copper or other metals or combinations of metals that will not corrode excessively during the expected service life under the existing conditions and, if practical, shall be without joint or splice. If joints are unavoidable, they shall be so made and maintained as to not materially increase the resistance of the grounding conductor and shall have appropriate mechanical and corrosion-resistant characteristics. For surge arresters and ground detectors, the grounding conductor or conductors shall be as short, straight, and free from sharp bends as practical. Metallic electrical equipment cases or the structural metal frame of a building or structure may serve as part of a grounding conductor to an acceptable grounding electrode.

In no case shall a circuit-opening device be inserted in the grounding conductor or connection except where its operation will result in the automatic disconnection from all sources of energy of the circuit leads connected to the equipment so grounded.

EXCEPTION 1: For dc systems over 750 V, grounding conductor circuit-opening devices shall be permitted for changing between a remote electrode and a local ground through surge arresters.

EXCEPTION 2: Temporary disconnection of grounding conductors for testing purposes, under competent supervision, shall be permitted.

EXCEPTION 3: Disconnection of a grounding conductor from a surge arrester is allowed when accomplished by means of a surge-arrester disconnector.

NOTE: The base of the surge arrester may remain at line potential following operation of the disconnector.

B. Connection of grounding conductors

Connection of the grounding conductor shall be made by a means matching the characteristics of both the grounded and grounding conductors, and shall be suitable for the environmental exposure. These means include brazing, welding, mechanical and compression connections, ground clamps, and ground straps. Soldering is acceptable only in conjunction with lead sheaths.

C. Ampacity and strength

For bare grounding conductors, the short time ampacity is the current that the conductor can carry for the time during which the current flows without melting or affecting the design characteristics of the conductor. For insulated grounding conductors, the short time ampacity is the current that the conductor can carry for the applicable time without affecting the design characteristics of the insulation. Where grounding conductors at one location are paralleled, the increased total current capacity may be considered.

1. System grounding conductors for single-grounded systems

   The system grounding conductor or conductors for a system with single-system grounding electrode or set of electrodes, exclusive of grounds at individual services, shall have a short time ampacity adequate for the fault current that can flow in the grounding conductors for the operating time of the system-protective device. If this value cannot be readily determined, continuous ampacity of the grounding conductor or conductors shall be not less than the full-load continuous current of the system supply transformer or other source of supply.

2. System grounding conductors for multi-grounded alternating current systems

   The system grounding conductors for an ac system with grounds at more than one location exclusive of grounds at individual services shall have continuous total ampacities at each location of not less than one-fifth that of the conductors to which they are attached. (See also Rule 93C8.)

3. Grounding conductors for instrument transformers

The grounding conductor for instrument cases and secondary circuits for instrument transformers shall not be smaller than AWG No. 12 copper or shall have equivalent short time ampacity.

4. Grounding conductors for primary surge arresters

   The grounding conductor or conductors shall have adequate short time ampacity under conditions of excess current caused by or following a surge. Individual arrester grounding conductors shall be no smaller than AWG No. 6 copper or AWG No. 4 aluminum.

   EXCEPTION: Arrester grounding conductors may be copper-clad or aluminum-clad steel wire having not less than 30% of the conductivity of solid copper or aluminum wire of the same diameter, respectively.

   Where flexibility of the grounding conductor, such as adjacent to the base of the arrester, is vital to its proper operation, a suitably flexible conductor shall be employed.

5. Grounding conductors for equipment, messenger wires, and guys

   a. Conductors

      The grounding conductors for equipment, raceways, cable, messenger wires, guys, sheaths, and other metal enclosures for wires shall have short time ampacities adequate for the available fault current and operating time of the system fault-protective device. If no overcurrent or fault protection is provided, the ampacity of the grounding conductor shall be determined by the design and operating conditions of the circuit, but shall be not less than that of AWG No. 8 copper. Where the adequacy and continuity of the conductor enclosures and their attachment to the equipment enclosures is assured, this path can constitute the equipment grounding conductor.

   b. Connections

      Connections of the grounding conductor shall be to a suitable lug, terminal, or device not disturbed in normal inspection, maintenance, or operation.

6. Fences

   The grounding conductor for fences required to be grounded by other parts of this Code shall meet the requirements of Rule 93C5 or shall be steel wire not smaller than Stl WG No. 5.

7. Bonding of equipment frames and enclosures

   Where required, a low-impedance metallic path shall be provided to conduct fault current back to the grounded terminal of the local supply. Where the supply is remote, the metallic path shall interconnect the equipment frames and enclosures with all other nonenergized conducting components within reach and shall additionally be connected to ground as outlined in Rule 93C5. Short time ampacities of bonding conductors shall be adequate for the duty involved.

8. Ampacity limit

   No grounding conductor need have greater ampacity than either:

   a. The phase conductors that would supply the ground fault current, or

   b. The maximum current that can flow through it to the ground electrode or electrodes to which it is attached. For a single grounding conductor and connected electrode or electrodes, this would be the supply voltage divided by the electrode resistance (approximately).

9. Strength

   All grounding conductors shall have mechanical strength suitable for the conditions to which they may reasonably be subjected.

   Furthermore, unguarded grounding conductors shall have a tensile strength not less than that of AWG No. 8 soft-drawn copper, except as noted in Rule 93C3.

D. Guarding and protection

   1. Single-grounded systems: Guarding is required for grounding conductors of single-grounded systems unless the installation is not readily accessible to the public.

2. Multi-grounded systems: Grounding conductors of multi-grounded systems need not be guarded.
3. Where guarding is required, grounding conductors shall be protected by guards suitable for the exposure to which they may reasonably be subjected. The guards should extend for not less than 2.45 m (8 ft) above the ground or platform from which the grounding conductors are accessible to the public.
4. Where guarding is not required, grounding conductors, installed in areas of exposure to mechanical damage, shall be protected by being substantially attached closely to the surface of the pole or other structure and, where practical, on the portion of the structure having least exposure.
5. Guards used for grounding conductors of lightning-protection equipment shall be of nonmetallic materials if the guard completely encloses the grounding conductor or is not bonded at both ends to the grounding conductor.

E. Underground

1. Grounding conductors laid directly underground shall be laid slack or shall be of sufficient strength to allow for earth movement or settling that is normal at the particular location.
2. Direct-buried uninsulated joints or splices in grounding conductors shall be made with methods suitable for the application and shall have appropriate corrosion resistance, required permanence, appropriate mechanical characteristics, and required ampacity. The number of joints or splices should be the minimum practical.
3. Grounding cable insulation shielding systems shall be interconnected with all other accessible grounded power supply equipment in manholes, handholes, and vaults.

   EXCEPTION: Where cathodic protection or shield cross-bonding is involved, interconnection may be omitted.
4. Looped magnetic elements such as structural steel, piping, reinforcing bars, etc., should not separate grounding conductors from the phase conductors of circuits they serve.
5. Metals used for grounding, in direct contact with earth, concrete, or masonry, shall have been proven suitable for such exposure.

   NOTE 1: Under present technology, aluminum has not generally been proven suitable for such use.

   NOTE 2: Metals of different galvanic potentials that are electrically interconnected may require protection against galvanic corrosion.
6. Sheath transposition connections (cross-bonding)
   a. Where cable insulating shields or sheaths, which are normally connected to ground, are insulated from ground to minimize shield circulating currents, they shall be insulated from personnel contact at accessible locations. Transposition connections and bonding jumpers shall be insulated for nominal 600 V service, unless the normal shielding voltage exceeds this level, in which case the insulation shall be ample for the working voltage to ground.
   b. Bonding jumpers and connecting means shall be sized and selected to carry the available fault current without damaging jumper insulation or sheath connections.

F. Common grounding conductor for circuits, metal raceways, and equipment

Where the ampacity of a supply system grounding conductor is also adequate for equipment grounding requirements, this conductor may be used for the combined purpose. Equipment referred to includes the frames and enclosures of supply system control and auxiliary components, conductor raceways, cable shields, and other enclosures.

