NERC

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Transmission Vegetation Management

Standard FAC-003-2 Technical Reference

Vegetation Management Standard Drafting Team

to ensure the reliability of the bulk power system

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Introduction

This document is intended to provide supplemental information and guidance for complying with the requirements of Reliability Standard FAC-003-2.

The purpose of the Standard is to improve the reliability of the electric transmission system by preventing those vegetation related outages that could lead to Cascading.

Compliance with the Standard is mandatory and enforceable.

Special Note: The Application of Results-Based Approach to FAC-003-2

In its three-year assessment as the ERO, NERC acknowledged stakeholder comments and committed to:

i) addressing quality issues to ensure each reliability standard has a clear statement of purpose, and has outcome-focused requirements that are clear and measurable; and

ii) eliminating requirements that do not have an impact on bulk power system reliability.

In 2010, the Standards Committee approved a recommendation to use Project 2007-07 Vegetation Management as a first proof of concept for developing results-based standards.

The Standard Drafting Team (SDT) employed a defense-in-depth[1] strategy for FAC-003-2, where each requirement has a role in preventing those vegetation related outages that could lead to Cascading. This portfolio of requirements was designed to achieve an overall defense-in-depth strategy and to comply with the quality objectives identified in the *Acceptance Criteria of a Reliability Standard* document.

The SDT developed a portfolio of performance, risk, and competency-based mandatory reliability requirements to support an effective defense-in-depth strategy. Each Requirement was developed using one of the following requirement types:

a. Performance-based - defines a particular reliability objective or outcome to be achieved. In its simplest form, a results-based requirement has four components: who, under what conditions (if any), shall perform what action, to achieve what particular result or outcome?

b. Risk-based - preventive requirements to reduce the risks of failure to acceptable tolerance levels. A risk-based reliability requirement should be framed as: who, under what conditions (if any), shall perform what action, to achieve what particular result or outcome that reduces a stated risk to the reliability of the bulk power system?

c. Competency-based - defines a minimum set of capabilities an entity needs to have to demonstrate it is able to perform its designated reliability functions. A competency-based reliability requirement should be framed as: who, under what conditions (if any), shall have what capability, to achieve what particular result or outcome to perform an action to achieve a result or outcome or to reduce a risk to the reliability of the bulk power system?

[1] A defense-in-depth strategy for reliability standards recognizes that each requirement in the NERC standards has a role in preventing system failures, and that these roles are complementary and reinforcing. These prevention measures should be arranged in a series of defensive layers or walls. No single defensive layer provides complete protection from failure by itself. But taken together, with well-designed layers including performance, risk, and competency-based, requirements, a defense-in-depth approach can be very effective in preventing future large scale power system failures.

The drafting team reviewed and edited version 1 of FAC-003-1 to remove prescriptive and administrative language in order to distill the technical requirements down to their essential reliability content. Text that is explanatory in nature is placed in a special section of the standard entitled Guideline and Technical Basis to aid in the understanding of the requirements. Furthermore, Rationale text boxes are inserted alongside each requirement to communicate the foundation for the requirement.

Disclaimer

This supporting document is supplemental to the reliability standard FAC-003-2 — Transmission Vegetation Management and does not contain mandatory requirements subject to compliance review.

Definition of Terms

Active Transmission Line Right of Way* — A strip or corridor of land that is occupied by active transmission facilities. This corridor does not include the parts of the Right-of-Way that are unused or intended for other facilities.

Examples of active portions of corridors include:

1) The width of any Active Transmission Line Right-of-Way (ROW) is the portion of the ROW that has been cleared of vegetation to meet design clearance requirements such as National Electrical Safety Code or other design criteria, for the reliable operation of active facilities.

Examples of inactive portions of corridors include:

2) The portions of the right of way acquired to accommodate future facilities. Power plant exits are examples where large rights-of-way are obtained for maximum corridor utilization and may currently have fewer structures constructed.
3) The portion of the ROW where corridor edge zones are designated by regulatory bodies for vegetation to exist.
4) The portions of the ROW where double-circuit structures are installed but only one circuit is currently strung with conductors.

Vegetation Inspection** — The systematic examination of vegetation conditions on an Active Transmission Line Right-of-Way which may be combined with a general line inspection.

The inspection includes the identification of any vegetation that may pose a threat to reliability prior to the next planned inspection or maintenance work, considering the current location of the conductor and other possible locations of the conductor due to sag and sway for rated conditions.

This definition allows both maintenance inspections and vegetation inspections to be performed concurrently.

*To be added to the NERC glossary of terms with final approval of this standard revision
** This is a modification to a defined term in the NERC glossary.

