

Requirements for Transmission System Interconnections to Generation, Transmission and End-User Facilities

Revised June 10, 2014



1040 O Street, P.O. Box 80869
Lincoln, NE 68501-0869

p: 402.475.4211
www.les.com

Lincoln Electric System

REQUIREMENTS FOR INTERCONNECTION

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INTRODUCTION

The Lincoln Electric System is a municipal electric utility serving the corporate area of Lincoln, Nebraska and a small area adjacent to Lincoln but outside of the corporate limits. For more details regarding the mission and background of LES facilities, refer to www.les.com

A small percentage of LES' customers are located outside the city limits, and to the extent that the city limits are expanded in the future, LES service area may be expanded. LES holds an exclusive franchise to serve customers within its service area.

LES owns a network of transmission lines which interconnect its generating plants to transmission lines of adjacent utilities and to various transmission and distribution substations serving the loads of Lincoln. The LES transmission lines are physically interconnected with the transmission systems of Omaha Public Power District (OPPD) and Nebraska Public Power District (NPPD).

The requirements herein are for all interconnections to the LES transmission system.

PURPOSE

1. The Lincoln Electric System (LES) has prepared this document to establish the technical and contractual facilities interconnection requirements for generation, transmission, and end-user facilities. These requirements intend to promote safe operation, system integrity and reliability of the LES and interconnected systems. References to the term “interconnection” include facility additions and modifications. These requirements are minimums to be used as a guide toward LES’s prompt processing of interconnection requests. A thorough review and understanding of these requirements will assist a requesting party in obtaining timely and mutually satisfactory responses.
2. Each request for an interconnection will be evaluated on a case-by-case basis and will be subject to meeting the reasonable needs of the requesting party. The requesting party may be another electric utility, a customer, an Independent Power Producer (IPP), a marketer or a Non-Utility Generator (NUG). Interconnections must meet electric utility standards, such as the North American Electric Reliability Corporation (NERC) standards, and specifically, LES Design Standards. Copies of the LES typical designs and structural design criteria (see appendix) will be furnished to the party requesting the interconnection.
3. Responsibilities to operate and maintain its interconnected facilities will normally be assumed by LES.
4. The review and approval requirements detailed here shall apply to all interconnected facilities regardless of who does the design or installation work.
5. This document will be revised as needed to meet current conditions and NERC Reliability Standards.

GENERAL REQUIREMENTS

1. Interconnections to the LES transmission system must be consistent with LES standards and with standard utility practices. A proposed interconnection must not degrade the reliability, operating flexibility or safety of the existing power system. System studies will be required to evaluate the impact of the requested interconnection.
2. All generation and transmission interconnections shall comply with the requirements of NERC Midwest Reliability Organization (MRO), and the Southwest Power Pool (SPP). SPP is the Planning Coordinator for LES so any proposed interconnections must follow SPP Criteria 3.5 and Appendix 11 that outlines the Interconnection Review Process. The proposed interconnection must be reviewed by all impacted transmission owners and approved by the SPP Transmission Working Group (TWG)
3. The party requesting the interconnection is responsible for notifying other affected entities per the SPP Criteria 3.5 and Appendix 11. At a minimum this shall include NPPD, OPPD, and the SPP Transmission Working Group (TWG).
4. The party requesting the interconnection will generally be responsible for obtaining any necessary rights-of-way or easements from landowners. All costs associated with the construction and environmental activities for the new facility will be the responsibility of the requesting party.
5. All arrangements for system studies, designs and construction, ownership, operations, maintenance, maintenance coordination, replacements or equipment, including metering, facility controls, compatible Remote Terminal Units (RTU), and communications, if applicable, must be set forth in written contracts between LES and the requesting party.
6. Advance funds will be required before any work is performed by LES for a requesting party.

ENVIRONMENTAL AND SAFETY REQUIREMENTS

LES is required to assess the potential environmental impacts of any proposed interconnection in accordance with National Environmental Policy Act of 1969 (NEPA), State and other environmental regulations. The party shall provide an environmental review of the proposed plan so that LES can determine what further actions, if any, are needed to comply with the above requirements. A copy of the environmental documents prepared by or for another agency involved with the project shall be furnished to LES. The final interconnection cannot be made until all environmental requirements have been met.