094. Grounding electrodes

The grounding electrode shall be permanent and adequate for the electrical system involved. A common electrode or electrode system shall be employed for grounding the electrical system and the conductor enclosures and equipment served by that system. This may be accomplished by interconnecting these elements at the point of connection of grounding conductor, Rule 92.

Grounding electrodes shall be one of the following:

A. Existing electrodes

Existing electrodes consist of conducting items installed for purposes other than grounding:

1. Metallic water piping system

Extensive metallic underground cold water piping systems may be used as grounding electrodes.

EXCEPTION: Water systems with nonmetallic, non-current-carrying pipe or insulating joints are not suitable for use as grounding electrodes.

NOTE: Such systems normally have very low resistance to earth and have been extensively used in the past.

2. Local systems

Isolated buried metallic cold water piping connecting to wells having sufficiently low measured resistance to earth may be used as grounding electrodes.

NOTE: Care should be exercised to ensure that all parts that might become disconnected are effectively bonded together.

3. Steel reinforcing bars in concrete foundations and footings

The reinforcing bar system of a concrete foundation or footing that is not insulated from direct contact with earth, and that extends at least 900 mm (3 ft) below grade, constitutes an effective and acceptable type of grounding electrode. Where steel supported on this foundation is to be used as a grounding conductor (tower, structure, etc.), it shall be interconnected by bonding between anchor bolts and reinforcing bars or by cable from the reinforcing bars to the structure above the concrete.

The normally applied steel ties are considered to provide adequate bonding between bars of the reinforcing cage.

NOTE: Where reinforcing bars in concrete are not suitably connected to a metal structure above the concrete, and the latter structure is subjected to grounding discharge currents (even connected to another electrode), there is likelihood of damage to the intervening concrete from ground-seeking current passing through the semiconducting concrete.

B. Made electrodes

1. General

Where made electrodes are used, they shall, as far as practical, penetrate permanent moisture level and below the frostline. Made electrodes shall be of metal or combinations of metals that do not corrode excessively under the existing conditions for the expected service life.

All outer surfaces of made electrodes shall be conductive, that is, not having paint, enamel, or other covering of an insulating type.

2. Driven rods

a. Driven rods may be sectional; the total length shall be not less than 2.44 (8 ft). Iron, zinc-coated steel, or steel rods shall have a diameter of not less than 15.87 mm (0.625 in). Copper-clad, stainless steel, or stainless steel-clad rods shall have a diameter of not less than 12.7 mm (0.5 in).

b. Longer rods or multiple rods may be used to reduce the ground resistance. Spacing between multiple rods should be not less than 1.8 m (6 ft).

EXCEPTION: Other diameters or configurations may be used if their suitability is supported by a qualified engineering study.

c. Driven depth shall be not less than 2.45 m (8 ft). The upper end shall be flush with or below the ground level unless suitably protected.

EXCEPTION 1: Where rock bottom is encountered, driven depth may be less than 2.45 m (8 ft), or other types of electrode may be employed.

EXCEPTION 2: When contained within pad-mounted equipment, vaults, manholes, or similar enclosures, the driven depth may be reduced to 2.3 m (7.5 ft).

3. Buried wire, strips, or plates

In areas of high soil resistivity or shallow bedrock, or where lower resistance is required than attainable with driven rods, one or more of the following electrodes may be more useful:

a. Wire

Bare wires 4 mm (0.162 in) in diameter or larger, conforming to Rule 93E5, buried in earth at a depth not less than 450 mm (18 in) and not less than 30 m (100 ft) total in length, laid approximately straight, constitute an acceptably made electrode. (This is frequently designated a counterpoise.) The wire may be in a single length or may be several lengths connected at ends or at some point away from the ends. The wire may take the form of a network with many parallel wires spaced in two-dimensional array, referred to as a grid.

EXCEPTION 1: Where rock bottom is encountered, burial depth may be less than 450 mm (18 in).

EXCEPTION 2: Other lengths or configurations may be used if their suitability is supported by a qualified engineering study.

b. Strips

Strips of metal not less than 3.0 m (10 ft) in total length and with total (two sides) surface not less than 0.47 m^2 (5 ft^2) buried in soil at a depth not less than 450 mm (18 in) constitute an acceptably made electrode. Ferrous metal electrodes shall be not less than 6 mm (0.25 in) in thickness and nonferrous metal electrodes not less than 1.5 mm (0.06 in).

NOTE: Strip electrodes are frequently useful in rocky areas where only irregularly shaped pits are practical to excavate.

c. Plates or sheets

Metal plates or sheets having not less than 0.185 m^2 (2 ft^2) of surface exposed to the soil, and at a depth of not less than 1.5 m (5 ft), constitute an acceptable made electrode. Ferrous metal electrodes shall be not less than 6 mm (0.25 in) in thickness and nonferrous metal electrodes not less than 1.5 mm (0.06 in).

4. Pole-butt plates and wire wraps

a. General

In areas of very low soil resistivity there are two constructions, described in specifications b and c below, that may provide effective grounding electrode functions although they are inadequate in most other locations. Where these have been proven to have adequately low earth resistance by the application of Rule 96, two such electrodes may be counted as one made electrode and ground for application of Rules 92C1a, 92C2b, 96C, and 97C; however, these types shall not be the sole grounding electrode at transformer locations.

b. Pole-butt plates

Subject to the limitations of Rule 94B4a, a pole-butt plate on the base of a wooden pole, possibly folded up around the base of the pole butt, may be considered an acceptable electrode in locations where the limitations of Rule 96 are met. The plates shall be not less than 6 mm (1/4 in) thick if of ferrous metal and not less than 1.5 mm (0.06 in) thick if of nonferrous metal. Further, the plate area exposed to the soil shall be not less than 0.046 m^2 (0.5 ft^2).

c. Wire wrap

Subject to the limitations of Rule 94B4a, made electrodes may be wire attached to the pole previous to the setting of the pole. The wire shall be of copper or other metals that will not corrode excessively under the existing conditions and shall have a continuous bare or exposed length below ground level of not less than 3.7 m (12 ft), shall extend to the bottom of the pole, and shall not be smaller than AWG No. 6.

5. Concentric neutral cable

   Systems employing extensive [30 m (100 ft) minimum length] buried bare concentric neutral cable in contact with the earth may employ the concentric neutral as a grounding electrode. The concentric neutral may be covered with a semi-conducting jacket that has a radial resistivity not exceeding 100 m · Ω and that will remain essentially stable in service. The radial resistivity of the jacket material is that value calculated from measurements on a unit length of cable, of the resistance between the concentric neutral and a surrounding conducting medium. Radial resistivity equals resistance of unit length times the surface area of jacket divided by the average thickness of the jacket over the neutral conductors. All dimensions are to be expressed in meters.

6. Concrete-encased electrodes

   A metallic wire, rod, or structural shape, meeting Rule 93E5 and encased in concrete, that is not insulated from direct contact with earth, shall constitute an acceptable ground electrode. The concrete depth below grade shall be not less than 300 mm (1 ft), and a depth of 750 mm (2.5 ft) is recommended. Wire shall be no smaller than AWG No. 4 if copper, or 9 mm (3/8 in) diameter or AWG No. 1/0 if steel. It shall be not less than 6.1 m (20 ft) long, and shall remain entirely within the concrete except for the external connection. The conductor should be run as straight as practical.

   The metal elements may be composed of a number of shorter lengths arrayed within the concrete and connected together (e.g., the reinforcing system in a structural footing).

   EXCEPTION: Other wire length or configurations may be used if their suitability is supported by a qualified engineering study.

   NOTE 1: The lowest resistance per unit wire length will result from a straight wire installation.

   NOTE 2: The outline of the concrete need not be regular, but may conform to an irregular or rocky excavation.

   NOTE 3: Concrete-encased electrodes are frequently more practical or effective than driven rods or strips or plates buried directly in earth.

7. Directly embedded metal poles

   Directly embedded steel poles shall constitute an acceptable electrode, if all of the following requirements are met:

   a. Backfill around the pole is native earth, concrete, or other conductive material
   b. Not less than 1.5 m (5.0 ft) of the embedded length is exposed directly to the earth, without nonconductive covering

   EXCEPTION: Other lengths, configurations, or type metal may be used if their suitability is supported by a qualified engineering study.