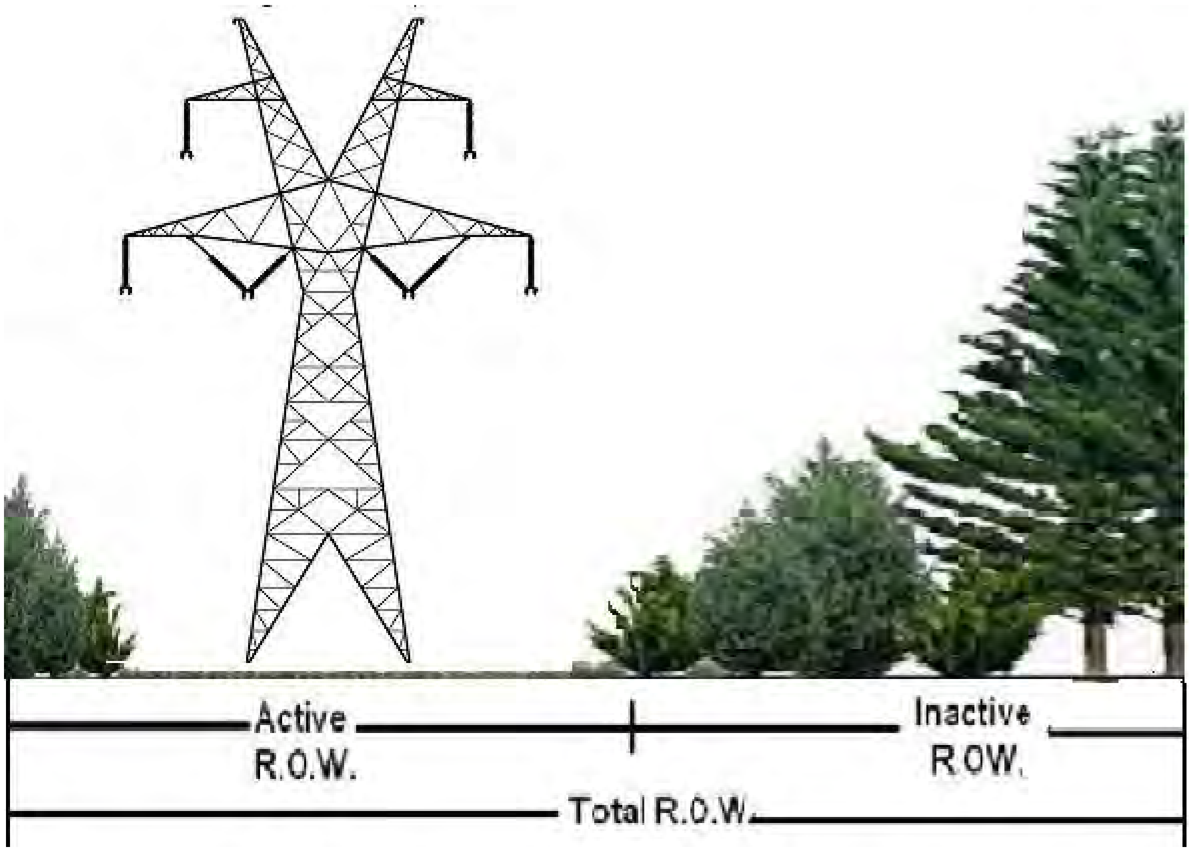

Figure 1

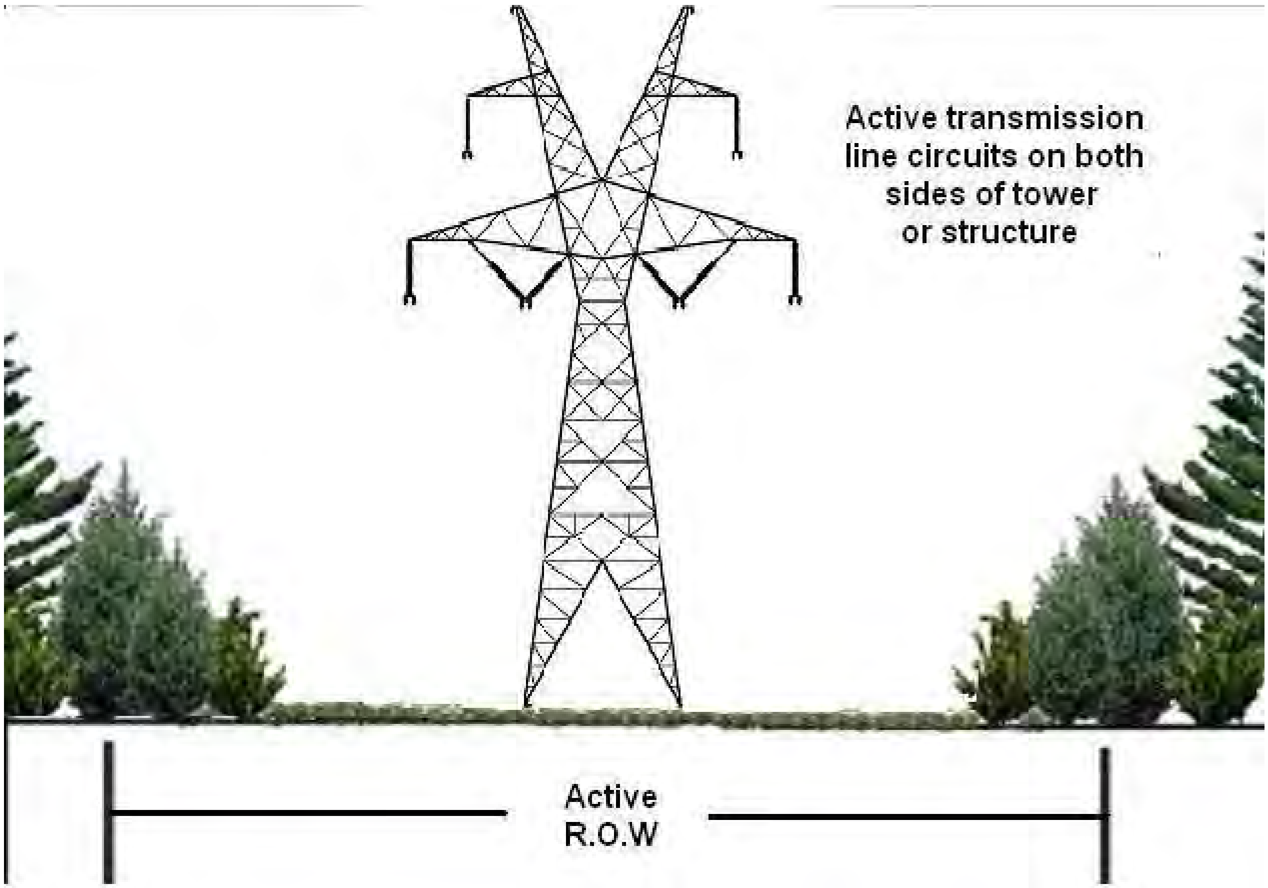
Active transmission
line circuits on both
sides of tower
or structure
Active
R.O.W