1. When the requesting party is to own equipment located in a LES substation, switchyard, or right-of-way, the requesting party shall be financially responsible for all activities necessary to comply with the requirements of existing or subsequent applicable Federal or State Environmental laws and regulations.
2. When making an interconnection to LES transmission system, the requesting party shall comply with applicable safety laws and building and construction codes, including provisions of applicable Federal, State, or local safety, health, or industrial regulations or codes, and the LES Safety Manual and programs.

TECHNICAL REQUIREMENTS FOR GENERATION, TRANSMISSION, AND END-USER FACILITIES

A. GENERAL

1. LES will conduct or review power system studies (at the expense of the requesting party) needed to substantiate system impact, reliability, and capability of the transmission system with the addition of the proposed interconnection. The studies may include, but not be limited to, powerflow, system stability, short circuit, breaker duty, surge protection, insulation coordination, equipment ratings, system grounding, safety, voltage level, MW capacity, MVAR capacity and synchronizing studies. Evaluation of alternatives to the proposed interconnection, such as lower voltage construction, reactive support facilities, or upgrading facilities, may be requested or conducted. Powerflow analysis will include 10-year load or resource growth projections and the planned facilities needed to satisfy such requirements.
2. The procedure for coordination of the joint studies of the proposed interconnect is to contact the designated LES personnel herein.
3. LES normally provides design, specification, and construction of the proposed interconnection. If the interconnecting entity chooses to design and construct the proposed project, three sets of prints of applicable facility drawings must be furnished to LES. LES will retain the review and approval authority over any design and construction on its right-of-way or associated with the proposed interconnection. All work performed by LES will be at the expense of the requesting party and will include revisions to the LES existing drawings.
4. Modifications to the existing system to accommodate the proposed project shall adhere to the appropriate LES standard design criteria and guides as contained herein. Variations from this design criteria or guides may be considered on a case-by-case basis.
5. Facilities involved in interconnections with the LES transmission system shall meet LES environmental safety requirements including fall protection features.
6. An inspection by LES personnel of the new or existing facility to be interconnected is required before energization may occur. The inspection requirements will be consistent with the inspection requirements of existing facilities. LES reserves the right to carry out an inspection thereafter from the date of interconnection if the facility is suspected of causing problems for other customers, upon reasonable notice and at the discretion of LES.
7. The requesting party making the interconnection with LES shall provide its written Standard Operating and Maintenance Coordination Procedures to LES for the interconnected facility.
8. Breakers and switches installed in LES facilities shall adhere to LES numbering schemes. All switches to be operated by LES will be locked with locks furnished by LES.
9. Equipment ratings shall be suitable for the ambient temperature range of -40° C to 50°C. Equipment ratings shall comply with the requirements of Table 1, and shall be

sized for load and system expansion for the 15-20 year time frame. Equipment ratings shall comply with the latest ANSI, IEEE, NEMA, and NERC requirements and must be in accordance with the LES methodology for determining facility ratings.

10. The grounding design shall meet the requirements of IEEE 80 and the requirements of NESC. The grounding system shall use 4/0 copper wire, copper clad ground rods and exothermic welds. The fence shall be grounded and a ground grid conductor shall run around the perimeter, three feet beyond the fence.
11. Drawings for facility additions must conform to LES drafting standards and be approved by LES. The requesting party will supply drawings on CD, compatible with LES computer-aided design system. The requesting party will reimburse LES for the cost of translating drawings into a format compatible with LES' format.
12. Three marked prints of each drawing should be provided to LES not more than 90 days after construction has been completed. The drawings shall be marked to show "as built" conditions. For substation and generation facilities, these drawings shall include, but not be limited to, station plot plans, equipment layouts, conduit and cable trench layouts, grounding plans, single-line diagrams, control circuit schematics, and wiring diagrams. For transmission facilities, the drawings shall include plans, profiles, hardware and assembly details.
13. Three copies of instruction books and manufacturer's drawings shall be furnished to LES for each piece of equipment placed within LES facilities.

