Information Document
Bulk Transmission Line Technical Requirements
ID#2010-005R

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1. Purpose and Background

This Information Document supports new ISO Rules Part 500, Division 502, Section 502.2 and provides additional information to assist market participants who are the legal owners of bulk transmission lines. Section 502.2 stipulates the minimum technical requirements for the design of a bulk transmission line connecting to the interconnected electric system.

To assist users, the section numbering in this document matches the corresponding subsection in section 502.2, as far as possible.

In Alberta, bulk transmission lines can be designed and constructed by a number of entities, including the legal owners of a transmission facility, industrial system designation area owners and others such as developers of wind aggregated generating facilities and those developing merchant lines for power import and/or export.

To ensure a consistent approach to the design of bulk transmission lines within Alberta, the AESO has implemented section 502.2, which addresses the minimum technical requirements in the areas of line design while considering reliability, safety and economics.

2. Applicability to New and Existing Bulk Transmission Lines

The new section 502.2 provisions in general do not apply to retrofit or change existing systems presently connected to the interconnected electric system. However, as noted in Subsection 2(5) of section 502.2, the AESO reserves the right, on a case-by-case basis, to endorse retrofitting an existing non compliant bulk transmission line with this standard for those lines the AESO deems critical to the interconnected electric system.

Existing bulk transmission lines, including maintenance replacements, additions and alterations, meeting the original designs that currently comply with the requirements of previous and current versions of the *Alberta Electrical Utility Code*, need not be modified to comply with section 502.2, except as might be required for safety reasons by the authority having jurisdiction.

In general, section 502.2 applies to new construction. For maintenance of existing bulk transmission lines, or additions to existing lines having a length less than 1500 m, the AESO Technical Standard in effect at the time of the original design (or a subsequent edition with which the installation has been brought into compliance) applies. However, when an extension having a length equal to or greater than 1500 m, or reconstruction of relatively large proportions is being carried out, the AESO may request the reconstruction of other portions of the bulk transmission line to comply with section 502.2.

The value of 1500 m was chosen to avoid application of the section 502.2 to minor taps and bulk transmission line extensions. It is normally not reasonable to design a very short portion of a line to meet criteria that may significantly exceed those of the majority of the line.

The 1500 m length represents approximately ten spans of single circuit 138 kV or 144 kV wood pole line, or approximately four spans of a 240 kV lattice tower bulk transmission line.

3. Functional Specifications

Any design aspect that deviates from the requirements of section 502.2, must be approved by the AESO and documented in the approved functional specification for the bulk transmission line project.

4. Successor to Prior Requirements

Information is not required at this time.

5. Other Code Requirements

See section 5 for a listing of other standards, codes and regulations that must be adhered to with regard to bulk transmission line design and construction. It should be noted that in Alberta the *Alberta Electrical Utility Code* (AEUC) has force of legislation. In general, the AEUC refers to the requirements of CSA C22.3 No. 1-06 but there are some requirements in the AEUC (most notably ground clearances) that exceed the values in CSA C22.3 No. 1. Designers need to be familiar with the requirements in both documents, and where there is a conflict, the requirements of the *Alberta Electrical Utility Code* will govern.

6A. Structural Design

This subsection 6A provides general information related to structural loading requirements outlined in section 502.2 and does not relate to specific subsections in those rules.

Requirements of subsections 6 through 15 are applicable to the determination of loads, and strength of structures and foundations, and the selection of conductors and overhead shieldwires.

A probability based approach is required for loads and is reflected in the requirements of section 502.2.

Both the 2006 and the 2010 versions of CSA C22.3 No. 1 state (Clause 10) that **"*Supply and communication lines shall be designed using the deterministic design method or the reliability-based design method*."** Since data for application of reliability based design is available and is provided in the AESO loading maps, there is no need to include deterministic design loads for the design of bulk transmission lines.

A probability based approach can be used for strength determination (as per CSA C22.3 No. 60826) but is not mandatory. Strength factors are used in Section 502.2 to account for strength variation of wood and similar materials, and as a method of designing for the desired sequence of failure.

As an alternative to using the specified strength factors in the design calculations, the strength factors can be converted to equivalent overload factors and are to be applied to the loads specified in section 502.2. For example, the strength factor of zero point nine (0.9) which is to be applied to angle and deadend structures for sequence of failure purposes can be converted to an equivalent overload factor equal to 1.0/0.9 = 1.1. The calculated loads for the angle and deadend structures are then multiplied by the additional 1.1 overload factor and the resulting factored loads are used for structure design.

Alberta legal owners of transmission facilities expressed concern with some requirements of CSA C22.3 No. 60826. Hence, adoption of C22.3 No. 60826 as published and in its entirety was determined to not meet the needs for design of bulk transmission lines in Alberta. Section 502.2 does accurately reflect weather loadings and other operating conditions in Alberta.

6B. Selection of Return Periods

It is recognized that there may be situations where the return period values specified in section 502.2 are not appropriate. Examples include:

(1) Critical river crossings (design return period may be higher);

(2) Line built and operated at a transmission voltage that actually performs the function of a distribution line (design return period may be lower); or

(3) A line that is designated as "system critical" by the AESO (design return period may be higher).

As per subsection 6(4) of section 502.2, for those situations where the AESO wishes to have a specific bulk transmission line designed for a non-standard return period, the requirements will be identified in the functional specification for the project.

For situations where the legal owner believes a non-standard return period should be used for all or part of a specific bulk transmission line, the legal owner is required to obtain approval from the AESO prior to beginning design of the line.

6C. Earthquake Loads

Section 502.2 does not include requirements for earthquake loads because these are not applicable to bulk transmission line structures. There was, however, a desire to include information in the Information Document explaining why earthquake loads are not applicable. Bulk transmission line structures need not be designed for ground-induced vibrations caused by earthquake motion and therefore this is not addressed in the new rule. This is because:

(1) Historically, bulk transmission line structures have performed extremely well under earthquake events; and

(2) Bulk transmission structure loadings caused by wind/ice combinations and broken wire forces exceed earthquake loads.

This may not be the case if the bulk transmission line structure is partially erected or if the foundations fail due to earth fracture or liquefaction.

Transmission structures are designed to resist large horizontal loads of wind blowing on the wires and structures. These loads and the resulting strengths provide ample resistance to the largely transverse motions of the majority of earthquakes. Decades of experience with transmission lines of all sizes has shown that the very infrequent transmission line damages have resulted from soil liquefaction or when earth failures affect the structural capacity of the foundation.