Figure 2

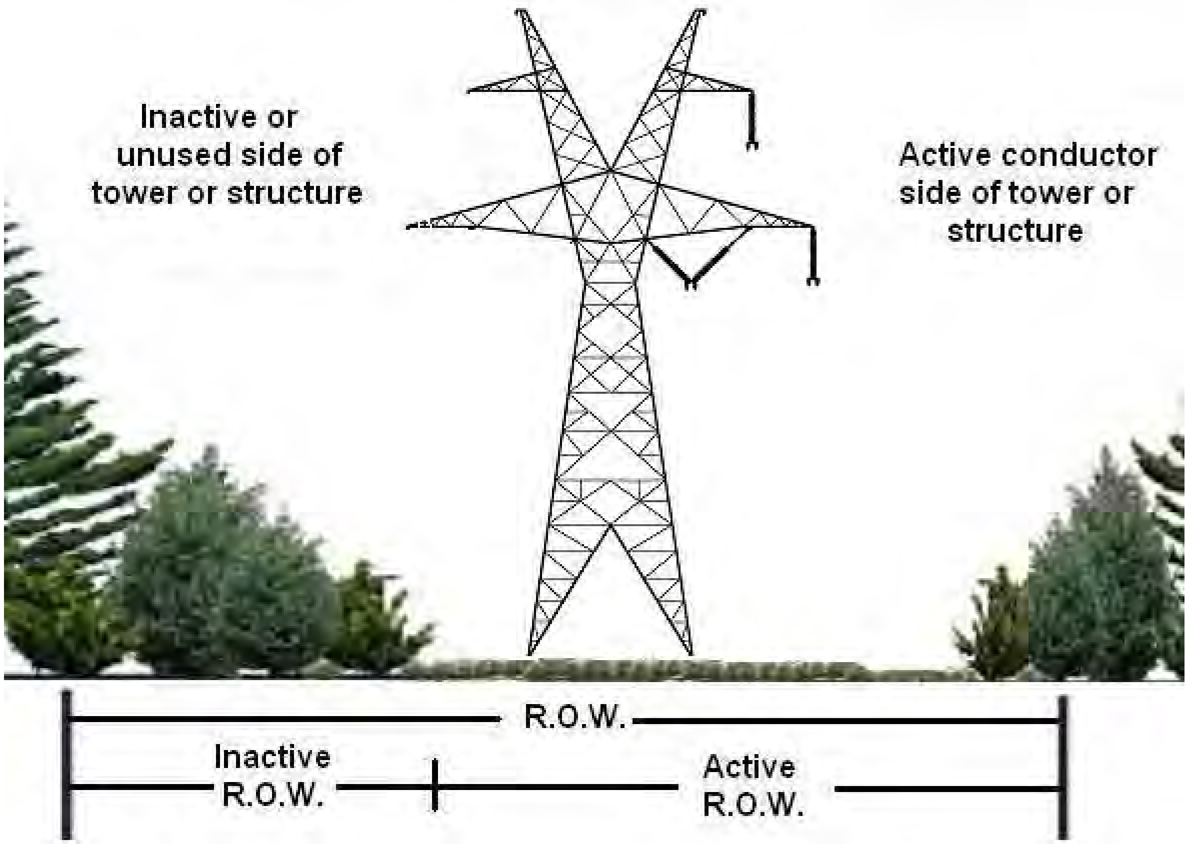
Inactive or
unused side of
tower or structure
Active conductor
side of tower or
structure
R.O.W.
Inactive
R.O.W.
Active
R.O.W.

Figure 3

Applicability of the Standard

4. Applicability

4.1. Functional Entities:

4.1.1 Transmission Owners

4.2. Facilities: Defined below, including but not limited to those that cross lands owned by federal[1], state, provincial, public, private, or tribal entities:

4.2.1 Overhead transmission lines operated at 200kV or higher.

4.2.2 Overhead transmission lines operated below 200kV having been identified as elements of an Interconnection Reliability Operating Limit (IROL).

4.2.3 Overhead transmission lines operated below 200 kV having been identified as included in the definition of one of the Major WECC Transfer Paths in the Bulk Electric System.

4.2.4 This Standard does not apply to Facilities identified above (4.2.1 through 4.2.3) located in the fenced area of a switchyard, station or substation.

4.3. Other:

4.3.1 This Standard does not apply to any occurrence, non-occurrence, or other set of circumstances that are beyond the reasonable control of a Transmission Owner subject to this Reliability Standard, and are not caused by the fault or negligence of the Transmission Owner, including acts of God, flood, drought, earthquake, major storms, fire, hurricane, tornado, landslides, logging activities, animals severing trees, lightning, epidemic, strike, war, riot, civil disturbance, sabotage, vandalism, terrorism, wind shear, or fresh gales that restricts or prevents performance to comply with this reliability standard's requirements.

In Order 693, FERC discussed the 200 kV bright-line test of applicability. While FERC did not change the 200 kV bright line, the Commission remained concerned that there may be some transmission lines operating at lesser voltages that could have significant impact on the Bulk Electric System that should therefore be subject to this standard.

NERC Standard FAC-014 has the stated purpose, "*To ensure that System Operating Limits (SOLs) used in the reliable planning and operation of the Bulk Electric System (BES) are determined based on an established methodology or methodologies.*" FAC-014 requires Reliability Coordinators, Planning Coordinators, and Transmission Planners to have a methodology to identify all lines that might comprise an IROL. Thus, these entities would identify sub-200 kV lines that qualify as part of an IROL and should be subject to FAC-003-2.

Although all three entities may prepare the list of elements, FAC-003-2 presently does not specify that it is the list from the Planning Coordinator that should be used by Transmission Owners for FAC-003. However, the Time Horizon needed to plan vegetation management work does not lend itself to the operating horizon of a Reliability Coordinator. Additionally, the Planning Coordinator has a wider-area view than the Transmission Planner and could thus identify any elements of importance to a sub-set of its area that might be missed by a Transmission Planner.

Transmission Owners, who do not already get the list of circuits included in the definition of an IROL, can get them from the Planning Coordinator. Specifically R5 of FAC-014 specifies that "*The Reliability Coordinator, Planning Authority (Coordinator) and Transmission Planner shall each provide its SOLs and IROLs to those entities that have a reliability-related need for those limits and provide a written request that includes a schedule for delivery of those limits"*

Vegetation-related Sustained Outages that occur due to natural disasters are beyond the control of the Transmission Owner. These events are not classified as vegetation-related Sustained Outages and are therefore exempt from the Standard. Transmission lines are not designed to withstand the impacts of natural disasters such as tornadoes, hurricanes, severe ice loads, landslides, etc. In the aftermath of catastrophic system damage from natural disasters the Transmission Owner's focus is on electric system restoration for public safety and critical support infrastructure.

Sustained Outages due to human or animal activity are beyond the control of the Transmission Owner. These outages are not classified as vegetation-related Sustained Outages and are therefore exempt from the Standard. Examples of these events may include new plantings by outside parties of tall vegetation under the transmission line planted since the last Vegetation Inspection, tree contacts with line initiated by vehicles, logging activities, etc.

The foregoing exemptions are addressed in a new subsection, 4.3 Other, of the Applicability section. Referred to collectively as force majeure events and activities, this section applies to all requirements in FAC-003-2.

The reliability objective of this NERC Vegetation Management Standard ("Standard") is to prevent vegetation-related outages which could lead to Cascading by effective vegetation maintenance while recognizing that certain outages such as those due to vandalism, human errors and acts of nature are not preventable. Operating experience clearly indicates that trees that have grown out of specification could contribute to a cascading grid failure, especially under heavy electrical loading conditions.