B. SYSTEM CONTROL

1. Supervisory control by LES of line circuit breakers or motor operated disconnects, or both, will be required on all interconnections where breaker or disconnect operations can, in LES' opinion, directly affect the security of the transmission system. The RTU(s) installed at the new facilities for supervisory control shall meet LES specifications and be compatible with the Supervisory Control and Data Acquisition (SCADA) system used by LES. The cost of providing and installing the RTU at a new location or proportionate cost of modifying an RTU at an existing facility shall be at the expense of the requesting party. LES will perform the necessary expansion, including hardware and software changes, to the SCADA master station equipment at the requesting party's expense for that portion of the cost attributed to the new interconnection. Transducers, interface hardware, and appropriate communication channels compatible with existing SCADA system requirements shall be furnished by the requesting party. Specifications for such equipment will be provided upon request. The requesting party shall provide necessary auxiliary and control relays, local supervisory switches, and all other miscellaneous equipment necessary to interface with the LES supervisory control equipment.
2. Interconnections that establish additional or new control area boundaries require the requesting party to furnish all the necessary control area metering equipment. These requirements may include, but are not limited to, any or all of the following:
 - a. Analog and/or digital telemetry at the point of interconnection;
 - b. Totaling equipment at the point of interconnection or some intermediate point on

the communications links. A multi-ported RTU may be substituted in some cases;

- c. Communications links to both LES and the other organization's power system control center; and
 - d. Automatic Generation Control (AGC) hardware and software changes or additions at the power system control centers.
3. Telemetry, scheduling and interconnection metering are performed on a megawatt or whole megawatt hour basis; therefore, interconnection metering and totalizing equipment shall meet this criterion.

C. SYSTEM PROTECTION

1. The interconnecting party shall provide protective relaying systems consistent with the quality and protection philosophies of LES. Proposed protective relaying requirements for each interconnection will be subject to review and approval by LES after receipt of a preliminary single-line drawing of the proposed interconnection and a single-line drawing and drawings of the party's interconnected system.
2. The interconnecting party shall provide recloser and fuse ratings, relaying data, relay bill of materials, and line and transformer impedances in coordination with LES.
3. Overcurrent relaying and backup overcurrent relaying are required for 35 kV and below interconnections. Some applications will require directional overcurrent relays. Immediate and time-delayed reclosing is required. Specialized relaying, such as direct transfer trip, may be required to provide automatic load or generation shedding, or interconnected system separation.
4. High-speed pilot primary relaying, high-speed non-pilot secondary relaying and breaker failure relaying are required for 115 kV and 161kV interconnections. Immediate and time-delayed reclosing is required. Specialized relaying, such as direct transfer trip, may be required to provide automatic load or generation shedding, or interconnected system separation.
5. High-speed pilot primary relaying, high-speed pilot secondary relaying, high speed dual-channel transfer trip and breaker failure relaying are required for 345kV interconnections. The primary and secondary pilot channels and direct transfer trip channels shall be on separate systems such as power line carrier and fiber optics. Immediate and time-delayed reclosing is required. Specialized relaying, such as direct transfer trip, may be required to provide automatic load or generation shedding, or interconnected system separation.

6. Transformer protection shall include the following: differential relay, sudden pressure relay, pressure relief devices, high side overcurrent backup and low side overcurrent backup. High side protection must be a power circuit breaker or a circuit switcher with adequate interrupting capability.
7. LES will not be responsible for protection of the interconnected party's system. The party is solely responsible for protecting their equipment in such a manner that faults, unbalances, or other disturbances on LES or the surrounding transmission do not cause damage to the party's facilities. Sync check and synchronizing of interconnected facilities is the responsibility of the interconnected facility owner.

D. COMMUNICATIONS:

1. The requesting party shall provide communications facilities sufficient to meet LES fiber, telephone, radio, system protection, remote meter reading, and Energy Management System/Supervisory Control and Data Acquisition (EMS/SCADA) requirements.
2. The communications channels and channel hardware will be provided by the requesting party. LES will specify the type, speed, and characteristics of the communication channel equipment so that compatibility with existing communications, supervisory control, relaying, and telemetering equipment is maintained. The specific type of communication equipment to be furnished by the requesting party will be reviewed and approved by LES. The requesting party will reimburse LES for the costs of any additional facilities provided by LES.