The above information is taken from *ASCE Manual 74 Guidelines for Electrical Transmission Line Structural Loading, Third Edition.*

7. Weather Loads for Wind

It has been determined that the values of gust response factors for wires (G_w) calculated by the ASCE method are not representative of wind structure in Alberta (open terrain and laminar wind flow). The values given in section 502.2 are more appropriate for Alberta weather conditions.

The AESO wind map referenced in section 502.2 and which is to be used for values of design wind, is posted on the AESO website.

There have been a number of bulk transmission line failures in Alberta resulting from tornado or downburst winds. However, given the difficulty in determining the expected location and magnitude of this type of loading, these wind loadings have not been included in section 502.2.

8. Weather Loads for Wet Snow and Wind

The magnitudes of combined wet snow and wind loadings for probability based design were determined through the use of a computer based analytical model. Alberta does not experience significant glaze ice accretion but does experience major wet snow and wind events, which have caused extensive damage to bulk transmission lines. Hence, the work to develop probability based combined loadings was focused on combined wet snow and wind events.

The AESO map that provides values of combined wet snow and wind for probability based design is posted on the AESO website.

Under the rule, there is no specified minimum requirement to design 138 or 144 kV bulk transmission lines for the probability based wet snow and wind loads. These lines normally have lower reliability requirements than lines of higher voltages, and there are usually redundant paths so an outage on one line does not have a major impact on the interconnected electric system. If the AESO determines that a specific 138 or 144 kV bulk transmission line should be designed to withstand the probability based wet snow and wind load, the loading requirement will be identified in the functional specification for the project.

9. Weather Loads for Vertical Load Alone

Since studies to determine specific rime ice loadings are not available, the radial accretion values from the combined wet snow and wind loads, with a density of 350 kg/ m^3 and a temperature of -20°C and with no wind, are used to represent the rime ice vertical loading condition. Experience in Alberta indicates that this is a reasonable approach.

10. Failure Containment Loads

Longitudinal loads on bulk transmission lines can result from different wet snow loads on adjacent spans, or from the failure of line components, including structures, wires, insulators or hardware.

In the past, bulk transmission lines were not specifically designed to withstand longitudinal loads, and a significant number of longitudinal cascades, which involved the failure of many structures from a single initiating event, took place. Several longitudinal cascades have been observed in Alberta.

Current bulk transmission line design standards and practice include requirements for unbalanced longitudinal, or failure containment, loads as part of the line design. The failure containment loading requirements in section 502.2 reflect conditions in Alberta and strike a balance between reliability and cost. Hence, the loading conditions specified are not the worst possible conditions that could occur, but were chosen to reflect conditions that might reasonably be expected to occur in Alberta. Designing bulk transmission lines to withstand the specified loads should limit the extent of line failure, in the event of an unbalanced longitudinal loading event, to a relatively small number of structures.

In section 502.2, the loading value for the broken wire case is specified as bare wires, no wind, at final tension and 0°C. For northern Alberta, where low temperatures are common, it may be prudent to use a temperature of -30°C for the broken wire load case. The values of load for this loading case are commonly referred to as residual static loads.

The wet snow load used for the unbalanced wet snow case are to be equal to the return period values required by subsections 6(1) and 8(2). For example, if the given line is to be designed for a vertical load of 70 mm radial wet snow, the loading used for the unbalanced wet snow load case is 70 mm wet snow.

The loading values calculated for the two (2) loading conditions set out in subsection 10(3) of section 502.2 should be determined using a computer program model that can model bulk transmission line sections with a number of spans.

The bulk transmission line computer program model should include the following specifications and assumptions:

(a) it should be a thirty (30) span section consisting of all tangent structures, with level ground;

(b) for the broken wire case, the break should be assumed to occur at any point in the bulk transmission line section, and the highest loading values obtained from the analysis should be used for structure design;

(c) for the unbalanced wet snow case, the bulk transmission line should be assumed to have an initial state of all wires with the specified wet snow loading, with wet snow then dropped from four (4) spans in the middle of the thirty (30) span section;

(d) for a single circuit bulk transmission line, wet snow should be assumed to be dropped from any one (1) phase or overhead shieldwire; and

(e) for a double circuit bulk transmission line, wet snow should be assumed to be dropped from any two (2) phases or overhead shieldwires, or one (1) phase and one (1) overhead shieldwire.

The above paragraph provides detailed recommendations for the line model used to determine values of broken wire and unbalanced wet snow loads. These recommendations reflect the outcome of extensive work, for bulk transmission lines in Alberta, to develop realistic models for failure containment loading. It was found that with line sections 30 spans or longer the magnitude of longitudinal load did not change with the addition of more spans. Long line sections of only tangent structures are also typical of numerous existing bulk transmission lines in Alberta, so the 30 span criteria is realistic.

The criteria described above for unbalanced wet snow represents realistic loading expectations for bulk transmission lines in Alberta. Observations of large diameter accretions of wet snow loads on bulk transmission lines in the province indicates that the wet snow tends to drop off in short sections, and in multiple spans at more or less the same time. Situations with a large number of spans with no snow, and adjacent bulk transmission line sections with full snow accretion have not been observed. Hence, the criteria of wet snow dropped from only four (4) spans is a realistic representation of unbalanced loading for Alberta.

It is recognized that the criteria recommended above does not represent a worst possible case situation. The intent is to reflect reasonable, or most likely, loading cases, not worst possible cases. Alberta does not experience significant glaze ice accretion, but does experience very significant wet snow events. That is why the unbalanced loading case assumes wet snow, rather than glaze ice.

Where the bulk transmission line structures are self supporting lattice towers and the requirement for failure containment loading is met by providing longitudinal strength at all suspension type structures, the towers should be of square base design. This recommendation is based on the practice of most major utilities in Canada and the U.S., including Hydro One and BPA and is further supported by the requirements of the *American Society of Civil Engineering Manual 74 –Guidelines for Electrical transmission Line Structural Loading Third Edition*.

The process of determining appropriate loading conditions and corresponding structural load values for longitudinal or failure containment loads is not a straightforward process. General practice is to use the tension of bare wires, under everyday conditions, with no ice or wind, as the basis for broken wire loads. In reality, broken wires (or failed deadend hardware) are more likely to take place when the wires are under ice and/or wind loading.

Unbalanced ice loads are also difficult to predict, since the degree of ice loading and shedding and many other variables make it very difficult to calculate accurate values of structure design loads for this situation.

With a square base tower, the overall structure normally has some “reserve” longitudinal capability should the actual unbalanced longitudinal loads be higher than the values specified for the tower design. With a rectangular base tower, this may not be the case and hence if a rectangular base is an option for the tower design, higher design values of longitudinal loads may be needed to ensure that the rectangular base tower will, in practice, have a reliability with respect to longitudinal and failure containment loads equal to that of a standard square base tower.