   NOTE 1: Aluminum installed belowground is not considered as an acceptable electrode. Weathering steel may not be an acceptable material for this application.

   NOTE 2: There are structural and corrosion concerns that should be investigated prior to using metal poles as grounding electrodes. See Sections 25 and 26.

095. Method of connection to electrode

A. Ground connections

   The grounding connection shall be as accessible as practical and shall be made to the electrode by methods that provide the required permanence, appropriate mechanical characteristics, corrosion resistance, and required ampacity such as:

   1. An effective clamp, fitting, braze, or weld.
   2. A bronze plug that has been tightly screwed into the electrode.

3. For steel-framed structures, employing a concrete-encased reinforcing bar electrode, a steel rod similar to the reinforcing bar shall be used to join, by welding, a main vertical reinforcing bar to an anchor bolt. The bolt shall be substantially connected to the baseplate of the steel column supported on that footing. The electrical system may then be connected (for grounding) to the building frame by welding or by a bronze bolt tapped into a structural member of that frame.
4. For nonsteel frame structures employing a concrete-encased rod or wire electrode, an insulated copper conductor of size meeting the requirements of Rule 93C (except not smaller than AWG No. 4) shall be connected to the steel rod or wire using a cable clamp suitable for steel cable. This clamp and all the bared portion of the copper conductor, including ends of exposed strands within the concrete, shall be completely covered with mastic or sealing compound before concrete is poured. The copper conductor end shall be brought to or out of the concrete surface at the required location for connection to the electrical system. If the copper wire is carried beyond the surface of the concrete, it shall be no smaller than AWG No. 2.

   Alternately, the copper wire may be brought out of the concrete at the bottom of the hole and carried external to the concrete for surface connection.

B. Point of connection to piping systems

1. The point of connection of a grounding conductor to a metallic water piping system shall be as near as is practical to the water-service entrance to the building or near the equipment to be grounded and shall be accessible. If a water meter is between the point of connection and the underground water pipe, the metallic water piping system shall be made electrically continuous by bonding together all parts between the connection and the pipe entrance that may become disconnected, such as meters and service unions.
2. Made grounds or grounded structures should be separated by 3.0 m (10 ft) or more from pipelines used for the transmission of flammable liquids or gases operating at high pressure [1030 kPa (150 lb/in^2) or greater] unless they are electrically interconnected and cathodically protected as a single unit. Grounds within 3.0 m (10 ft) of such pipelines should be avoided or shall be coordinated so that hazardous ac conditions will not exist and cathodic protection of the pipeline will not be nullified.

   RECOMMENDATION: It is recommended that calculations or tests be used to determine the required separation of ground electrodes for high-voltage direct-current (HVDC) systems from flammable liquid or high-pressure gas pipelines.

   NOTE: Ground electrodes for HVDC systems over 750 V may require greater separation.

C. Contact surfaces

If any coating of nonconducting material, such as enamel, rust, or scale, is present on electrode contact surfaces at the point of connection, such a coating shall be thoroughly removed where required to obtain the requisite good connection. Special fittings so designed as to make such removal of nonconducting coatings unnecessary may also be used.

096. Ground resistance requirements

A. General

Grounding systems shall be designed to minimize hazard to personnel and shall have resistances to ground low enough to permit prompt operation of circuit protective devices. Grounding systems may consist of buried conductors and grounding electrodes.

B. Supply stations

Supply stations may require extensive grounding systems consisting of multiple buried conductors, grounding electrodes, or interconnected combinations of both. Grounding systems shall be designed to limit touch, step, mesh, and transferred potentials in accordance with industry practices.

NOTE: IEEE Std 80-2000 [B34] is one source that may be utilized to provide guidance in meeting these requirements.

C. Multi-grounded systems

The neutral, which shall be of sufficient size and ampacity for the duty involved, shall be connected to a made or existing electrode at each transformer location and at a sufficient number of additional points with made or existing electrodes to total not less than four grounds in each 1.6 km (1 mi) of the entire line, not including grounds at individual services.

RECOMMENDATION: This rule may be applied to shield wire(s) grounded at the source and which meet the multi-grounding requirements of this rule.

EXCEPTION: Where underwater crossings are encountered, the requirement of made electrodes to total not less than four grounds in each 1.6 km (1 mi) of the entire line does not apply for the underwater portion if the neutral is of sufficient size and capacity for the duty involved and the requirements of Rule 92B2 are met.

NOTE 1: Multi-grounded systems extending over a substantial distance are more dependent on the multiplicity of grounding electrodes than on the resistance to ground of any individual electrode. Therefore, no specific values are imposed for the resistance of individual electrodes.

NOTE 2: The intent is to ensure that grounding electrodes are distributed at approximately 400 m (1/4 mi) or smaller intervals, although some intervals may exceed 400 m (1/4 mi).

D. Single-grounded (unigrounded or delta) systems

The ground resistance of an individual made electrode used for a single-grounded system should meet the requirements of Rule 96A and should not exceed 25 Ω. If a single electrode resistance cannot meet these requirements, then other methods of grounding as described in Rule 94B shall be used to meet the requirements of Rule 96A.

097. Separation of grounding conductors

A. Except as permitted in Rule 97B, grounding conductors from equipment and circuits of each of the following classes shall be run separately to the grounding electrode for each of the following classes:

1. Surge arresters of circuits over 750 V and frames of any equipment operating at over 750 V.
2. Lighting and power circuits under 750 V.
3. Shield wires of power circuits.
4. Lightning rods, unless attached to a grounded metal supporting structure.

Alternatively, the grounding conductors shall be run separately to a sufficiently heavy ground bus or system ground cable that is well connected to ground at more than one place.

B. The grounding conductors of the equipment classes detailed in Rules 97A1, 97A2, and 97A3 may be interconnected utilizing a single grounding conductor, provided:

1. There is a direct-earth grounding connection at each surge-arrester location, and
2. The secondary neutral or the grounded secondary phase conductor is common with or connected to a primary neutral or a shield wire meeting the grounding requirements of Rule 97C.

C. Primary and secondary circuits utilizing a single conductor as a common neutral shall have at least four ground connections on such conductor in each 1.6 km (1 mi) of line, exclusive of ground connections at customers' service equipment.

D. Ungrounded or single-grounded systems and multi-grounded systems

1. Ungrounded or single-grounded systems

Where the secondary neutral is not interconnected with the primary surge-arrester grounding conductor as in Rule 97B, interconnection may be made through a spark gap or device that performs an equivalent function. The gap or device shall have a 60 Hz breakdown voltage of at least twice the primary circuit voltage but not necessarily more than 10 kV. At least one other grounding connection on the secondary neutral shall be provided with its grounding electrode located at a distance of not less than 6.1 m (20 ft) from the surge-arrester grounding electrode in addition to customer's grounds at each service entrance. The primary grounding conductor, or the secondary grounding conductor, shall be insulated for 600 V.

NOTE: For single-grounded systems, also see Rules 93C1, 93D, and 96D.

2. Multi-grounded systems

On multi-grounded systems, the primary and secondary neutrals should be interconnected according to Rule 97B. However, where it is necessary to separate the neutrals, interconnection of the neutrals shall be made through a spark gap or a device that performs an equivalent function. The gap or device shall have a 60 Hz breakdown voltage not exceeding 3 kV. At least one other grounding connection on the secondary neutral shall be provided with its grounding electrode located at a distance not less than 1.80 m (6 ft) from the primary neutral and surge-arrester grounding electrode in addition to the customer's grounds at each service entrance. Where the primary and secondary neutrals are not directly interconnected, (a) the primary grounding conductor, or the secondary grounding conductor, or both, shall be insulated for 600 V, and (b) the secondary grounding conductor shall be guarded according to Rule 93D2.

NOTE 1: A difference of voltage can exist where primary and secondary neutrals are not directly interconnected. For example, where metallic equipment is bonded to the secondary grounding conductor and is installed on the same pole, the primary grounding conductor would be insulated.

NOTE 2: Cooperation of all communications and supply utilities, customers of these utilities, and others may be necessary to obtain effective isolation between primary and secondary neutrals.