E. METERING:

1. Current transformers used for revenue metering circuits must meet the accuracy standards, as specified under the American National Standards Institute (ANSI) C57.13, for an accuracy class of 0.3 percent at all burdens. Current transformers shall have a thermal rating factor of 2.0.
2. Voltage transformers used for revenue metering circuits must meet the accuracy standards, as specified under ANSI C57.13, of 0.3 percent accuracy with the following burdens:
 - a. "W" through "Y" burden for 5 kV through 25 kV; and
 - b. "W" through "Z" burden for 25 kV and above.
3. LES will install, own, operate and maintain the revenue metering. Revenue metering with a recording demand device shall be used if the estimated maximum demand is 100 kilovolt-amperes or greater, or if maximum simultaneous demand billing is contractually required. Such revenue metering shall be compatible with the LES metering policy.

F. OPERATING LIMITS

1. Abnormal Frequency and Voltages

It shall be the responsibility of the Owner to provide adequate protection or safeguards to prevent damage to LES caused by over/under voltages or over/under frequency originating in the interconnected facility. The Owner shall provide adequate protection and safeguards to protect the interconnected facility from inadvertent over/under voltage or over/under frequency conditions originating from the LES electrical system. Steady-state voltages and frequency must be maintained within the normal and emergency limits as defined in the current NERC and MRO Reliability Standards.

Studies will also need to be conducted by the interconnected facility owner to show no adverse effects to LES from probable and extreme disturbances as defined in the current NERC and MRO Reliability Standards.

2. Power Factor

The interconnected facility shall be responsible for providing their own reactive power needs. LES will impose penalties for power factors that are lower than 0.93 lagging. The penalty rates can be found in LES Rate Schedules which are available on request. All reactive resources must be capable of operating within the voltage limits stated in the current NERC and MRO Reliability Standards for normal and emergency conditions. Switched reactive resources must be designed to not cause voltage transients on the system.

3. Power Quality

Adequate design precaution must be taken by the interconnected facility owner to prevent excessive and deleterious harmonic voltages and/or currents from occurring on the electrical system of LES or interconnected owners. The interconnected facility must be designed to operate with normal harmonic voltage and currents that originate from LES. Voltage and current harmonic levels need to be below the stated values in the current IEEE Std. 519 document. Excessive harmonics originating from within the interconnected facility will be the responsibility of the interconnected facility owner to correct at their own expense.

4. Voltage Flicker

Voltage surges or flicker caused by the operation, synchronization, or isolation of the interconnected facility shall be within the standards as set forth in the International Electrotechnical Commission (IEC) voltage flicker curves. The interconnected facility shall provide suitable equipment to limit voltage flicker to below the "Border Line of Irritation" curve on the IEC voltage flicker chart at the point of interconnection.

5. Synchronization

Synchronization of an interconnected facility with generation shall be accomplished by providing suitable equipment to measure both the phase angle across the breaker and the voltage on each side of the breaker. If possible, the phase rotation should be stopped and the phase angle reduced to 10 degrees or less before interconnection is made.

G. SPECIFIC FACILITIES FOR GENERATION INTERCONNECTIONS:

1. Generation interconnections shall be in compliance with the current LES "Policy and Guidelines for Customer Owned Generation", LES "Service Regulations", LES "Rate Schedules". The most current revisions of these documents can be found at www.les.com or by contacting LES Consumer Services.
2. When LES considers integrating generation into the system, special operational studies may be required. Operational problems on the LES' system, either during normal or emergency conditions, may affect LES control performance, and under certain conditions, the generator may have to relinquish unit load and voltage control to the LES system dispatcher. LES' "Policy and Guidelines for Customer Owned Generation," identifies the considerations LES will evaluate. A contract will be required with each generator to describe the interconnection and the specific operational procedures and obligations.

H. SPECIFIC FACILITIES FOR TRANSMISSION CONNECTIONS

1. Proposed connections to the LES transmission system are subject to approval on a case-by-case basis.
2. Connections to transmission lines at less than 345 kV shall meet the following minimum criteria:
 - a) A proposed interconnection to a transmission line, whenever possible, will be connected at an existing substation. Interconnects at a new location on an existing line will require the requesting party to provide a substation site suitable for breakers, relaying and transformer installations.
 - b) No more than one connection without line sectionalizing circuit breakers will be permitted between transmission line breakers. If the requested connection exceeds the one connection between circuit breakers, the requesting party shall be responsible for adding necessary circuit breakers, relaying and compatible relaying at adjacent terminals at its own expense.
 - c) The interconnecting transmission lines shall have overhead ground wire (OHGW) shielding over the entire length of the line.