Towers of existing designs which do not have square bases may be used for any short tap or short extension project of an existing bulk transmission line, until such time as new towers are developed.

Subsection 10(5) specifies the interval between anti cascade structures. However, this interval can take into account the relative importance of the line and the availability of replacement material, should a line failure occur. If the bulk transmission line designer believes that a different interval is appropriate taking into account these factors, a request should be made to the AESO for use of the alternative interval.

It should be noted that wood structures are inherently flexible and the deflection of the poles under unbalanced longitudinal loads tends to limit the cascade to a small number of structures. Hence, section 502.2 allows use of a computer analysis to determine whether the number of wood structures that will fail under the specified longitudinal loading is acceptable. If it is determined that no structures are likely to fail, or if the number of structures that are likely to fail is acceptable, given the nature of the line, then anti-cascade structures are not required.

11A Construction and Maintenance Safety

Although section 502.2 does not have requirements for construction and maintenance loadings, these are an important consideration in the design of bulk transmission lines and were included in this Information Document as reference information for bulk transmission line designers.

These loadings are intended to ensure the safety of personnel during construction and maintenance operations. The magnitude of these loads, and the applied overload factors, are set so as to provide a reasonable safety margin relative to failure. The loads are considered constant and are treated in a deterministic manner. There is no requirement to include ice or high wind as part of the construction and maintenance loadings, since it is reasonable to assume that the operations included in these situations are not normally conducted during storm conditions.

The following criteria reflect generally accepted practice in terms of design loadings for bulk transmission line structures, to ensure a reasonable margin for the safety of personnel during construction and maintenance operations on any bulk transmission line:

(a) for structure erection, the strength of all lifting points and related components can withstand two (2) times the static loads produced by the proposed erection method, subject to the discretion and responsibility of any on site engineer in situations where the erection operations are under the direct supervision of that engineer;

(b) with regard to conductor stringing and sagging, structures can withstand wire tensions equal to the greater of either:

   (i) one point five (1.5) times the sagging tension; and

   (ii) two point zero (2.0) times the stringing or pulling tension;

(c) all tensions are calculated at the minimum temperatures likely to be encountered by personnel during the stringing and sagging operations for the bulk transmission line, and take into account wind speeds expected to occur while the stringing and sagging operations are underway where such personnel are reasonably expected to be present;

(d) tension increase due to conductor overpull for deadending, particularly in short spans between deadend structures, are to be taken into account;

(e) the arms of structures are designed to withstand the loads imposed by conductor tie down operations, with an overload factor of two point zero (2.0);

(f) for maintenance operations, all wire attachment points are able to support at least two point zero (2.0) times the bare vertical weight of wire on the structure at sagging tensions;

(g) any temporary lifting or deadending points located near permanent wire attachment points are able to resist at least two point zero (2.0) times the bare wire loads at sagging tensions;

(h) all structural members that may be required to support personnel are designed for a force of at least 1500 N applied vertically at the most critical point of the member, in addition to the stresses imposed by external bare wire loadings; and

(I) bulk transmission line structures are designed with clearances, strength and rigging points necessary for live line maintenance work methods.

11B. Overload and Strength Factors for Reliability Based Loads

Reliability based design uses weather loading values that are probabilistic in nature and are therefore return period based.

In the application of the probabilistic methodology, the objective is to design a structure (or structural system) with resistance greater than the maximum calculated design load. The structure must also have an acceptable level of safety and reliability.

The strength factor, which is used to adjust the allowable strength of line components, is used to account for the strength variability of wood poles and also to adjust the relative strengths of components on a steel structure line to produce a target sequence of failure. The strength factors provided in Table 2 of section 502.2 are from the *National Electrical Safety Code Standard C2-2007*. The NESC data was used since it includes both steel and wood structures and the information was not readily available from applicable CSA standards. The NESC values are reasonable for use in Alberta.

For laminated wood or fibre-reinforced composite poles, a strength factor equal to that of metal structures may be used if the manufacturer of the poles can demonstrate, by way of certified test reports, that the coefficient of variation, COV (standard deviation divided by the mean) for poles manufactured with the given material, is 10% or less.

As noted in Section 6 above, the strength factors can be converted to equivalent overload factors, which are applied to the basic load values to produce factored loads. If this approach is adopted, the strength factors are not applied, or are assumed to be equal to 1.0.

12. Conductor Selection

With reference to subsection 12 of section 502.2, the use of standard conductor sizes will simplify the process of maintaining emergency spare material and allow sharing of spare material for emergency restoration. Common ACSR and ACSR/TW conductor sizes used in Alberta are listed in Table 1, below.

Table 1
Bulk Transmission Line
Conductor Types Commonly Used in Alberta.

266 kcmil Partridge
397 kcmil Ibis
477 kcmil Hawk
795 kcmil Drake
1033 kcmil Curlew
1192 kcmil Grackle
1234 kcmil Yukon / TW
1590 kcmil Falcon

The conductor types in Table 1 are ACSR with high strength strandings (high ratio of steel to aluminum). These conductor designs are more able to withstand the heavy wet snow and wind loads, and heavy rime ice loadings, experienced in Alberta.

For major 240 kV and 500 kV bulk transmission lines, additional factors may apply to conductor selection and bundle configuration, such as system compatibility, line impedance, electrical load sharing and other system related issues. These factors will be identified in the AESO's functional specification for the project.

Non-standard conductors may be the correct choice for certain situations, such as reconductoring of existing bulk transmission lines or long spans such as major river or lake crossings. The use of non-standard conductors will be identified in the AESO's functional specification for the project.

To address the issue of electrical losses, section 502.2 includes requirements for conductor or line optimization studies. The studies include consideration of capital costs and the net present value of electrical losses in the selection of a conductor for a given project.

The purpose of the conductor (or line) optimization study is to identify the optimum conductor based on expected average load flow and estimated values of losses. In reality, it's an estimate based on currently available information. The risk associated with a wrong guess is relatively small – additional costs for losses.

The purpose of the 100°C requirement of subsection 17(2)(b) of section 502.2 is to ensure that bulk transmission lines are capable of carrying the maximum amount of power. Although AESO planners determine maximum load transfer values based on the best available information, unexpected load growth can easily take place in the future. If a given bulk transmission line is designed for a maximum conductor temperature less than 100C, and the line load (steady state or emergency) results in a temperature higher than the design value, then a new bulk transmission line would need to be built (or system operation would need to be limited) even though an existing bulk transmission line is not fully utilized.

Hence, the requirements for conductor (or line) optimization studies and the requirement for bulk transmission lines less than 500 kV to be designed for ground clearance at 100°C are not in conflict.