E. Where separate electrodes are used for system isolation, separate grounding conductors shall be used. Where multiple electrodes are used to reduce grounding resistance, they may be bonded together and connected to a single grounding conductor.

F. Made electrodes used for grounding surge arresters of ungrounded supply systems operated at potentials exceeding 15 kV phase to phase should be located at least 6.1 m (20 ft) from buried communication cables. Where lines with lesser separations are to be constructed, reasonable advance notice should be given to the owners or operators of the affected systems.

G. Bonding of communication systems to electric supply systems

Where both electric supply systems and communication systems are grounded on a joint use structure, either a single grounding conductor shall be used for both systems or the electric supply and communication grounding conductors shall be bonded together, except where separation is required by Rule 97A. Where the electric supply utility is maintaining isolation between primary and secondary neutrals, the communication system ground shall be connected only to the primary grounding conductor.

098. Number 098 not used in this edition.

099. Additional requirements for grounding and bonding of communication apparatus

Where required to be grounded by other parts of this Code, communication apparatus shall be grounded in the following manner.

See *NOTE 2* in Rule 97D2.

A. Electrode

The grounding conductor shall be connected to an acceptable grounding electrode as follows:

1. Where available and where the supply service is grounded to an acceptable electrode, as described in Rule 94, to the grounded metallic supply service conduit, service equipment enclosure, grounding electrode conductors, or grounding electrode conductors' metal enclosure.
2. Where the grounding means of Rule 99A1 is not available, to a grounding electrode as described in Rule 94A.

3. Where the grounding means of Rule 99A1 or 99A2 are not available, to a grounding electrode as described in Rule 94B.

   EXCEPTION: A variance to Rule 94B2 is allowed for this application. Iron or steel rods may have a cross-sectional dimension of not less than 13 mm (.50 in) and a length of not less than 1.50 m (5 ft). The driven depth shall be 1.50 m (5 ft), subject to *EXCEPTION 1* of Rule 94B2.

B. Electrode connection

The grounding conductor shall preferably be made of copper (or other material that will not corrode excessively under the prevailing conditions of use) and shall be not less than AWG No. 6 in size. The grounding conductor shall be attached to the electrode by means of a bolted clamp or other suitable methods.

NOTE: For requirements on proper materials, methods, and precautions to be taken in the selection and application of grounding and bonding, refer to Rules 93B and 95.

C. Bonding of electrodes

A bond not smaller than AWG No. 6 copper or equivalent shall be placed between the communication grounding electrode and the supply system neutral grounding electrode where separate electrodes are used at the structure or building being served. All separate electrodes shall be bonded together except where separation is required per Rule 97.

RECOMMENDATION: If water piping is used as a bonding means, care must be taken to assure that the metallic path is continuous between electrodes.

NOTE 1: See NEC Article 800-100(D) for corresponding NEC requirements.

NOTE 2: The bonding together of all separate electrodes limits potential differences between them and between their associated wiring systems.

7.8.5.1 Reporting Procedures

Generator Owner/Operators shall provide control area, SPP, and NERC as requested (30 business days) with information that ensures generator controls coordinate with the generator short term duration capabilities and protective relays. The information shall be supplied on the "Voltage Regulator Control Setting Status Report" as supplied by SPP is control area operator does not have its own form.

7.8.6 Governor Control Operation

Prime mover control (governors) shall operate with appropriate speed/load characteristics to regulate frequency. Governors' speed regulation response shall be set such that a decrease in system frequency causes the governor to respond by increasing the generator real power output.

7.8.6.1 Reporting Procedures

a. Generator Owner/Operators shall provide control area, SPP, and NERC as requested (30 business days) with the characteristics of the generator's speed/load governing system. Boiler or nuclear reactor control shall be coordinated to maintain the capability of the generator to aid control of system frequency during an electric system disturbance. Information shall be supplied on "Generator Governor Characteristic Reporting" report supplied by SPP if control area operator does not have its own form.
b. Non-functioning or blocked speed/load governor controls shall be reported to control area, SPP, and NERC on request (30 business days). Information shall be supplied on "Non-Functioning Governor Control" report supplied by SPP if control area operator does not have its own form.

7.9 Inter-Connection Revenue Metering

7.9.1 Meter Technical and Data Reporting Protocols

The protection design may also include various types and accuracies of metering and associated equipment. The metering may include, but not be limited to, the following: local station or plant annunciated / displayed metering, SCADA type operational metering exchanged among parties within a station or plant, SCADA type station to control center metering used for operational purposes, control center to control center ICCP type metering, and inter-connection revenue metering. These metering types may or may not have specific SPP criteria requirements. Other metering design requirements may need to be referenced when creating metering and protection design, especially those that include the control center to control center metering and revenue metering. SPP has specific functional and design type requirements for Inter-Connection Revenue Metering.

7.9.2 Revenue "Meter Technical and Data Reporting Protocols" Cross Reference

The Southwest Power Pool (SPP) Market Working Group's (MWG) Settlement Data and Meter Standards Task Force (SDMSTF) subcommittee has jurisdictional control over the power plant and transmission system "inter-connection settlement revenue metering". The SPP System Protection and Control Working Group (SPCWG) and other parties providing inter-connection settlement revenue metering designs in the SPP area must refer to the MWG - - SDMSTF Market Protocol Document "Appendix D: Meter Technical and Data Reporting Protocols" for inter-connection settlement revenue metering equipment design requirements. Per the SPP Market Protocol Document, the inter-connection revenue metering design requirements must be met for all new installations.

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IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems

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IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems

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Abstract: Goals for the design of electrical systems that include both linear and nonlinear loads are established in this recommended practice. The voltage and current waveforms that may exist throughout the system are described, and waveform distortion goals for the system designer are established. The interface between sources and loads is described as the point of common coupling and observance of the design goals will reduce interference between electrical equipment.

This recommended practice addresses steady-state limitations. Transient conditions exceeding these limitations may be encountered. This document sets the quality of power that is to be provided at the point of common coupling. This document does not cover the effects of radio-frequency interference; however, guidance is offered for wired telephone systems.

Keywords: harmonics, IEEE 519™, power quality

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Introduction

This introduction is not part of IEEE Std 519-2014, IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems.

The uses of nonlinear loads connected to electric power systems include static power converters, arc discharge devices, saturated magnetic devices, and, to a lesser degree, rotating machines. Static power converters of electric power are the largest nonlinear loads and are used in industry for a variety of purposes, such as electrochemical power supplies, adjustable speed drives, and uninterruptible power supplies. These devices are useful because they can convert ac to dc, dc to dc, dc to ac, and ac to ac.

Nonlinear loads change the sinusoidal nature of the ac power current (and consequently the ac voltage drop), thereby resulting in the flow of harmonic currents in the ac power system that can cause interference with communication circuits and other types of equipment. These harmonic currents also lead to increased losses and heating in numerous electromagnetic devices (motors, transformers, etc.). When reactive power compensation, in the form of power factor improvement capacitors, is used, resonant conditions can occur that may result in high levels of harmonic voltage and current distortion when the resonant condition occurs at a harmonic associated with nonlinear loads.

Common sources of harmonic currents in power systems include power electronic converters, arc furnaces, static VAR systems, inverters for distributed generation, ac phase controllers, cycloconverters, and ac-dc converters (rectifiers) commonly used in switched mode power supplies and pulse width modulated (PWM) motor drives. Each of these harmonic-producing devices can have fairly consistent harmonic current emission characteristics over time or each may present a widely-varying characteristic depending on the control of the device, the characteristics of the system, and other variables. This recommended practice is to be used for guidance in the design of power systems with nonlinear loads. The limits set are for steady-state operation and are recommended for "worst case" conditions. Transient conditions exceeding these limits may be encountered. In any case, the limit values given in this document are recommendations and should not be considered binding in all cases. Because of the nature of the recommendations, some conservatism is present that may not be necessary in all cases.