- d) Interrupter switches, or equivalent, capable of interrupting either load or charging current shall be installed in the line sectionalizing positions for all interconnected substations. These interrupters would be used to de-energize line sections without interruption of the connected loads. LES would assume ownership of the sectionalizing switches. The bus configuration shall provide isolation of the interconnection while maintaining the integrity of the LES system.
3. Since lines at higher voltage levels require the highest reliability, taps to transmission lines of voltages 345 kV and higher are not permitted.
 4. Parties requesting transmission line taps shall submit verification that the transmission line structures and foundations have been, or will be, designed in accordance with the Standard Design Criteria as described in Appendix 1.
 5. Taps to transmission lines with optical ground wire may require optical ground wire on the taps.
 6. Transmission interconnections that include generation shall also meet the requirements of generation's interconnections.

I. SPECIFIC FACILITIES FOR END USER CONNECTIONS

- A. Interconnections within a LES substation shall be made with power circuit breakers. Breaker duty shall be in accordance with Table 1. Typical specifications covering circuit breaker requirements are available from LES.
- B. Installation of equipment in substations must conform to LES requirements and must be approved by LES. Oil-filled equipment, including bushings, shall not contain polychlorinated biphenyls (PCBs). In addition, oil-filled equipment shall be permanently labeled by the manufacturer as non-PCB. Certification shall be provided to LES before the time of installation. Oil-filled equipment may require an oil spill containment system to comply with EPA or state regulations. Any increased equipment costs due to these requirements will be borne by the party requesting the equipment.
- C. The owner of the installed equipment will be responsible for its proper operation and maintenance (O&M). The equipment must be operated and maintained in accordance with prudent utility practices and applicable environmental and safety standards. This may include fall protection requirements. LES may require additional equipment to assure a reliable interconnection and to safeguard the proper operating conditions of its power system. LES may prefer to provide required O&M on a contract basis.
- D. End User interconnections that include generation shall also meet the requirements of generation interconnections.

TABLE 1

MINIMUM BREAKER DUTY, SURGE PROTECTION AND EQUIPMENT RATING REQUIREMENTS FOR GENERATION, TRANSMISSION, AND END-USER FACILITIES

System Voltage (KV)	BIL (KV)	Arrester MCOV (KV)	Breaker Interrupting (KA)	Continuous Rating (A)
115	550	74	63	3000
161	750 ⁽¹⁾	98	40	2000
345	1300 ⁽¹⁾	212	40	3000

NOTES

- 1. Transformers have 1 level reduced insulation:
161kV - 650kV BIL
345kV - 1050kV BIL

CONTRACTUAL AND OPERATIONAL REQUIREMENTS

1. When LES determines that an interconnection is consistent with the requirements in this document, contractual agreements will be prepared and furnished to the requesting party.
2. LES will require an advanced payment of funds to cover its estimated costs prior to actual expenditures or obligations for work or equipment for another party. An estimate of LES costs, including administrative overhead and other costs associated with construction, operation, and maintenance, will be provided to the requesting party. The contractual arrangements will specify the amount of funds required to be advanced. Upon receipt by LES, advanced funds will be placed in a cost account for the project. Periodic cost statements will be furnished to the requesting party as planning, design, and construction work progresses.
3. If construction is done by others, a LES representative will be present, as needed, to coordinate and provide for switching, clearances, special work permits, and inspections during construction work on LES's right-of-way associated with the interconnection. Final electrical connections to the power system will be typically made by LES or with LES' supervision.
4. Ownership of facilities installed will typically reside with the party advancing funds for construction. Those facilities considered by LES to be an integral part of an existing LES substation or transmission line may become the property of LES upon termination of the contractual arrangements.
5. The cost of major repairs or replacements of facilities installed for the interconnection shall be the responsibility of the requesting party. LES may, as its own discretion, share in the cost of major repairs or replacements if it is a benefit to LES.
6. Contractual arrangements with a party for facilities which are installed in or connected to the transmission system will normally allow LES the right to connect to either the high-side or low-side bus of the substation. Appropriate compensation for use of the tap substation facilities by LES will be arranged if the low-side bus of the substation is being tapped.
7. LES reserves the right to approve transmission system changes at the tap, substation, or interconnection which affect operation of the transmission system, including interconnecting with facilities of a third party.
8. LES will perform operation and routine maintenance on facilities located in its substations unless otherwise agreed to when the proposed replacement or additions are at a LES substation. The contractual arrangements will include provisions for an advancement of funds for the costs of labor and other expenses, including allocable overhead costs, associated with the operation and routine maintenance work performed by LES. When an existing transmission system transformer is replaced, the maintenance costs attributed to the new transformer will be paid by LES on the basis of the ratio of the capacity retained by the LES to the capacity of the new transformer. When an additional transformer is involved, the maintenance costs attributed to the new transformer normally will be the responsibility of the equipment owner. Periodic advancement of funds will be required to cover the estimated cost of operation and maintenance work to be performed by LES on equipment owned by others.