For small and medium size projects, which are assumed to include bulk transmission lines having the following characteristics:

a) rated design voltages of 138 or 144 kV and length exceeding 10 km; and

b) rated design voltage of 240 kV or above and length between 10 and 50 km

conductor selection is to be based on either a conductor optimization study or a line optimization study, at the discretion of the line designer. For large projects, which are assumed to include bulk transmission lines having a rated design voltage of 240 kV or above and a length greater than 50 km, a full bulk transmission line optimization study is required.

Although section 502.2 does not require an economic study for conductor selection for bulk transmission lines less than 10 km long, the cost of losses should be considered for heavily loaded lines regardless of the length.

The AESO will provide information on loading levels, cost of losses and other economic parameters and this data is to be used in the economic studies.

Conductors considered in the conductor and line optimization studies noted above need not be limited to those in Table 1, above. The legal owner of the bulk transmission line should use good engineering judgment in the selection of conductor sizes and types to be included in the study. Should the study results indicate a significant benefit from the use of a conductor other than standard ACSR or ACSR/TW types, the legal owner should discuss with the AESO the possibility of using the alternative conductor for the project.

Line optimization studies for a bulk transmission line with lattice steel structures will often calculate estimated tower weights as part of the optimization process. At the completion of the study, the legal owner of the bulk transmission line should consider whether it is best to use standard towers, for which design and detail information is available, or to develop new structures. The legal owner is to discuss with the AESO the rationale for development of new towers before proceeding with tower design.

13. Sequence of Failure

The following criteria (based on *CSA Standard C22.3 No. 60826:06*) were used to develop the sequence of failure specified in subsection 13 of section 502.2 and are recommended for establishing a failure sequence:

(1) The first component to fail should introduce the least secondary load effect (dynamic or static) on other components, in order to minimize cascading failure;
(2) Repair time and costs following a failure should be kept to a minimum; and
(3) A low cost component in series with a high cost component should be at least as strong and reliable as the high cost component, in particular when the consequences of failure are high.

Conductors and related components (in particular deadend insulators and hardware) are chosen as the last to fail because of the possible large extent of a longitudinal cascade failure, and the time and cost associated with bulk transmission line restoration following such a failure.

Although the failure of suspension insulators or their associated hardware is unlikely to initiate a longitudinal cascade, such a failure can initiate a vertical cascade, which can result in extensive structural damage and significant outage time and restoration cost.

It may not be appropriate to rigorously apply the sequence of failure specified in section 502.2 to all bulk transmission line components. For example, it is commonly accepted practice to design the foundations for angle structures to withstand only the loads imposed by the tower with the actual line angle, not the maximum loads for which the tower is designed. In this case, it is not appropriate to design the foundations to be stronger than the tower. Applying an overload factor to the calculated footing reactions which is higher than the overload factor applied to footing reactions for tangent structures would be appropriate.

It is also recognized that where angle structures are used at line angles significantly less than the maximum values, the structures may not fail prior to components of the conductor system. This is acceptable since it is expected that a large number of tangent towers will have failed prior to the conductor system reaching a failure condition. Significant amounts of conductor are likely to be on the ground, which should retain the integrity of the conductor system and hence avoid initiation of a longitudinal cascade, which is the objective of the specified failure sequence.

For long span river crossings, the crossing structures could be designed stronger than the conductors.

In addition, where the conductor tension for the most severe loading case does not exceed approximately 60% of the rated tensile strength and non-standard insulators and/or hardware would be required to meet the sequence of failure criteria, consideration should be given to the use of standard insulators and hardware. It is expected that the strength of the standard insulators and hardware will be equal to at least 85% of the conductor rated tensile strength.

Based on the above, the legal owner therefore should seek and obtain the AESO approval for any derivations on the sequence of failure minimum requirements set out in subsection 13.

14. Overhead Shieldwires

Subsection 14(7) specifies that for bulk transmission lines having average span lengths in excess of 150 m, the minimum size of the shieldwire must be 3/8” Gr. 220. Stronger shieldwire is intended to avoid failure under heavy loadings such as those resulting from wet snow or in-cloud icing, which are common in Alberta. Some older bulk transmission lines in Alberta were designed and constructed with 5/16” overhead shieldwires, and there have been failures of these shieldwires under icing and wet snow conditions.

It should be noted that 3/8” Gr. 220 shieldwire is the minimum size required for bulk transmission lines with average span lengths greater than 150 m. Where bulk transmission lines must be designed for heavy wet snow and wind loadings, a larger size (higher strength) overhead shieldwire may be required, as indicated in Subsection 14(6) of section 502.2.

For bulk transmission lines having average spans shorter than 150 m, but with individual long spans in excess of 200 m, the use of 3/8” Gr. 220 shieldwire for the long spans is recommended. This requirement is intended to apply to individual long spans (such as river crossings) with deadend type structures at each end of the span. The recommendation is not intended to create the need for deadend type structures where they would not otherwise be required. For example, if a section of bulk transmission line consisting of tangent type structures has a span longer than 200 m and would otherwise not require use of 3/8” overhead shieldwire, the recommendation for 3/8” Gr. 220 in long spans should not be the only reason to install deadend structures at each end of the long span so that the larger overhead can be installed on that span.

The purpose of shieldwires, as addressed in subsection 14, is to provide adequate reliability with respect to lightning caused outages. The report *Forced Outage Performance of Transmission Equipment*, published by the Canadian Electricity Association, provides information on historical reliability of transmission lines of various voltage levels and structure types operated by Canadian utilities. The AESO believes it is appropriate to use this data as one of the tools for establishing a target level of lightning performance for a new bulk transmission line. Another tool is the historical lightning performance of bulk transmission lines of similar voltage and construction, located in the same general area as the proposed new line, provided that the performance is better (lower outage rates) than the applicable values given in the CEA report.

Where a bulk transmission line has two shield wires, it may generally be assumed that the fault current is shared equally between both wires.

The AESO recommends that the calculated value of the maximum temperature of shield wires should not exceed the values given in Table 2, below, unless the cable manufacturer can provide documented, independent testing which proves the wire can withstand such temperatures with no loss of strength, functionality, or other damage which may affect its long-term performance. If a bulk transmission line designer wishes to use higher temperature values, a request for approval is to be made to the AESO, supported by the cable manufacturer data noted above.