This recommended practice should be applied at interface points between system owners or operators and users in the power system. The limits in this recommended practice are intended for application at a point of common coupling (PCC) between the system owner or operator and a user, where the PCC is usually taken as the point in the power system closest to the user where the system owner or operator could offer service to another user. Frequently for service to industrial users (i.e., manufacturing plants) via a dedicated service transformer, the PCC is at the HV side of the transformer. For commercial users (office parks, shopping malls, etc.) supplied through a common service transformer, the PCC is commonly at the LV side of the service transformer.

The limits in this recommended practice represent a shared responsibility for harmonic control between system owners or operators and users. Users produce harmonic currents that flow through the system owner's or operator's system, which lead to voltage harmonics in the voltages supplied to other users. The amount of harmonic voltage distortion supplied to other users is a function of the aggregate effects of the harmonic current producing loads of all users and the impedance characteristics of the supply system.

Harmonic voltage distortion limits are provided to reduce the potential negative effects on user and system equipment. Maintaining harmonic voltages below these levels necessitates that

- All users limit their harmonic current emissions to reasonable values determined in an equitable manner based on the inherent ownership stake each user has in the supply system and

- Each system owner or operator takes action to decrease voltage distortion levels by modifying the supply system impedance characteristics as necessary.

In order to allow the system owner or operator to control the system impedance characteristics to reduce voltage distortion when necessary, users should not add passive equipment that affects the impedance characteristic in a way such that voltage distortions are increased. In effect, such actions by a user could amount to producing excessive voltage harmonic distortion. Such passive equipment additions (that lead to undesirable system impedance characteristics) should be controlled by the user in the same manner as current harmonic-producing devices operated by the user.

Contents

IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems

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1. Overview

The uses of nonlinear loads connected to electric power systems include static power converters, arc discharge devices, saturated magnetic devices, and, to a lesser degree, rotating machines. Static power converters of electric power are the largest nonlinear loads and are used in industry for a variety of purposes, such as electrochemical power supplies, adjustable speed drives, and uninterruptible power supplies. These devices are useful because they can convert ac to dc, dc to dc, dc to ac, and ac to ac.

Nonlinear loads change the sinusoidal nature of the ac power current (and consequently the ac voltage drop), thereby resulting in the flow of harmonic currents in the ac power system that can cause interference with communication circuits and other types of equipment. These harmonic currents also lead to increased losses and heating in numerous electromagnetic devices (motors, transformers, etc.). When reactive power compensation, in the form of power factor improvement capacitors, is used, resonant conditions can occur that may result in high levels of harmonic voltage and current distortion when the resonant condition occurs at a harmonic associated with nonlinear loads.

Common sources of harmonic currents in power systems include power electronic converters, arc furnaces, static VAR systems, inverters for distributed generation, ac phase controllers, cycloconverters, and ac-dc converters (rectifiers) commonly used in switched mode power supplies and pulse width modulated (PWM) motor drives. Each of these harmonic-producing devices can have fairly consistent harmonic current emission characteristics over time or each may present a widely-varying characteristic depending on the control of the device, the characteristics of the system, and other variables.

1.1 Scope

This recommended practice establishes goals for the design of electrical systems that include both linear and nonlinear loads. The voltage and current waveforms that may exist throughout the system are described, and waveform distortion goals for the system designer are established. The interface between sources and loads is described as the point of common coupling and observance of the design goals will minimize interference between electrical equipment.

This recommended practice addresses steady-state limitations. Transient conditions exceeding these limitations may be encountered. This document sets the quality of power that is to be provided at the point of common coupling. This document does not cover the effects of radio-frequency interference; however, guidance is offered for wired telephone systems.

1.2 Purpose

This recommended practice is to be used for guidance in the design of power systems with nonlinear loads. The limits set are for steady-state operation and are recommended for "worst case" conditions. Transient conditions exceeding these limits may be encountered. In any case, the limit values given in this document are recommendations and should not be considered binding in all cases. Because of the nature of the recommendations, some conservatism is present that may not be necessary in all cases.

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Harmonic voltage distortion limits are provided to reduce the potential negative effects on user and system equipment. Maintaining harmonic voltages below these levels necessitates that

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In order to allow the system owner or operator to control the system impedance characteristics to reduce voltage distortion when necessary, users should not add passive equipment that affects the impedance characteristic in a way such that voltage distortions are increased. In effect, such actions by a user could amount to producing excessive voltage harmonic distortion. Such passive equipment additions (that lead to undesirable system impedance characteristics) should be controlled by the user in the same manner as current harmonic-producing devices operated by the user.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEC Standard 61000-4-7, General Guide on Harmonics and Interharmonics Measurement and Instrumentation, for Power Supply Systems and Equipment Connected Thereto.[1]

IEC Standard 61000-4-30, Power Quality Measurement Methods.

IEC Standard 61000-4-15, Testing and Measurement Techniques—Flickermeter—Functional and Design Specifications.

IEEE Std 1453™, IEEE Recommended Practice—Adoption of IEC 61000-4-15:2010, Electromagnetic compatibility (EMC)—Testing and Measurement Techniques—Flickermeter—Functional and Design Specifications.[2]

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.[3]

harmonic (component): A component of order greater than one of the Fourier series of a periodic quantity. For example, in a 60 Hz system, the harmonic order 3, also known as the "third harmonic," is 180 Hz.

interharmonic (component): A frequency component of a periodic quantity that is not an integer multiple of the frequency at which the supply system is operating (e.g., 50 Hz or 60 Hz).

I-T product: The inductive influence expressed in terms of the product of root-mean-square current magnitude (I), in amperes, times its telephone influence factor (TIF).

kV-T product: Inductive influence expressed in terms of the product of root-mean-square voltage magnitude (V), in kilovolts, times its telephone influence factor (TIF).

maximum demand load current: This current value is established at the point of common coupling and should be taken as the sum of the currents corresponding to the maximum demand during each of the twelve previous months divided by 12.

notch: A switching (or other) disturbance in the normal power voltage waveform, lasting less than 0.5 cycles, which is initially of opposite polarity than the waveform and is thus subtracted from the normal waveform in terms of the peak value of the disturbance voltage. This includes complete loss of voltage for up to 0.5 cycles.

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[1] IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http:// www.ansi.org/).

[2] IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08854, USA (http://standards.ieee.org/).

[3] IEEE Standards Dictionary Online subscription is available at: http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.

notch depth: The average depth of the line voltage notch from the sine wave of voltage.

notch area: The area of the line voltage notch. It is the product of the notch depth, in volts, times the width of the notch measured in microseconds.

point of common coupling (PCC): Point on a public power supply system, electrically nearest to a particular load, at which other loads are, or could be, connected. The PCC is a point located upstream of the considered installation.

pulse number: The total number of successive nonsimultaneous commutations occurring within the converter circuit during each cycle when operating without phase control. It is also equal to the order of the principal harmonic in the direct voltage, that is, the number of pulses present in the dc output voltage in one cycle of the supply voltage.

short-circuit ratio: At a particular location, the ratio of the available short-circuit current, in amperes, to the load current, in amperes.

telephone influence factor (TIF): For a voltage or current wave in an electric supply circuit, the ratio of the square root of the sum of the squares of the weighted root-mean-square values of all the sine-wave components (including alternating current waves both fundamental and harmonic) to the root-mean-square value (unweighted) of the entire wave.

total demand distortion (TDD): The ratio of the root mean square of the harmonic content, considering harmonic components up to the 50th order and specifically excluding interharmonics, expressed as a percent of the maximum demand current. Harmonic components of order greater than 50 may be included when necessary.

total harmonic distortion (THD): The ratio of the root mean square of the harmonic content, considering harmonic components up to the 50th order and specifically excluding interharmonics, expressed as a percent of the fundamental. Harmonic components of order greater than 50 may be included when necessary.

4. Harmonic measurements

For the purposes of assessing harmonic levels for comparison with the recommended limits in this document, any instrument used should comply with the specifications of IEC 61000-4-7 and IEC 61000-4-30. The most relevant portions of the IEC specifications are summarized in 4.1 through 4.4.