Serious outages and operational problems have resulted from interference between overgrown vegetation and transmission lines located on many types of lands and ownership situations. To properly reduce and manage this risk, it is necessary to apply the Standard to applicable lines on any kind of land or easement, whether they are Federal Lands, state or provincial lands, public or private lands, franchises, easements or lands owned in fee. For the purposes of the Standard and this technical paper, the term "public lands" includes municipal lands, village lands, city lands, and land owned by a host of other governmental entities.

The Standard addresses vegetation management along applicable overhead lines that serve to connect one electric station to another. However, it is not intended to be applied to lines sections inside the electric station fence or other boundary of an electric station or underground lines.

The Standard is intended to reduce the risk of Cascading involving vegetation. It is not intended to prevent customer outages from occurring due to tree contact with all transmission lines and voltages. For example, localized customer service might be disrupted if vegetation were to make contact with a 69kV transmission line supplying power to a 12kV distribution station. However, this Standard is not written to address such isolated situations which have little impact on the overall Bulk Electric System. In fact, the inclusion of such a transmission line (which does not lead to the undesirable conditions listed in Requirement R10) on the Planning Coordinator's list of sub-200kV lines may constitute a violation of Requirement R10.

Vegetation growth is constant and always present. Unmanaged vegetation poses an increased outage risk when numerous transmission lines are operating at or near their Rating. This poses a significant risk of multiple line failures and Cascading. On the other hand, most other outage causes (such as trees falling into lines, lightning, animals, motor vehicles, etc.) are statistically intermittent. The probability of occurrence of these events is not dependent on heavy loads. There is no cause-effect relationship which creates the probability of simultaneous occurrence of other such events. Therefore these types of events are highly unlikely to cause large-scale grid failures.

In preparing the original vegetation management standard in 2005, industry stakeholders set the threshold for applicability of the standard at 200kV. This was because an unexpected loss of lines operating at above 200kV has a higher probability of initiating a widespread blackout or cascading outages compared with lines operating at less than 200kV.

The NERC vegetation management standard FAC-003-1 also allowed for application of the standard to "critical" circuits (critical from the perspective of initiating widespread blackouts or cascading outages) operating below 200kV. While the percentage of these circuits is relatively low, it remains a fact that there are sub-200kV circuits whose loss could contribute to a widespread outage. Given the very limited exposure and unlikelihood of a major event related to these lower-voltage lines, it would be an imprudent use of resources to apply the Standard to all sub-200kV lines. The drafting team, after evaluating several alternatives, selected the IROL and WECC Major Transfer Path criteria to determine applicable lines below 200 kV that are subject to this standard.

Requirements R1 and R2

> **Rationale**
> The MVCD is a calculated minimum distance stated in feet (meters) to prevent spark-over between conductors and vegetation, for various altitudes and operating voltages. The distances in Table 2 were derived using a proven transmission design method.

R1. *Each Transmission Owner shall prevent vegetation from encroaching within the Minimum Vegetation Clearance Distance (MVCD) of each line conductor that is identified as an element of an Interconnection Reliability Operating Limit (IROL) or Major Western Electricity Coordinating Council (WECC) transfer path (operating within Rating and Rated Electrical Operating Conditions) to avoid a Sustained Outage.*

R2*.* *Each Transmission Owner shall prevent vegetation from encroaching within the MVCD of each applicable line conductor, which are not elements of an IROL and are not a Major WECC transfer path, (operating within Rating and Rated Electrical Operating Conditions) to avoid a Sustained Outage.*

M1. *Evidence of violation of Requirement R1 is limited to:*

- *Real-time observation of encroachment into the MVCD, or*
- *A vegetation-related Sustained Outage due to a fall-in from inside the Active Transmission Line ROW, or*
- *A vegetation-related Sustained Outage due to blowing together of applicable lines and vegetation located inside the Active Transmission Line ROW, or*
- *A vegetation-related Sustained Outage due to a grow-in.*

Multiple Sustained Outages on an individual line, if caused by the same vegetation, will be reported as one outage regardless of the actual number of outages within a 24-hour period.

M2. *Evidence of violation of Requirement R2 is limited to:*

- *Real-time observation of encroachment into the MVCD, or*
- *A vegetation-related Sustained Outage due to a fall-in from inside the Active Transmission Line ROW, or*
- *A vegetation-related Sustained Outage due to blowing together of applicable lines and vegetation located inside the Active Transmission Line ROW, or*
- *A vegetation-related Sustained Outage due to a grow-in.*

Multiple Sustained Outages on an individual line, if caused by the same vegetation, will be reported as one outage regardless of the actual number of outages within a 24-hour period.

R1 and R2 are performance-based requirements. The reliability objective or outcome to be achieved is the prevention of vegetation encroachments within a minimum distance of transmission lines. Content-wise, R1 and R2 are the same requirements, however, they apply to different Facilities. Both R1 and R2 require each Transmission Owner to prevent vegetation from encroaching within the Minimum Vegetation Clearance Distance of transmission lines. R1 is applicable to lines “identified as an element of an Interconnection Reliability Operating Limit (IROL) or Major Western Electricity Coordinating Council (WECC) transfer path (operating within Rating and Rated Electrical Operating Conditions) to avoid a Sustained Outage”. R2 applies to all other applicable lines that are not an element of an IROL or Major WECC Transfer Path.

The separation of applicability (between R1 and R2) recognizes that an encroachment into the MVCD of an IROL or Major WECC Transfer Path transmission line is a greater risk to the electric transmission system. Applicable lines that are not an element of an IROL or Major WECC Transfer Path are required to be clear of vegetation but these lines are comparatively less operationally significant. As a reflection of this difference in risk impact, the Violation Risk Factors (VRFs) are assigned as High for R1 and Medium for R2.

These requirements (R1 and R2) state that if vegetation encroaches within the distances prescribed in Table 1 in Appendix 1 of this Technical Reference document, it is in violation of the standard. Table 1 delineates the distances necessary to prevent spark-over based on the Gallet equations as described more fully in Appendix 1.

This requirement assumes that transmission lines and their conductors are operating within their Rating. If a line conductor is intentionally or inadvertently operated beyond its rating (potentially in violation of other standards), the occurrence of a clearance encroachment may not be a violation of this Standard. Conductor position, and the associated vegetation distance, that result from operation of a transmission line beyond its recognized Rating (for example emergency actions taken by a TOP or RC to protect an Interconnection) is beyond the scope of this standard.

Evidence of violation of Requirement R1 and R2 is limited to a real-time observation of encroachment into the MVCD, or a vegetation-related Sustained Outage due to a fall-in from inside the Active Transmission Line ROW, or a vegetation-related Sustained Outage due to blowing together of applicable lines and vegetation located inside the Active Transmission Line ROW, or a vegetation-related Sustained Outage due to a grow-in.