Table 2

Allowable Maximum Temperatures For Shield Wires

Product	Maximum Temp (°C)
Galvanized Steel (CSA G12)	400
Aluminum Coated Steel	600
Copper Coated Steel	1000
ACSR	400
All Aluminum Conductor	340
OPGW	215

Although overhead shieldwires are a general requirement for bulk transmission lines of 138 or 144 kV and above, there may be special circumstances where it is appropriate to not have an overhead shieldwire for specific spans. Where one bulk transmission line crosses under another bulk transmission line, it may be necessary to remove the overhead shieldwire from the spans of the lower line at the crossing. On long river crossing spans where it is not practical to design the crossing structures to avoid contact of the overhead shieldwire with the phase conductors under differential loading conditions, the overhead shieldwire can be removed in the crossing span.

Removal of the overhead shieldwire from specific spans or line sections should not result in a significant increase in lightning related outages for the subject bulk transmission line.

15. Aeolian Vibration Control

Spacer dampers are specified in the subsection for bulk transmission lines having a rated design voltage of 500 kV or greater. This includes both AC and HVDC bulk transmission lines. Lines at these voltage levels have bundles of three or four subconductors where industry practice is to use spacer dampers rather than spacers.

Subsection 15(5) prohibits the use of spacer dampers with two part metal clamps that result in metal to metal contact between the conductor and the clamp. This requirement is based on field experience, in different parts of the world, where cold flow in the aluminum of the conductor and/or the clamp, or other problems, resulted in loosening of the clamp on the conductor. The loose clamps resulted in damage to the conductor, in some cases leaving only the steel core undamaged.

Examples of spacer damper designs that would be acceptable are those using an elastomer insert between the conductor and clamp, or a clamp that uses preform rods to attach the conductor to the clamp of the spacer damper.

For bulk transmission lines having a rated design voltage of 240 kV or less, with bundled conductors, vibration control is to be achieved either by use of spacer dampers or wireform spacers in the span and dampers at the ends of the span.

The tension limits specified in subsection 15 are based on historical experience with bulk transmission lines in Alberta. The open terrain in the southern part of the province results in laminar wind flow, which creates high levels of Aeolian vibration. Tension limits higher than those specified in subsection 15 have resulted in fatigue failure of conductors. The tension limits assume use of properly designed and installed vibration dampers.

It is recognized that other standards allow conductor tension values higher than the values specified here, but as indicated above operating experience in Alberta (including data from vibration recorders) does not support use of those higher tension limits in Alberta.

It is further recommended that the tension limits be verified using the CIGRE methodology, as outlined in CIGRE Technical Brochure No. 273 *Overhead Conductor Safe Design Tension with Respect to Aeolian Vibrations*, taking into account wire characteristics, spans, tensions and terrain. The CIGRE methodology should only be applied to conductors (not overhead shieldwires). If the CIGRE method indicates tension limits lower than those specified in section 502.2, the CIGRE tension values should be used. The CIGRE approach should not be used to justify tension limits higher than those indicated in section 502.2.

16. Voltage Values for Electrical Clearances

Information is not required at this time.

17. Basic Design Clearances

It should be noted that clearance requirements of the *Alberta Electrical Utility Code* include values contained in its Tables and also requirements specified in CSA C22.3 No. 1-06. Should there be a conflict between values in the *Alberta Electrical Utility Code* and those of CSA C22.3 No. 1-06, the values in the *Alberta Electrical Utility Code* will govern.

In general, ground clearance requirements in the Alberta Electrical Utility Code exceed those in CSA C22.3 No. 1. These higher ground clearance requirements recognize the large farm and other equipment that are common in Alberta.

CSA C22.3 No. 1 allows lines to be designed with maximum temperature for thermal loading conditions less than 100° C. In Alberta, the location of future loads is not clearly defined, as oilfield development, gas compression load and other large loads can develop at unexpected locations. In order to provide the best flexibility for future load development and to ensure the maximum possible utilization of existing facilities, all lines less than 500 kV are to be designed assuming a maximum operating temperature of 100° C. The 100C requirement also maximizes the capability of bulk transmission lines for emergency operation.

The requirement for 12.2 m of clearance for 500 kV alternating current or +/- 500 kV high voltage direct current bulk transmission lines is based in part on the ever increasing size and height of farm equipment in Alberta. Equipment having a height of over 6 m is common, and this height significantly exceeds the value assumed for the clearance calculations in the AEUC (4.9 m, or 16 ft). Also, 12.2 m of clearance is the accepted standard for 500 kV lines used by other major utilities in Canada, including Hydro One.

Ground clearances under conditions of maximum design loading of combined wet snow and wind, or vertical loading alone, should be maintained for any crossings of roads, railways, other bulk transmission lines and for all other locations where the normal activities associated with the given locations are likely to be carried out while the loadings represented by the extreme events are in place. This recommendation is included to address safety under all weather conditions that the line is designed to withstand.

The *Alberta Electrical Utility Code* clearances apply only to the maximum loading conditions specified by that *Code*, which would be maximum temperature and the applicable CSA ice and wind loadings. Therefore, it is not necessary to maintain *Alberta Electrical Utility Code* clearances in all locations under the combined wet snow and wind loads or vertical wet snow alone loads. The rationale is based on recognizing that high farm and other similar equipment is unlikely to be operating under bulk transmission lines at the same time as the extreme wet snow and wind loads, or wet snow loads alone, are affecting the lines. However, large highway vehicles and trains are likely to pass under bulk transmission lines under all loading conditions.

A number of highways in Alberta are specified as high load corridors. Bulk transmission lines crossing these highways must be designed to accommodate loads of at least 9.0 metres in height. A map showing the high load corridors is available on the Alberta Transportation web site. The link to the web site and map is: http://www.transportation.alberta.ca/3192.htm

Prior to building a bulk transmission line that crosses a designated high load corridor, the required clearance should be confirmed with the appropriate authorities.
Clearances to both structures and to the edge of the right of way use a five year return wind gust. The value of the five (5) year gust can be calculated directly from the basic wind data, using the appropriate probability distribution and calculation method. An alternative method is to use the fifty (50) year return gust from the AESO wind loading map, multiplied by a factor of 0.78.

Values of 60 Hz wet flashover distances are given in the following Table 3:

Table 3

60 Hz Flashover Distances

	Air Gap (mm)	
Nominal Voltage	**Phase to Ground**	**Phase to Phase**
69 kV	190	320
72 kV	200	330
138 kV	350	600
144 kV	370	630
240 kV	590	1020
500 kV	1240	2230

Clearance buffers (additional clearance above minimum AEUC requirements) are commonly used in the design of bulk transmission lines. The purpose of these buffers is to ensure that the minimum requirements are met after construction and under normally expected operating conditions, Since the risks associated with meeting AEUC electrical clearance requirements vary depending on many factors, such as the type of construction, terrain, etc. no specific requirements for clearance buffers are included in section 502.2.