4.1 Measurement window width

The width of the measurement window used by digital instruments employing Discrete Fourier Transform techniques should be 12 cycles (approximately 200 ms) for 60 Hz power systems (10 cycles for 50 Hz power systems). With this window width, spectral components will be available every 5 Hz (e.g., 0, 5, 10…50, 55, 60, 65, 70,… Hz). For the purposes of this document, a harmonic component magnitude is considered to be the value at a center frequency (60, 120, 180, etc. and 50, 100, 150, etc. Hz for 60 Hz and 50 Hz power systems, respectively) combined with the two adjacent 5 Hz bin values. The three values are combined into a single rms value that defines the harmonic magnitude for the particular center frequency component.

4.2 Very short time harmonic measurements

Very short time harmonic values are assessed over a 3-second interval based on an aggregation of 15 consecutive 12 (10) cycle windows for 60 (50) Hz power systems. Individual frequency components are aggregated based on an rms calculation as shown in Equation (1) where F represents voltage (V) or current (I), n represents the harmonic order, and i is a simple counter. The subscript vs is used to denote "very short." In all cases, F represents an rms value.

$$F_{n,vs} = \sqrt[2]{\frac{1}{15}\sum_{i=1}^{15} F_{n,i}^2} \tag{1}$$

4.3 Short time harmonic measurements

Short time harmonic values are assessed over a 10-minute interval based on an aggregation of 200 consecutive very short time values for a specific frequency component. The 200 values are aggregated based on an rms calculation as shown in Equation (2) where F represents voltage (V) or current (I), n represents the harmonic order, and i is a simple counter. The subscript sh is used to denote "short." In all cases, F represents an rms value.

$$F_{n,sh} = \sqrt[2]{\frac{1}{200}\sum_{i=1}^{200} F_{(n,vs),i}^2} \tag{2}$$

4.4 Statistical evaluation

Very short and short time harmonic values should be accumulated over periods of one day and one week, respectively. For very short time harmonic measurements, the 99th percentile value (i.e., the value that is exceeded for 1% of the measurement period) should be calculated for each 24-hour period for comparison with the recommend limits in Clause 5. For short time harmonic measurements, the 95th and 99th percentile values (i.e., those values that are exceeded for 5% and 1% of the measurement period) should be calculated for each 7-day period for comparison with the recommended limits in Clause 5. These statistics should be used for both voltage and current harmonics with the exception that the 99th percentile short time value is not recommended for use with voltage harmonics.

5. Recommended harmonic limits

Because managing harmonics in a power system is considered a joint responsibility involving both end-users and system owners or operators, harmonic limits are recommended for both voltages and currents. The recommended values in this clause are based on the fact that some level of voltage distortion is generally acceptable and both system owners or operators and users must work cooperatively to keep actual voltage distortion below objectionable levels. The underlying assumption of these recommended limits is that by limiting harmonic current injections by users, voltage distortion can be kept below objectionable levels. In the event that limiting harmonic currents alone does not result in acceptable levels of voltage distortion, system owners or operators should take action to modify system characteristics so that voltage distortion levels are acceptable. The acceptable voltage distortion levels form the basis of the harmonic voltage limits in 5.1.

The recommended limits in this clause apply only at the point of common coupling and should not be applied to either individual pieces of equipment or at locations within a user's facility. In most cases, harmonic voltages and currents at these locations could be found to be significantly greater than the limits recommended at the PCC due to the lack of diversity, cancellation, and other phenomena that tend to reduce the combined effects of multiple harmonic sources to levels below their algebraic summation.

5.1 Recommended harmonic voltage limits

At the PCC, system owners or operators should limit line-to-neutral voltage harmonics as follows:

— Daily 99th percentile very short time (3 s) values should be less than 1.5 times the values given in Table 1.

— Weekly 95th percentile short time (10 min) values should be less than the values given in Table 1.

All values should be in percent of the rated power frequency voltage at the PCC. Table 1 applies to voltage harmonics whose frequencies are integer multiples of the power frequency.

Table 1—Voltage distortion limits

Bus voltage V at PCC	Individual harmonic (%)	Total harmonic distortion THD (%)
$V \leq 1.0$ kV	5.0	8.0
1 kV < $V \leq 69$ kV	3.0	5.0
69 kV < $V \leq 161$ kV	1.5	2.5
161 kV < V	1.0	1.5[a]

[a]High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal whose effects will have attenuated at points in the network where future users may be connected.

Information on voltage interharmonic limits is given in Annex A and is based on lamp flicker assessed using the measurement technique described in IEEE Std 1453 and IEC 61000-4-15. The information of Annex A is not based on the effects of interharmonics on other equipment and systems such as generator mechanical systems, motors, transformers, signaling and communication systems, and filters. Due consideration should be given to these effects and appropriate interharmonic current limits should be developed starting from the information in Annex A on a case-by-case basis using specific knowledge of the supply system, connected user loads, and provisions for future users.

5.2 Recommended current distortion limits for systems nominally rated 120 V through 69 kV

The limits in this subclause apply to users connected to systems where the rated voltage at the PCC is 120 V to 69 kV. At the PCC, users should limit their harmonic currents as follows:

— Daily 99th percentile very short time (3 s) harmonic currents should be less than 2.0 times the values given in Table 2.

— Weekly 99th percentile short time (10 min) harmonic currents should be less than 1.5 times the values given in Table 2.

— Weekly 95th percentile short time (10 min) harmonic currents should be less than the values given in Table 2.

All values should be in percent of the maximum demand current, I_L. This current value is established at the PCC and should be taken as the sum of the currents corresponding to the maximum demand during each of the twelve previous months divided by 12. Table 2 applies to harmonic currents whose frequencies are integer multiples of the power frequency.

Table 2—Current distortion limits for systems rated 120 V through 69 kV

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order (odd harmonics)[a, b]						
I_{SC}/I_L	$3 \le h < 11$	$11 \le h < 17$	$17 \le h < 23$	$23 \le h < 35$	$35 \le h \le 50$	TDD
< 20[c]	4.0	2.0	1.5	0.6	0.3	5.0
20 < 50	7.0	3.5	2.5	1.0	0.5	8.0
50 < 100	10.0	4.5	4.0	1.5	0.7	12.0
100 < 1000	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0

[a]Even harmonics are limited to 25% of the odd harmonic limits above.

[b]Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

[c]All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L.

where

I_{sc} = maximum short-circuit current at PCC

I_L = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions

For interharmonic current components with frequencies that are not integer multiples of the power frequency, users should limit the components to sufficiently low levels so as to not produce undesirable effects on the power system and connected equipment. Limiting values and appropriate statistical indices should be developed on a case-by-case basis starting from the guidance of Annex A and considering the specifics of the supply system, connected user loads, and provisions for other users.

5.3 Recommended current distortion limits for systems nominally rated above 69 kV through 161 kV

The limits in this subclause apply to users connected to systems where the rated voltage V at the PCC is 69 kV < $V \le$ 161 kV. At the PCC, users should limit their harmonic currents as follows:

— Daily 99th percentile very short time (3 s) harmonic currents should be less than 2.0 times the values given in Table 3.

— Weekly 99th percentile short time (10 min) harmonic currents should be less than 1.5 times the values given in Table 3.

— Weekly 95th percentile short time (10 min) harmonic currents should be less than the values given in Table 3.

All values should be in percent of the maximum demand current, I_L. This current value is established at the PCC and should be taken as the sum of the currents corresponding to the maximum demand during each of the twelve previous months divided by 12. Table 3 applies to harmonic currents whose frequencies are integer multiples of the power frequency.

Table 3—Current distortion limits for systems rated above 69 kV through 161 kV

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order (odd harmonics)[a, b]						
I_{sc}/I_L	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h \leq 50$	TDD
< 20[c]	2.0	1.0	0.75	0.3	0.15	2.5
20 < 50	3.5	1.75	1.25	0.5	0.25	4.0
50 < 100	5.0	2.25	2.0	0.75	0.35	6.0
100 < 1000	6.0	2.75	2.5	1.0	0.5	7.5
> 1000	7.5	3.5	3.0	1.25	0.7	10.0

[a]Even harmonics are limited to 25% of the odd harmonic limits above.