It is also important to note that Multiple Sustained Outages on an individual line can be caused by the same vegetation. Such events are considered to be a single vegetation-related Sustained Outage under the Standard where the Sustained Outages occur within a 24 hour period.

Requirement R3

R3. *Each Transmission Owner shall have a documented transmission vegetation management program that describes how it conducts work on its Active Transmission Line ROWs to avoid Sustained Outages due to vegetation, considering all possible locations the conductor may occupy assuming operation within Rating and Rated Electrical Operating Conditions.*

Rationale
Provide a basis for evaluation on the intent and competency of the Transmission Owner in maintaining vegetation. There may be many acceptable approaches to maintain clearances. However, the Transmission Owner should be able to state what its approach is and how it conducts work to maintain clearances. See Figure 1 for an illustration of possible conductor locations.

M3. *Each Transmission Owner has a documented transmission vegetation management program that describes how it conducts work on its Active Transmission Line ROW to avoid Sustained Outages due to vegetation, considering all possible locations the conductor may occupy assuming operation within Rating and Rated Electrical Operating Conditions.*

Whitepaper for section R3: (Competency Based Requirement)

Requirement R3 is a competency based requirement concerned with the content of the TVMP and supporting documentation.

An adequate transmission vegetation management program formally establishes the approach the Transmission Owner uses to plan and perform vegetation work that is necessary to prevent transmission Sustained Outages and minimize risk to the Transmission System.
This approach provides the basis for evaluating the intent, allocation of appropriate resources and the competency of the Transmission Owner in managing vegetation. There are many acceptable approaches to manage vegetation and avoid sustained outages. However, the Transmission Owner must be able to state what its approach is and how it conducts work to maintain clearances.

An example of one approach commonly used by industry is ANSI Standard A300, part 7. However, regardless of the approach a utility uses to manage vegetation, any approach a Transmission Owner chooses to use will generally contain the following elements:

1. *the maintenance strategy used (such as minimum vegetation-to-conductor distance or maximum vegetation height) to ensure that MVCD clearances are never violated.*
2. *the work methods that the Transmission Owner uses to control vegetation*
3. *a stated Vegetation Inspection frequency*
4. *an annual work plan*

Conductor Dynamics
In order for a Transmission Owner to develop a specific maintenance approach, it is important to understand the dynamics of a line conductor's movement. This paper will first address the

complexities inherent in observing and predicting conductor movement, particularly for field personnel. It will then present some examples of maintenance approaches which Transmission Owners may consider that take into account these complexities, while resulting in practical approaches for field personnel.

Additionally, it is important the Transmission Owner consider all conductor locations, the MVCD, and vegetation growth between maintenance activities when developing a maintenance approach.

Understanding Conductor Position and Movement

The conductor's position in space at any point in time is continuously changing as a reaction to a number of different loading variables. Changes in vertical and horizontal conductor positioning are the result of thermal and physical loads applied to the line. Thermal loading is a function of line current and the combination of numerous variables influencing ambient heat dissipation including wind velocity/direction, ambient air temperature and precipitation. Physical loading applied to the conductor affects sag and sway by combining physical factors such as ice and wind loading.

As a consequence of these loading variables, the conductor's position in space is dynamic and moving. When calculating the range of conductor positions, the Transmission Owner should use the same design criteria and assumptions that the Transmission Owner uses when establishing Ratings and SOL, as described in other standards. Typically, the greatest conductor movement would be at mid-span. As the conductor moves through various positions, a spark-over zone surrounding the conductor moves with it. The radius of the spark-over zone may be found by referring to Table 1 ("Minimum Vegetation Clearance Distances") in the standard. For illustrations of this zone and conductor movements, Figures 4 through 6 below demonstrate these concepts. At the time of making a field observation, however, it is very difficult to precisely know where the conductor is in relation to its wide range of all possible positions. Therefore, Transmission Owners must adopt maintenance approaches that account for this dynamic situation.