Insulator Swing - Historical Basis

With the growth in 138kV transmission through the 1950's and 1960's, most utilities in Alberta became aware that high winds acting on transmission lines with suspension insulators frequently resulted in flashovers to the pole or crossarms resulting from insulator swing. This was the fact even though design code requirements of the day were met or exceeded.

There were no comprehensive meteorological studies available at the time which could have been used to establish a rational basis for design of insulator swing. However, through a process of trial and error, wind criteria were established indirectly and were found to provide an acceptable level of performance.

In 1977 a series of meteorological studies were conducted to establish design wind speeds for the 500kV Keephills-Ellerslie-Genesee loop and for the 500kV British Columbia Tie Line. The wind studies were updated a number of times and ultimately formed the basis for the AESO wind map which is used for bulk transmission line design in Alberta. The AESO wind map is provided on the AESO's web site.

TransAlta Utilities compared their performance-based insulator swing design criteria with the original 500kV wind study results. TransAlta Utilities found that the performance based criteria roughly approximated a 5-year return gust speed throughout their service area (which also incorporated the windy South West region of the province). As a result, TransAlta adopted a 5-year return wind gust for conductor swing considerations in the design of transmission structures. This criteria is included as part of section 502.2.

Insulator Swing - Requirements

Three separate criteria are applicable to the clearance between conductors attached to suspension insulators and the supporting structures. Each of the three criteria should be checked in order to determine which will govern. The insulator swing criteria are an important aspect of bulk transmission line design and are required to ensure that the bulk transmission lines are reliable.

The following items address the three swing clearance criteria of subsection 17(5):

(a) The requirements of CSA C22.3 No. 1-06 are part of the *Alberta Electrical Utility Code* and hence are mandatory. Switching surge factors, switching surge crest voltage values and switching surge flashover-to-ground distances are to be as specified in Table A.1 of CSA C22.3 No. 1-06 unless a switching study is completed by the designer of the bulk transmission line and provides other values.

(b) The five (5) year gust criteria address the situation of reasonably high winds (which occur infrequently) and minimum clearance requirements (60 Hz power frequency stress).

(c) The moderate wind gust criteria provide adequate clearance for electrical stresses that occur occasionally on the system (e.g. switching surge). The following overlapping probabilities apply to this criterion:

(1) Probability of switching surge occurring while the insulators are in the defined swing position;

(2) Probability of the switching surge voltage having the maximum value; and

(3) Probability of the switching surge causing a flashover at the location of the reduced clearance.

The loading areas specified for the moderate gust wind pressure values are the same as those on the AESO wet snow and wind loading map. The pressure values are based on operating experience.

Air gap distances for use with the moderate wind gusts of Table 3 of subsection 17 are to be calculated in accordance with the methodology described in *IEEE Standard 1313.2 The Application of Insulation Coordination,* for transmission line phase to ground switching overvoltages.

It should be noted that while the IEEE Standard does not provide a formula for the calculation of strike distance (air gap), it does provide a formula giving the relationship between critical flashover (CFO) and strike distance. This formula can be rearranged to solve for strike distance although an adjusted equation for CFO, taking into account actual air density (elevation) must be used. For further details of the IEEE calculation methodology, including example calculations, see the book *Insulation Coordination for Power Systems*, by Andrew R. Hileman, in particular the chapter on Insulation Strength Characteristics.

For angle structures with suspension type insulators, the required clearances are to be met with both forward and reverse wind, and for both initial and final tensions. This approach is expected to provide acceptable reliability for the angle structures for a range of operating conditions.

18. Clearances Under Differential Loading

The requirement for specified clearances under differential loading conditions recognizes the situation where an overhead shieldwire or upper phase is loaded with ice or wet snow, and the wires below have reduced loading, or are bare. Operating experience in Alberta indicates that these conditions occur on a reasonably frequent basis, and resulted in line outages prior to the adoption of clearance requirements for these loading situations.

The first loading case represents a condition with glaze ice or in-cloud (rime) ice accumulation on the shieldwire or upper phase conductor, with the wires below being bare. The temperature of -20°C is typical for in-cloud icing events in Alberta. The requirement applies to bulk transmission lines of all voltages. The specified value of 12.5 mm radial glaze ice is a reasonable representation of rime icing events that have been observed in all parts of the province.

The second loading requirement is more severe, and hence is applied only to those bulk transmission lines which normally require higher levels of reliability. The specified loading represents a situation where rime ice has dropped off of the lower phase and remains on the upper phase or overhead shieldwire(s). The temperature of 0°C represents a melting point for the ice. The specified value of ice accretion and the density are typical of rime icing events observed in Alberta.

19. Clearances to Edge of Right of Way

The right of way width should meet the requirements of conductor swing out under a five (5) year return wind gust, with a switching surge clearance distance from the conductor in the blown out position to the edge of the right of way, and clearance distances should be as specified either in Table 4 of Section 502.2, for voltages below 500 kV, or from an insulation design study for voltages at 500 kV.

Conductor blow out should be calculated for a full span, and with a span factor of one point zero (1.0), and conductor sag must be the calculated final sag at four (4) degrees Celsius.

The requirements in subsection 19 and the above paragraph were developed jointly by the AESO and the major legal owners of transmission facilities in Alberta, and meet the following criteria:

(1) Recognize the possible high cost and sometimes impractical nature of meeting a “maximum design wind” requirement;

(2) Provide consistency in the approach to right of way width for all parties building bulk transmission lines in the province; and

(3) Result in a reasonable probability that structures built up to the edge of the right-of-way, that could be contacted by swinging conductors under high wind conditions, will be identified (with remedial action taken) before a line contact occurs.

The 4°C temperature specified for conductor blowout, and for other requirements in Section 502.2, is the annual average temperature for Alberta.

Subsection 19(1) of section 502.2 refers to horizontal clearance requirements in CSA C22.3 No. 1. The CSA Standard does not specifically address the issue of clearance to edge of right of way but the requirements of CSA C22.3 No. 1 will be met if the edge of the right of way is assumed to coincide with the location of a building or other structure, as specified in CSA C22.3 No. 1.

In urban areas there are set back requirements that usually prevent structures from being built up to the edge of transmission line rights of way. However, in rural areas structures can, and have been, built up to the edge of the transmission line right of way.

The requirements in subsection 19 of section 502.2 are intended to manage the risk of conductors of a bulk transmission line contacting or flashing over to structures located adjacent to the location of the bulk transmission line. Hence, the term “Edge of Right of Way”, as used in subsection 19 should be interpreted to mean those boundaries that are adjacent to areas where structures such as buildings, trees and high equipment are likely to be found. The boundary of a bulk transmission line that is adjacent to the right of way of another powerline or other linear facilities (such as pipelines or roads) does not need to be interpreted as “Edge of Right of Way” for the purposes of subsection 19.