[b]Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

[c]All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L.
where
I_{sc} = maximum short-circuit current at PCC
I_L = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions

For interharmonic current components with frequencies that are not integer multiples of the power frequency, users should limit the components to sufficiently low levels so as to not produce undesirable effects on the power system and connected equipment. Limiting values and appropriate statistical indices should be developed on a case-by-case basis starting from the guidance of Annex A and considering the specifics of the supply system, connected user loads, and provisions for other users.

5.4 Recommended current distortion limits for systems nominally rated above 161 kV

The limits in this subclause apply to users connected to general transmission systems where the rated voltage V at the PCC is greater than 161 kV. At the PCC, users should limit their harmonic currents as follows:

— Daily 99th percentile very short time (3 s) harmonic currents should be less than 2.0 times the values given in Table 4.

— Weekly 99th percentile short time (10 min) harmonic currents should be less than 1.5 times the values given in Table 4.

— Weekly 95th percentile short time (10 min) harmonic currents should be less than the values given in Table 4.

All values should be in percent of the maximum demand current, I_L. This current value is established at the PCC and should be taken as the sum of the currents corresponding to the maximum demand during each of the twelve previous months divided by 12. Table 4 applies to harmonic currents whose frequencies are integer multiples of the power frequency.

Table 4—Current distortion limits for systems rated > 161 kV

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order (odd harmonics)[a, b]						
I_{sc}/I_L	$3 \le h < 11$	$11 \le h < 17$	$17 \le h < 23$	$23 \le h < 35$	$35 \le h \le 50$	TDD
< 25[c]	1.0	0.5	0.38	0.15	0.1	1.5
25 < 50	2.0	1.0	0.75	0.3	0.15	2.5
≥ 50	3.0	1.5	1.15	0.45	0.22	3.75

[a]Even harmonics are limited to 25% of the odd harmonic limits above.

[b]Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

[c]All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L.

where

I_{sc} = maximum short-circuit current at PCC
I_L = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions

For interharmonic current components with frequencies which are not integer multiples of the power frequency, users should limit the components to sufficiently low levels so as to not produce undesirable effects on the power system and connected equipment. Limiting values and appropriate statistical indices should be developed on a case-by-case basis starting from the guidance of Annex A and considering the specifics of the supply system, connected user loads, and provisions for other users.

5.5 Recommendations for increasing harmonic current limits

It is recommended that the values given in Table 2, Table 3, and Table 4 be increased by a multiplying factor when actions are taken by a user to reduce lower-order harmonics. The multipliers given in the second column of Table 5 are applicable when steps are taken to reduce the harmonic orders given in the first column.

Table 5—Recommended multipliers for increases in harmonic current limits

Harmonics orders limited to 25% of values given in Table 2, Table 3, and Table 4	Multiplier
5, 7	1.4
5,7,11,13	1.7
5,7,11,13,17,19	2.0
5,7,11,13,17,19,23,25	2.2
↓	↓

The multipliers in Table 5 can be obtained as shown in Equation (3) where p is the pulse-order of a three-phase rectifier-based converter ($p = 6$, 12, 18, 24, etc.). These converters produce dominant or characteristic harmonic currents at orders of $p(n \pm 1)$, where n is a simple counter, $n = 1$, 2, 3 etc., and significantly lower current magnitudes at other orders. However, the recommended multipliers in Table 3 apply regardless of the method used to reduce the harmonics that would be considered "non-characteristic harmonics" for a p-pulse converter as long as all "non-characteristic harmonics," including even-order harmonics, are kept below 25% of the limit values given in Table 2, Table 3, or Table 4 as appropriate.

$$\text{Multiplier} = \sqrt{\frac{p}{6}} \tag{3}$$

Annex A

(informative)

Interharmonic voltage limits based on flicker

For interharmonic components that are not integer multiples of the power frequency, system owners or operators may limit the weekly 95th percentile short time harmonic voltages to the values shown graphically in Figure A-1 up to 120 Hz for 60 Hz systems. Depending on the voltage level, the integer harmonic limits in Table 1 may be more restrictive and should be used. The portions of the 0–120 Hz range where the integer harmonic limits of Table 1 are more restrictive are appropriately labeled in Figure A-1. The numerical values corresponding to Figure A-1 are given in Table A-1 for voltages at the PCC less than 1 kV. It is important to recognize that the suggested voltage interharmonic limits are based on lamp flicker assessed using the measurement technique described in IEEE Std 1453 and IEC 61000-4-15. These voltage interharmonic limits correlate with a short-term flicker severity Pst value equal to 1.0 for 60 Hz systems; different (but similar) limit values can be derived for 50 Hz systems. The recommended limits in Figure A-1 are not based on the effects of interharmonics on other equipment and systems such as generator mechanical systems, motors, transformers, signaling and communication systems, and filters. Due consideration should be given to these effects and appropriate interharmonic current limits should be developed on a case-by-case basis using specific knowledge of the supply system, connected user loads, and provisions for future users.

There is no limit on the 60 Hz component in Figure A-1. The 5% maximum applies to frequency components very near (but not equal to) 60 Hz.

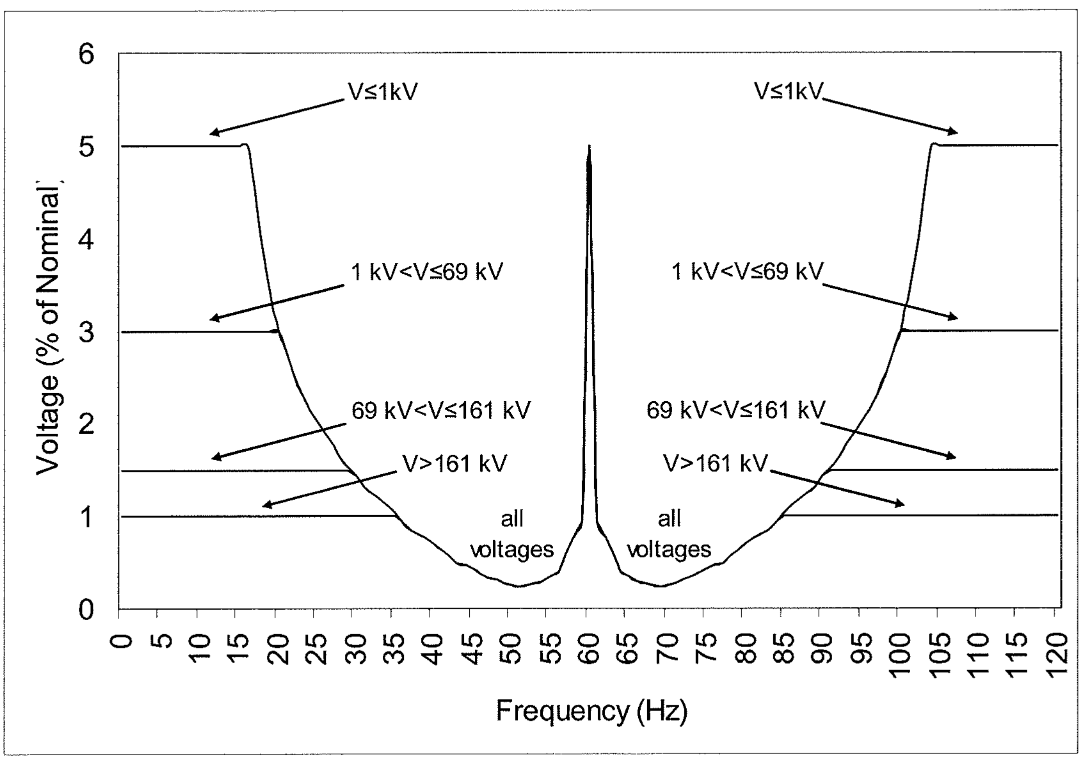

Figure A-1—Interharmonic voltage limits based on flicker for frequencies up to 120 Hz for 60 Hz systems

Table A-1—Voltage interharmonic limits corresponding to Figure A-1 for PCC voltage less than 1 kV[a, b]

Frequency (Hz)	Magnitude (%)	Frequency (Hz)	Magnitude (%)	Frequency (Hz)	Magnitude (%)	Frequency (Hz)	Magnitude (%)
16	5.00	27	1.78	38	0.81	49	0.28
17	4.50	28	1.64	39	0.78	50	0.25
18	3.90	29	1.54	40	0.71	51	0.23
19	3.45	30	1.43	41	0.64	52	0.25
20	3.00	31	1.33	42	0.57	53	0.27
21	2.77	32	1.26	43	0.50	54	0.29
22	2.53	33	1.20	44	0.48	55	0.35
23	2.30	34	1.13	45	0.43	56	0.40
24	2.15	35	1.05	46	0.38	57	0.58
25	2.03	36	0.95	47	0.34	58	0.77
26	1.90	37	0.85	48	0.31	59	0.95

[a]The values for frequencies above 60 (but less than 120) Hz are identical to those given in this table except the frequency of interest must be subtracted from 120 Hz before reading the corresponding value. For example, the interharmonic voltage limit for 61 Hz is equal to that given in the table for 120 − 61 = 59 Hz, which is 0.95%.