9. LES will perform maintenance on relaying and control equipment and other associated equipment for which LES has operating responsibility, unless otherwise agreed.
10. Maintenance will normally be performed by and at the expense of the party which owns the equipment or facility when the proposed interconnection involves a tap or substation sectionalizing a LES line.
11. Maintenance coordination is required when scheduling maintenance and outages. LES shall be notified and have the right to witness settings and testing of relays, meters, and controls which affect the integrity and security of the transmission system. LES shall also have the right of entry for inspection, emergency operation and maintenance of those particular devices deemed necessary for power system integrity. Maintenance coordination may require rescheduling maintenance and outages due to system conditions.
12. LES shall have the operation and dispatching authority of the circuit breakers, disconnects, and interrupters that are an integral part of the transmission system and will order switching and issue all clearances and hot-line permits on the transmission portion of the interconnection or substation. This will involve use of LES' switching and clearance procedures, including use of LES locks and tags. Issuance of clearance or hot-line permits may be in the form of an inter-company clearance to a dispatching agent of the utility owning the facility rather than directly to a job supervisor.
13. Requirements for operations, maintenance, ownership, and replacement of equipment associated with an interconnection will be specified in a new or amended contract with the requesting party.
14. Abnormal Conditions/Emergency Conditions may arise when the reliability of the electric system and interconnected systems are in jeopardy. During these conditions, the owners of interconnected facilities may be asked to place control of their facilities under the direction of LES until conditions return to normal. LES may require interconnected facilities to adjust generation, shed load, or isolate from LES to bring LES frequency and voltage within acceptable operating limits. LES will perform the actions as required by the Reliability Coordinator to ensure reliable operation of the regional grid as defined in NERC and MRO Reliability Standards.
15. Detailed procedures will be written and mutually agreed upon before the facility is interconnected to LES. LES will require the interconnected facility to provide personnel names and phone numbers who may be contacted during normal and emergency operating conditions. LES will also provide a phone number to contact LES when the interconnected facility will be making changes to their facilities which will affect LES. Examples of changes would include generation or load variations of more than 10 MW, operation of transmission equipment that affects line flows, or isolation of the interconnected facility.

LINCOLN ELECTRIC SYSTEM CONTACT

If you have any questions concerning these requirements, please telephone or write:
Lincoln Electric System

Scott Benson, P.E.
Manager, Resource & Transmission Planning
Lincoln Electric System
P.O. Box 80869
Lincoln, NE 68501-0869
Phone (402) 473-3390
Fax (402) 473-3208
sbenson@les.com

APPENDIX 1

STANDARD DESIGN CRITERIA FOR TRANSMISSION LINE STRUCTURES

1. General

Transmission structures are usually constructed of wood, lattice steel, steel poles, or reinforced or pre-stressed concrete. Load combinations and overload factors (OLF) used for the design of these structures are generally chosen after careful consideration is given to the life of the line, operation and maintenance procedures, reliability and safety. Unless otherwise justified, a structure design life of at least 50 years is suggested.

Loads to be applied when designing a transmission line require search and sound engineering judgment. Designers should be familiar with the following manual:

American Society of Civil Engineers (ASCE) Manual No. 74, Guidelines for Electrical Transmission Line Structural Loadings.

The latest edition of the National Electrical Safety Code (NESC) specifies the minimum requirements for strength and clearances used in transmission line design and construction. Factors affecting design are diverse weather conditions, type of terrain, operating voltage, clearance requirements, conductor size and tension, span lengths, structure height, and other requirements necessary to meet local operating conditions. Criteria beyond minimum requirements may be necessary for unusual conditions or particular operating features.