In Alberta, single circuit 138 kV and 144 kV bulk transmission lines are commonly built on road allowances. In general there are no easements for these lines and hence the requirements of subsection 19 should not apply. Subsection 19(4) exempts 138 kV and 144 kV bulk transmission lines located on road allowances from the requirements of clearances to edge of right of way.

20. Fall Free Spacing

Subsection 20(2) allows the failure location on a structure to be taken as other than the groundline if analysis, or a full scale structure test, indicates a different failure point. If the structure analysis or full scale test is not carried out, the structure failure point is to be assumed as the groundline.

It is recognized that where bulk transmission lines enter and exit substations, and for other situations such as lines in congested and limited width corridors, it may not be possible to meet the fall free spacing requirements outlined in subsection 20 of section 502.2. Where the required spacing cannot be maintained, additional steps should be taken to improve the structural reliability of either the lower voltage bulk transmission lines or the 500 kV alternating current or +/- 500 kV high voltage direct current bulk transmission lines (as applicable). These steps could include use of H-frame structures, instead of single pole structures (for lower voltage lines) and use of shorter spans for lines of all voltages. To the extent reasonably possible, the length of bulk transmission lines in the vicinity of substations that does not meet the fall free criteria should be minimized.

21 Insulation

Use of synthetic insulators with silicone rubber skirts should be considered for areas of high contamination. The silicone rubber material has performed very well in Alberta under contaminated conditions that range from moderate to extreme. Given that synthetic insulators with silicone rubber skirts are readily available from a number of manufacturers, and that the material is cost competitive with other materials that are less consistent in terms of contaminated area performance, use of silicone rubber is required for synthetic insulators in contaminated areas. Where synthetic insulators are used in areas not subjected to significant contamination, the shed material can be determined by the line designer.

Dovetail and straight head designs are shown in Figure 1. The dovetail design results in stress concentrations that have resulted in insulator failures. The straight head design is used by major insulator manufacturers and is the preferred option.

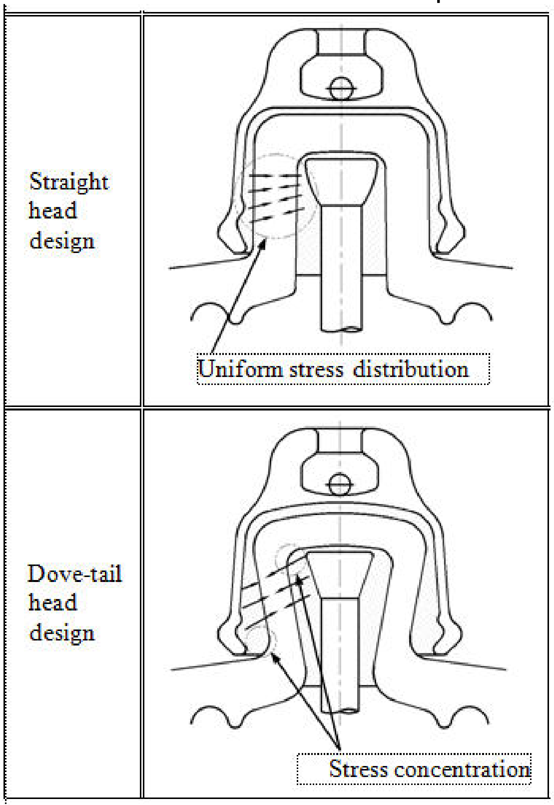

Figure 1
Insulator Head Designs

The insulation levels given in section 502.2 were calculated from system Basic Impulse Level (BIL) values, as shown in the following Table 4. The relationship between Basic Impulse Level and Critical Impulse Flashover is given by CIFO = BIL / 0.91

Table 4 Values of Basic Impulse Level and Critical Impulse Flashover Voltage

Nominal Voltage (kV)	System Basic Impulse Level (kV)	Critical Impulse Flashover (kV)
25	150	165
69/72	350	385
138/144	650	715
240	1050	1155

As noted in section 502.2, the 25 kV insulation requirement applies only to those 25 kV distribution lines placed on bulk transmission line structures. This requirement recognizes the need for insulation coordination between circuits of different voltages located on common structures, and further recognizes the operating experience with combined 138 or 144 kV and 25 kV structures in Alberta.

Insulation levels for 500 kV alternating current or +/- 500 kV high voltage direct current lines are determined from insulation studies carried out for each such line, as part of the design process. Hence, section 502.2 does not include insulation levels for 500 kV class lines.

22. Conductor Thermal Ratings Methodology

Under subsection 22(3) the AESO will consider requests to operate non-standard conductors (in particular those of the high temperature low sag design) at temperatures exceeding 100ºC.

Dynamic line rating is an effective method of improving the utilization of line capacity in certain circumstances. Requirements for dynamic rating will be identified by the AESO in the functional specification for a given bulk transmission line.

Subsection 22 deals only with the thermal rating methodology for the conductor of a bulk transmission line. For system operating purposes, thermal ratings are established for complete line segments, which take into account all components that affect the capability of the segment, including jumpers, current transformers, switches and circuit breakers.

23. Conductor Emergency Thermal Ratings Methodology

Subsection 23(1) requires that emergency thermal ratings of bulk transmission line conductors be based on a thirty (30) minute time period. This is based on the time required by system operators to assess a given contingency condition and complete remedial action.

For conductors of sizes commonly used on bulk transmission lines, the conductor will reach a steady state temperature in approximately thirty (30) minutes, or even less. Hence, the emergency rating for new bulk transmission lines has been set equal to the static rating.

24. Galloping

Conductor galloping has been observed on lines in various locations within Alberta. Although glaze ice is not a major loading condition in the province, small glaze accumulations do occur and are adequate to initiate galloping. Also, wet snow events are common, and the wet snow accretion profiles on conductors appear to be at least as efficient in terms of creating lift forces as glaze ice. As a result, galloping associated with wet snow events is a common occurrence.

The galloping criteria outlined in subsection 24 is based on methods from *CIGRE Brochure #322,* modified based on discussions with Dr. David Havard, a recognized authority on conductor galloping.

Galloping envelopes are to be calculated as required under the Appendices to section 502.2. Galloping is to be assumed as single loop regardless of the span length. This assumption reflects operating experience in Alberta, where spans in excess of 400 m have been observed to gallop in a single loop mode. The limit of 12 m for maximum galloping amplitude will prevent very large ellipse amplitudes from being used for long spans, such as river crossings.