[b]The frequency resolution in Table A-1 is 1 Hz. The resolution available using the methods recommended in Clause 4 is 5 Hz. Special instrumentation to be agreed upon at the time of its use, may be needed to obtain 1 Hz resolution.

Annex B

(informative)

Telephone influence factor (TIF)

The TIF weighting is a combination of the C message weighting characteristic, which accounts for the relative interfering effect of various frequencies in the voice band (including the response of the telephone set and the ear), and a capacitor, which provides weighting that is directly proportional to frequency to account for the assumed coupling function. TIF is a dimensionless quantity that is indicative of the waveform and not the amplitude and is given by Equation (B.1).

$$\mathrm{TIF} = \sqrt{\sum\left[\frac{(X_n \cdot W_n)}{X}\right]^2} \qquad \text{(B.1)}$$

where

X = total rms voltage or current
X_n = single frequency rms current or voltage at the frequency corresponding to harmonic order n
W_n = single frequency TIF weighting at the frequency corresponding to harmonic order n

In practice, telephone interference is often expressed as a product of the current and the TIF, i.e., the *I-T* product, where the *I* is rms current in amperes and *T* is TIF as calculated in Equation (B.1). Alternatively, it is sometimes expressed as a product of the voltage and the TIF weighting, where the voltage is in rms kV, i.e., the *kV-T* product. The single frequency weighting values, based on 1960-vintage C-message weighting, are listed in Table B-1. Linear interpolation may be used as necessary in Table B-1.

Table B-1—Weighting values (W_f)

FREQ	W_f	FREQ	W_f	FREQ	W_f	FREQ	W_f
60	0.5	1020	5100	1860	7820	3000	9670
180	30	1080	5400	1980	8330	3180	8740
300	225	1140	5630	2100	8830	3300	8090
360	400	1260	6050	2160	9080	3540	6730
420	650	1380	6370	2220	9330	3660	6130
540	1320	1440	6560	2340	9840	3900	4400
660	2260	1500	6680	2460	10340	4020	3700
720	2760	1620	6970	2580	10600	4260	2750
780	3360	1740	7320	2820	10210	4380	2190
900	4350	1800	7570	2940	9820	5000	840
1000	5000						

B.1 Guidelines for *I-T* product

Table B-2 provides representative *I-T* guidelines for distribution systems operating at voltages less than (or equal to) 34.5 kV where it is more likely to have joint use of facilities, particularly poles and structures, involving electric power and telephone/communications companies. These guidelines should not be considered as recommended limits due to the wide range of variability in system and equipment compatibility that is encountered in practice. The use of categories is for illustration purposes only and is provided in the event that it is desirable to assess or compare interference potentials in multiple areas of a particular electrical system.

Table B-2—*I-T* guidelines for distribution systems[a]

Category	Description	*I-T*
I	Levels most unlikely to cause interference	Up to 10 000[b]
II	Levels that might cause interference	10 000 up to 25 000
III	Levels that probably will cause interference	Greater than 25 000

[a]These values of *I-T* product are for circuits with an exposure between overhead systems, both power and telephone. Within an industrial plant or commercial building, the exposure between power distribution cables and telephone lines with twisted pairs is extremely low and no interference is normally encountered; the use of fiber optic cables for communications virtually eliminates the entire concern.
[b]For some areas that use a ground return for either telephone or power circuits, this value may be as low as 1500.

Annex C

(informative)

Limits on commutation notches

C.1 Recommended limits on commutation notches

The notch depth and the notch area of the line-to-line voltage at PCC should be limited as shown in Table C-1.

Table C-1—Recommended limits on commutation notches

	Special applications[a]	General system	Dedicated system[b]
Notch depth	10%	20%	50%
Notch area (A_N)[c, d]	16400	22800	36500

[a]Special applications include hospitals and airports.
[b]A dedicated system exclusively supplies a specific user or user load.
[c]In volt-microseconds at rated voltage and current.
[d]The values for A_N have been developed for 480 V systems. It is necessary to multiply the values given by V/480 for application at all other voltages.

These limits are recommended for low-voltage systems in which the notch area is easily measured on an oscilloscope or power quality monitor with oscilloscope capability. In the event that direct measurement is not possible, detailed simulations including advanced models of the supply system and loads may provide approximate waveforms that may be used in place of oscilloscope measurements. The relevant variables for use in Table C-1 are defined in Figure C-1.

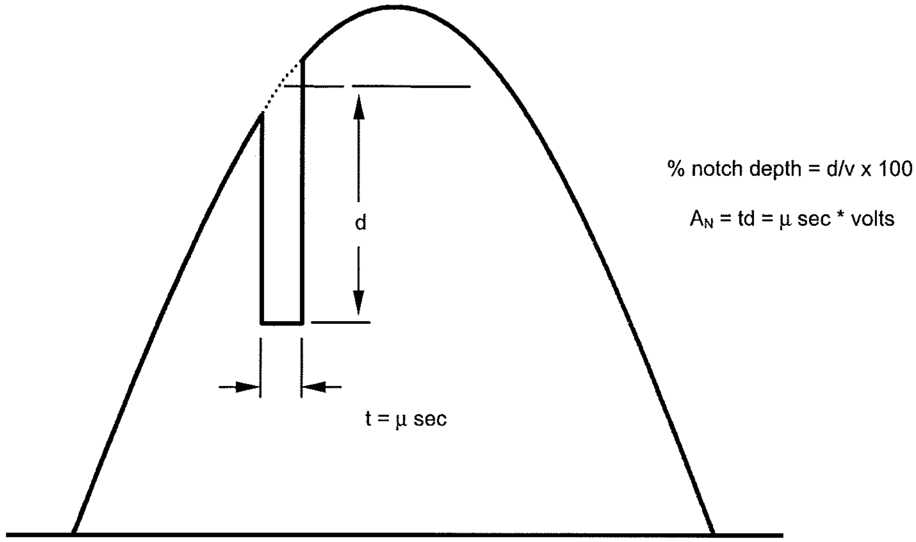

Figure C-1—Definition of notch depth and notch area

Annex D

(informative)

Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only.

[B1] IEEE Std C57.110™-1986, IEEE Recommended Practice for Establishing Transformer Capability When Supplying Nonsinusoidal Load Current.[4, 5]

[B2] IEEE Std 18™-1992, IEEE Standard for Shunt Power Capacitors.

[B3] IEEE Std 368™-1977 (Withdrawn), IEEE Recommended Practice for Measurement of Electrical Noise and Harmonic Filter Performance of High-Voltage Direct-Current Systems.[6]

[B4] IEEE Std 1100™-2005, IEEE Recommended Practice for Powering and Grounding Electronic Equipment.

[B5] IEEE Std 1159™-2009, IEEE Recommended Practice for Monitoring Electric Power Quality.

[B6] IEEE Std 1531™-2003, IEEE Guide for Application and Specification of Harmonic Filters.

[4] IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08854, USA (http://standards.ieee.org/).
[5] The IEEE standards or products referred to in this clause are trademarks of the Institute of Electrical and Electronics Engineers, Inc.
[6] IEEE Std C57.110-1986 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (http://global.ihs.com/).