Structures and foundations should be designed in accordance with the following codes (guides) as applicable:

- a) Institute of Electrical & Electronic Engineers (IEEE) Trial-Use Design Guide for Wood Transmission Structures
- b) American Institute of Steel Construction (AISC) Manual of Steel Construction, Allowable Stress Design
- c) ASCE Manual No. 7 Minimum Design Loads for Building and Other Structures.
- d) ASCE Manual No. 52 Guide for Design of Steel Transmission Towers
- e) ASCE Manual No. 72, Design of Steel Transmission Pole Structures
- f) American Concrete Institute (ACI) Standard 318 Building Code Requirements for Reinforced Concrete

2. Transmission Structures

Transmission structures shall be designed, at a minimum, to withstand the loads specified by the most recent NESC Guidelines, multiplied by the appropriate overload capacity factor given by NESC Guidelines, without exceeding designated stresses.

Additional loads not specified in NESC, but which should be designed for, include:

- a) Wind per NESC Guidelines shall be increased by a gust and height factor of 1.3 overload factors for all high wind loads shall be 1.1.
- b) A heavy ice condition of 1-¼ inch radial ice on conductors and shield wires at 30°F with no wind. Overload factors for all loads shall be 1.1.
- c) Stringing loads as necessary with 1.1 overload factors.

Each load case could be considered independently to determine the maximum stress in any member. The structure should be analyzed for the simultaneous application of ultimate vertical, transverse, and longitudinal wire loads, structure wind loads, and structure dead load. Structure wind loads shall include the appropriate shape factor.

Maximum reactions derived from the structure loading shall be increased by 15 percent when designing the foundation by the “strength design” method of ACI-318.

3. Tap Structures

Load cases for two types of tap structures are listed below. A tap structure which is not actually a dead-end, but may be subject to some unbalanced longitudinal or line angle tensions, is inserted “in-line” with equal tensions on both sides. A full “dead-end” tap is subject to longitudinal tensions and line angles, if any. For wood tap structures the listed OLFs are appropriate only when the strength reduction factors of NESC Guidelines are utilized. The applicable loading area of the NESC applies for all load cases.

a) “In-Line” Tap:

1) Case I. Intact (NESC Loading)

- Longitudinal - All wires intact; no unbalanced loading
- Transverse - Wind on iced wires; OLF = 2.5
- Vertical - Weight of iced wires; OLF = 1.5

2) Case II. High Winds

- Longitudinal - All wires intact; no unbalanced loading
- Transverse - Wind per NESC Guidelines increased by a gust factor of 1.3
- Vertical - Weight of bare wires
- OLF = .1 for all loads

3) Case III. Broken Wire

- Longitudinal - Any one phase or one ground wire broken when all remaining wires intact; utilize NESC design tension
- Transverse - Wind on unbroken iced wires
- Vertical - Weight of unbroken iced wires
- OLF = 1.1 for all loads

- 4) Case IV. Stringing
Longitudinal - Dead-end the structure using any combination of wires attached to one side only and utilizing stringing tensions;
OLF = 1.65
Transverse - Four-pound wind on base wires; OLF = 1.1
Vertical - Two times the weight of bare wires; OLF = 1.5

b) "Dead-end" Tap:

- 1) Case I. Intact (NESC Loading)
Longitudinal - All wires dead-ended with NESC load tension; OLF = 1.65
Transverse - Wind on attached iced wires; OLF = 2.5, plus angle component of wire tension; OLF = 1.65
Vertical - Weight of attached iced wires; OLF = 1.5
- 2) Case II. High Winds (Wind applied at any direction to transmission line)
Longitudinal - Dead-end tension resulting from the wind per NESC Guidelines increased by a gust and height factor of 1.3
Transverse - Wind on base wires plus angle component of wire tension
OLF = 1.1 for all loads
- 3) Case III. Heavy Ice (57 pcf ice at 30°F, 1-1/4 inch radial ice for NESC heavy and 1 inch radial ice for NESC Medium areas.)
Longitudinal - Dead-end tension resulting from the iced condition.
Transverse - Angle component of wire tension
Vertical - Weight of iced wires
OLF = 1.1 for all loads