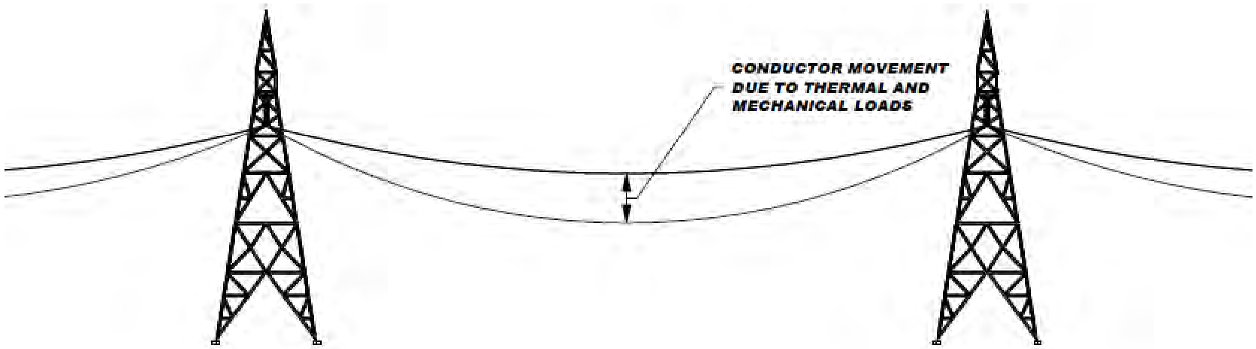

Figure 4

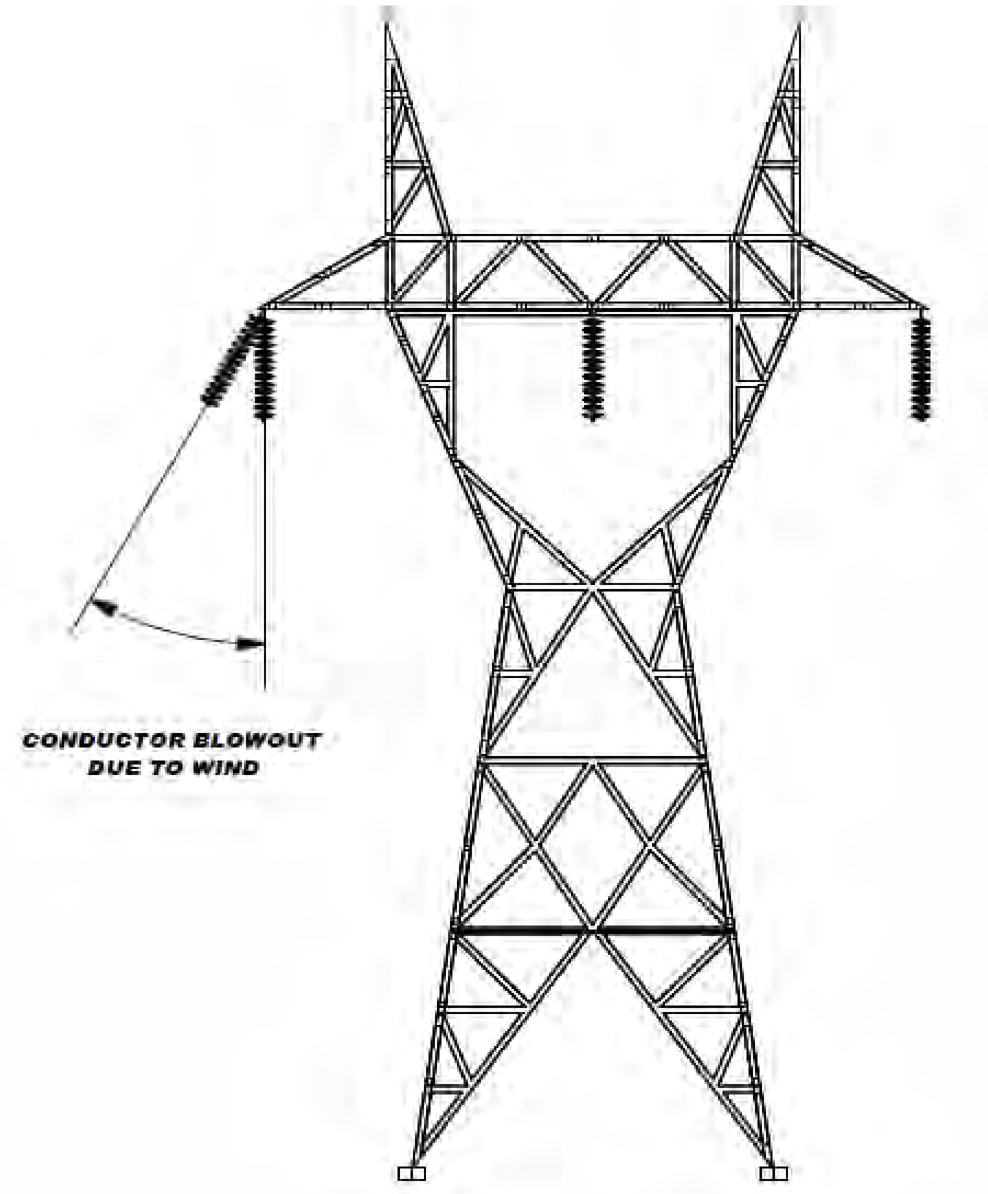

Figure 5

Cross-Section View of a Single Conductor
At a Given Point Along The Span
Showing Six Possible Conductor Positions Due to Movement
Resulting From Thermal and Mechanical Loading
For Consideration in Developing a Maintenance Approach

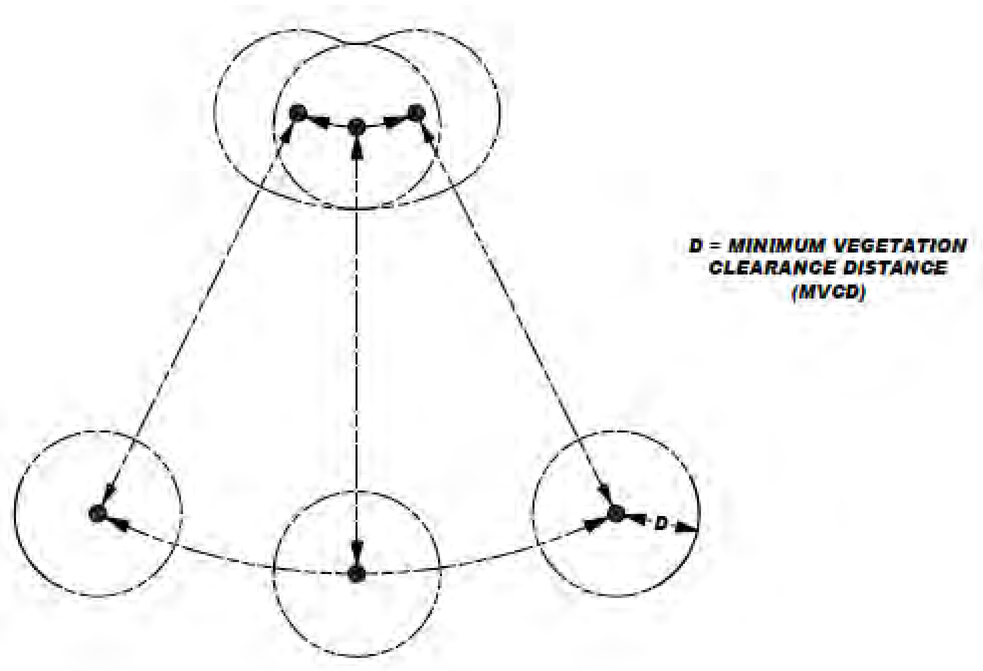

Figure 6

Selecting a Maintenance Approach

In order to maintain adequate separation between vegetation and transmission line conductors, the Transmission Owner must craft a maintenance strategy that keeps vegetation well away from the spark-over zone mentioned above. In fact, it is generally necessary to incorporate a variety of maintenance strategies. For example, one Transmission Owner may utilize a combination of routine cycles, traditional IVM techniques and long-term planning. Another Transmission Owner may place a higher reliance on frequent inspections and quick remediation as opposed to a cyclical approach. This variation of approaches is further warranted when factors, such as terrain, legal and other constraints, vegetation types, and climates, are considered in developing a Transmission Owner's specific approach to satisfying this requirement.

The following is a sample description of one combination of strategies which may be utilized by a Transmission Owner.

A Transmission Owner's basic maintenance approach could be to remove all incompatible vegetation from the right of way if it has the right to do so and has no constraints. In mountainous terrain, however, this strategy could change to one where the Transmission Owner manages vegetation based on vegetation-to-conductor clearances, since it might not be necessary to remove vegetation in a valley that is far below.