The 12 m limit for maximum galloping amplitude is based upon the numerous observations of galloping summarized by Dr. Havard in the following Figure 2 as noted in his CIGRE presentation (Lilien & Havard, TF B2.11.06).

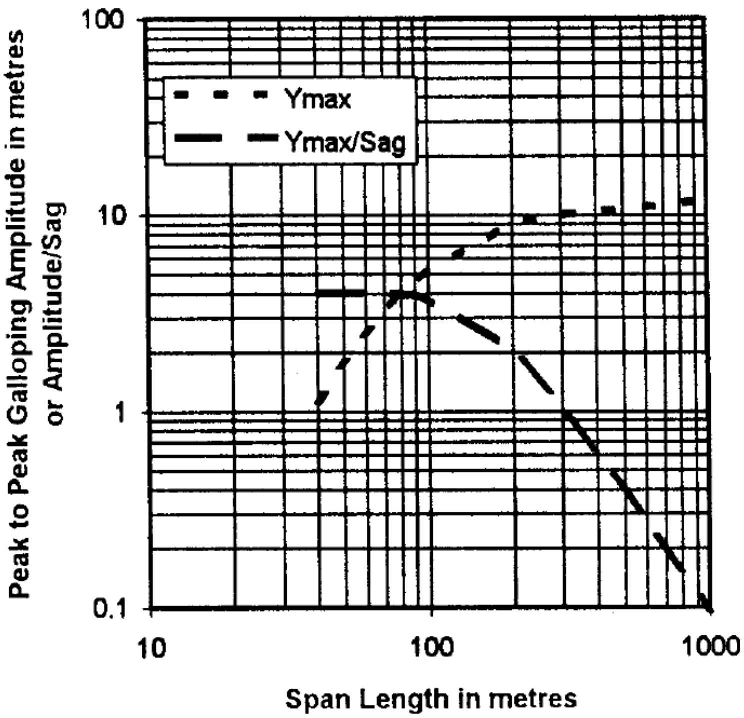

Figure 2 Observed Galloping Amplitude vs. Span Length

These observations from Figure 2 tend to support a practical upper limit in the order of 12m for galloping amplitude; regardless of span length.

Based on extensive plotting of actual galloping Dr. Havard has reported that galloping is primarily a vertical motion, and that the predicted inclinations of the galloping ellipse by the REA method were not generally observed during the recorded events. Lateral deviations tended to be within about 5 degrees of the vertical axis.

Dynamic loads on towers due to galloping are not considered. Static loads are used for tower design. While dynamic loads can be roughly quantified, their comparison against static strength is not considered representative of the structure's ability to resist dynamic loads.

The compact line designs specified in subsection 24(5) may be required in congested areas such as urban areas or the vicinity of large substations with multiple existing bulk transmission lines. Compact line designs would not normally be used where there is adequate space to allow construction of standard configuration bulk transmission lines.

25. Hardware Requirements

Bulk transmission lines in Alberta are subject to low temperatures (-50°C or lower in the northern parts of the province) sometimes combined with wet snow or in-cloud icing events.

Hence, there is a significant risk of impact loads from dropped ice accretions or other events, such as vehicle impacts, occurring at times of low temperature. Brittle fracture of ferrous hardware as the result of an impact load could trigger a major line failure. Hence, it is prudent to include a requirement for low temperature impact properties for ferrous hardware.

The CSA C83 Standard contains two levels of impact toughness. The less stringent of the two is specified in section 502.2, and is consistent with the requirements of several other electrical utilities in Canada. One or more of the large utilities in Canada requires the more stringent of the two criteria in C83, but this level of impact toughness was deemed to be excessive for Alberta requirements.

The concept of low temperature impact toughness is not applicable to hardware components manufactured from aluminum, and hence the requirement is specific to ferrous materials.

26. Provisions for Maintenance

Bulk transmission line maintenance is an important aspect of overall line reliability. Effective planning for maintenance as part of the initial line design is a key component of the overall maintenance process.

Designing bulk transmission lines with the ability for live line maintenance work procedures reduces the need for planned outages and improves overall system reliability.

In order to minimize the duration of a forced line outage, ready access to the location of the failed structure or line component is essential. Access by means of roads or trails on the ground is not always possible or feasible. This is recognized by use of the words “or otherwise” in subsection 28(b). It is expected that the legal owner of a bulk transmission line will have a plan for access to all structures of the line, which will include identification of the equipment required (such as helicopters or swamp vehicles) and the availability of the equipment.

27. Transposition Structures

Although section 502.2 does not have requirements for voltage unbalance, it may be an important consideration in the design of longer bulk transmission lines and is included in this Information Document as a way of ensuring that the issue is not overlooked.

The **ISO** is presently reviewing the need to limit voltage unbalance on bulk transmission lines to not more than 1% of the nominal voltage. For now the AESO will identify any requirements for voltage unbalance in the project functional specification.

28. Radio Interference

A bulk transmission line should be designed so that conductors and hardware will not operate in positive corona under normal operating conditions.

A bulk transmission line design in addition should satisfy the federal provisions of *Industry Canada ICES-004 Spectrum Management and Telecommunications Policy, Interference-Causing Equipment Standard, Alternating Current High Voltage Power Systems.*

Radio interference results from corona discharge from conductors or line hardware. Positive corona generates significantly higher levels of radio noise than negative corona, which is why it is recommended that the conductors and hardware of bulk transmission lines should not operate in positive corona under normal operating conditions.

The Canadian government regulation (ICES-004) sets the limits for RI from powerlines. The regulation also contains information on the measurement methodology and requirements. There is a requirement for field measurements to be taken, within six months after the bulk transmission line is placed in operation, to verify that the lines meet the specified RI limits.

When a new bulk transmission line is of the same design as an existing bulk transmission line for which measurements demonstrating compliance with ICES-004 have been made and documented, the legal owner of the new bulk transmission line may choose to request a waiver from the measurement requirements for the new bulk transmission line. The request for a waiver is to be made in consultation with the Industry Canada Regional Office.

29. Documentation of Design Criteria

The design criteria of a bulk transmission line should be documented in accordance with *IEEE Standard 1724 Guide for the Preparation of a Transmission Line Design Criteria Document.*

It is good engineering practice to document the design criteria for each new bulk transmission line. The practice is followed by most utilities and consulting firms, for their own purposes and records. The noted IEEE standard, which is currently in the final stages of review and approval, provides a consistent format for the documentation. Until such time as the IEEE Standard is readily available, legal owners of new bulk transmission lines are to use their own format for the Design Criteria documents.

Revision History

Version	Effective Date	Description of Changes
Rev 1	December 16, 2010	New document created to support ISO rules, section 502.2.