If faced with constraints and assuming a line design with sufficient ground clearance, the Transmission Owner 's approach could then be to allow vegetation such as fruit trees, but perhaps only up to a given height at maturity (perhaps 10 feet from the ground). If constraints cannot be overcome and if design clearances are sufficient, an exception to the Transmission Owner's 10-foot guideline might be made. Finally, if the Transmission Owner has chosen to utilize vegetation-to-conductor clearance distance methods, the Transmission Owner could have an inspection regimen in place to regularly ensure that any impending clearance problems are identified early for rectification.

ANSI A300 – Best Management Practices for Tree Care Operations

A description of ANSI A-300, part 7, is offered below to illustrate another maintenance approach that could be used in developing a comprehensive transmission vegetation management program.

Introduction

Integrated Vegetation Management (IVM) is a best management practice conveyed in the American National Standard for Tree Care Operations, Part 7 (ANSI 2006) and the International Society of Arboriculture Best Management Practices: Integrated Vegetation Management (Miller 2007). IVM is consistent with the requirements in FAC-003-02, and it provides practitioners with what industry experts consider to be appropriate techniques to apply to electric right-of-way projects in order to meet or exceed the Standard.

IVM is a system of managing plant communities whereby managers set objectives; identify compatible and incompatible vegetation; consider action thresholds; and evaluate, select and implement the most appropriate control method or methods to achieve set objectives. The choice of control method or methods should be based on the environmental impact and anticipated effectiveness; along with site characteristics, security, economics, current land use and other factors.

Planning and Implementation
Best management practices provide a systematic way of planning and implementing a vegetation management program. While designed primarily with transmission systems in mind, it is also applicable to distribution projects. As presented in ANSI A300 part 7 and the ISA best management practices, IVM consists of 6 elements:

1) Set Objectives
2) Evaluate the Site
3) Define Action Thresholds
4) Evaluate and Select Control Methods
5) Implement IVM
6) Monitor Treatment and Quality Assurance

The setting of objectives, defining action thresholds, and evaluating and selecting control methods all require decisions. The planning and implementation process is cyclical and continuous, because vegetation is dynamic and managers must have the flexibility to adjust their plans. Adjustments may be made at each stage as new information becomes available and circumstances evolve.

Set Objectives
Objectives should be clearly defined and documented. Examples of objectives can include promoting safety, preventing sustained outages caused by vegetation growing into electric facilities, maintaining regulatory compliance, protecting structures and security, restoring electric service during emergencies, maintaining access and clear lines of sight, protecting the environment, and facilitating cost effectiveness.

Objectives should be based on site factors, such as workload and vegetation type, in addition to human, equipment and financial resources. They will vary from utility to utility and project to project, depending on line voltage and criticality, as well as topographical, environmental, fiscal and political considerations. However, where it is appropriate, the overriding focus should be on environmentally-sound, cost effective control of species that potentially conflict with the electric facility, while promoting compatible, early successional, sustainable plant communities.

Work Load Evaluations
Work-load evaluations are inventories of vegetation that could have a bearing on management objectives. Work load assessments can capture a variety of vegetation characteristics, such as location, height, species, size and condition, hazard status, density and clearance from conductors. Assessments should be conducted considering voltage, conductor sag from ambient temperatures and loading, and the potential influence of wind on line sway.

Evaluate and Select Control Methods

Control methods are the process through which managers achieve objectives. The most suitable control method best achieves management objectives at a particular site. Many cases call for a combination of methods. Managers have a variety of controls from which to choose, including manual, mechanical, herbicide and tree growth regulators, biological, and cultural options.

Manual Control Methods

Manual methods employ workers with hand-carried tools, including chainsaws, handsaws, pruning shears and other devices to control incompatible vegetation. The advantage of manual techniques is that they are selective and can be used where others may not be. On the other hand, manual techniques can be inefficient and expensive compared to other methods.

Mechanical Control Methods

Mechanical controls are done with machines. They are efficient and cost effective, particularly for clearing dense vegetation during initial establishment, or reclaiming neglected or overgrown right of way. On the other hand, mechanical control methods can be non-selective and disturb sensitive sites.

Tree Growth Regulator and Herbicide Control Methods

Tree growth regulators and herbicides can be effective for vegetation management. Tree growth regulators (TGRs) are designed to reduce growth rates by interfering with natural plant processes. TGRs can be helpful where removals are prohibited or impractical by reducing the growth rates of some fast-growing species.

Herbicides control plants by interfering with specific botanical biochemical pathways. Herbicide use can control individual plants that are prone to re-sprout or sucker after removal. When trees that re-sprout or sucker are removed without herbicide treatment, dense thickets develop, impeding access, swelling workloads, increasing costs, blocking lines-of-site, and deteriorating wildlife habitat. Treating suckering plants allows early successional, compatible species to dominate the right-of-way and out-compete incompatible species, ultimately reducing work.

Cultural Control Methods

Cultural methods modify habitat to discourage incompatible vegetation and establish and manage desirable, early successional plant communities. Cultural methods take advantage of seed banks of native, compatible species lying dormant on site. In the long run, cultural control is the most desirable method where it is applicable.

A cultural control known as cover-type conversion provides a competitive advantage to short-growing, early successional plants, allowing them to thrive and eventually out-compete unwanted tree species for sunlight, essential elements and water. The early successional plant community is relatively stable, tree-resistant and reduces the amount of work, including herbicide application, with each successive treatment.

Wire-Border Zone

The wire-border zone technique is a management philosophy that can be applied through cultural control. W.C. Bramble and W.R. Byrnes developed it in the mid-1980s out of research begun in 1952 on a transmission right-of-way in the Pennsylvania State Game Lands 33 Research and Demonstration project (Yahner and Hutnik (2004).

The wire zone is the section of a utility transmission right-of-way directly under the wires and extending outward about 10 feet on each side. The wire zone is managed to promote a low-growing plant community dominated by grasses, herbs and small shrubs (under 3 feet in height at maturity). The border zone is the remainder of the right-of-way. It is managed to establish small trees and tall shrubs (under 25 feet in height at maturity). When properly managed, diverse, tree-resistant plant communities develop in wire and border zones. The communities not only protect the electric facility and reduce long-term maintenance, but also enhance wildlife habitat, forest ecology and aesthetic values.

Although the wire-border zone is a best practice in many instances, it is not necessarily universally suitable. For example, standard wire-border zone prescriptions may be unnecessary where lines are high off the ground, such as across low valleys or canyons, so the technique can be modified without sacrificing reliability.

One way to accommodate variances in topography is to establish different regions based on wire height. For example, over canyon bottoms or other areas where conductors are 100 feet or more above the ground, only a few trees are likely to be tall enough to conflict with the lines. In those cases, trees that potentially interfere with the transmission lines can be removed selectively on a case-by-case basis.

In areas where the wire is lower, perhaps between 50-100 feet from the ground, a border zone community can be developed throughout the right-of-way. Note that in many cases, conductor attachment points are more than 50 feet off the ground, so a border zone community can be cultivated near structures. Where the line is less than 50 feet off the ground, managers could apply a full wire-border zone prescription.

An environmental advantage of this type of modification is stream protection. Streams often course through the valleys and canyons where lines are likely to be elevated. Leaving timber or border zone communities in canyon bottoms helps shelter this valuable habitat, enabling managers to achieve environmentally sensitive objectives.

Implement IVM

All laws and regulations governing IVM practices and specifications written by qualified vegetation managers must be followed. Integrated vegetation management control methods should be implemented on regular work schedules, which are based on established objectives and completed assessments. Work should progress systematically, using control measures determined to be best for varying conditions at specific locations along a right-of-way. Some considerations used in developing schedules include the importance and type of line, vegetation clearances, work loads, growth rate of predominant vegetation, geography, accessibility, and in some cases, time lapsed since the last scheduled work.

Clearances Following Work
Clearances following work should be sufficient to meet management objectives, including preventing trees from entering the Minimum Vegetation Clearance Distance, electric safety risks, service-reliability threats and cost.

Monitor Treatment and Quality Assurance
An effective program includes documented processes to evaluate results. Evaluations can involve quality assurance while work is underway and after it is completed. Monitoring for quality assurance should begin early to correct any possible miscommunication or misunderstanding on the part of crewmembers. Early and consistent observation and evaluation also provides an opportunity to modify the plan, if need be, in time for a successful outcome.

Utility vegetation management programs should have systems and procedures in place for documenting and verifying that vegetation management work was completed to specifications. Post-control reviews can be comprehensive or based on a statistically representative sample. This final review points back to the first step and the planning process begins again.

Summary of A-300 example
Integrated Vegetation Management offers among others, a systematic way of planning and implementing a vegetation management program as presented in ANSI A300 Part 7. This methodology enables a program to comply with the NERC *Transmission Vegetation Management Program* standard (FAC-003-2). Managers should select control options to best promote management objectives.

Vegetation Inspections
As with the ANSI A-300 example, The Transmission Owner's transmission vegetation management program (TVMP) establishes the frequency of vegetation inspections based upon many factors. Such local and environmental factors may include anticipated growth rates of the local vegetation, length of the growing season for the geographical area, limited Active Transmission Rights of Way width, rainfall amounts, etc.

Annual Work Plan
Requirement R7 of the Standard addresses the execution of the annual work plan. A comprehensive approach that exercises the full extent of legal rights is superior to incremental management in the long term because it reduces overall encroachments, and it ensures that future planned work and future planned inspection cycles are sufficient at all locations on the Active Transmission Line Right of Way. Removal is superior to pruning. Removal minimizes the possibility of conflicts between energized conductors and vegetation. Since this is not always possible, the Transmission Owner's approach should be to use its prescribed vegetation maintenance methods to work towards or achieve the maximum use of the Active Transmission Line Right of Way.

Requirement R4

R4. *Each Transmission Owner shall notify the responsible control center when it has verified knowledge of a vegetation imminent threat condition. A vegetation imminent threat condition is one which is likely to cause a Sustained Outage at any moment.*

The term "imminent threat" refers to a vegetation condition which is likely to cause a Sustained Outage at any moment. An imminent threat requires immediate action by the Transmission Owner to prevent the occurrence of a Sustained Outage.

Rationale
To ensure rapid notification of the correct personnel when an occurrence of a critical situation is observed. Verified knowledge includes observations by journeyman lineman, utility arborist, or other qualified personnel, or a report verified by these personnel.

M4. *Each Transmission Owner that has experienced a verified vegetation imminent threat will have evidence that it notified the responsible control center.*

R4 is a risk-based requirement type. It focuses upon preventative actions to be taken by the Transmission Owner for the mitigation of Sustained Outage risk when a vegetation imminent threat is verified. R4 involves the expeditious notification to the responsible control center of potentially threatening vegetation conditions to transmission lines.

The term "verified knowledge" implies reliable confirmation that an imminent threat actually exists due to vegetation. Verification could be that the initial call-in came from a trained employee able to identify such a threat or it could be verified by sending out such a trained person to confirm a call-in from a citizen or an untrained employee.

Vegetation-related conditions that warrant a response include vegetation that is near or encroaching into the MVCD (a grow-in issue) or vegetation that presents an imminent danger of falling into the transmission conductor (a fall-in issue). A knowledgeable verification of the risk would include an assessment of the possible sag or movement of the conductor operating between no-load and its rating.

The term "responsible control center" refers to personnel with direct responsibility for operating the transmission lines, such as the Transmission Owner's local control center, Transmission Operator, Independent System Operator, or other operating entity. In the case where the responsible control center is not the Transmission Operator, the communication between the responsible control center and the Transmission Operator will occur by the normal policies that govern their relationship.

The Transmission Owner has the responsibility to ensure the proper communication between field personnel and the responsible control center to allow the responsible control center to take the appropriate action until the threat is relieved. Appropriate actions may include a temporary reduction in the line loading, switching the line out of service or positioning the system in recognition of the increasing risk of outage on that circuit.

The imminent threat notification should be communicated in terms of minutes or hours as opposed to a longer time frame for interim corrective action plans (see R5).
All potential grow-in or fall-in vegetation-related conditions are not necessarily considered imminent threats under this Standard. For example, some Transmission Owners may have a danger tree identification program that identifies tree for removal with the potential to fall near the line. These trees are not necessarily considered imminent threats under the Standard unless they pose an immediate fall-in threat.

Requirement R5

R5. *Each Transmission Owner shall take interim corrective action when it is temporarily constrained from performing planned vegetation work, where a transmission line is put at potential risk due to the constraint.*

M5. *Each Transmission Owner has evidence of the interim corrective action taken for each temporary constraint where a transmission line was put at potential risk. Examples of acceptable forms of evidence may include work orders, invoices, or inspection records.*

Rationale
Legal actions and other events may occur which result in constraints that prevent the Transmission Owner from performing planned vegetation maintenance work. When this event occurs and the work is essential to avoid risk to the transmission line the Transmission Owner must establish and act on a plan to prevent an imminent threat. This is not intended to address situations where a planned work methodology cannot be performed but an alternate work methodology can be used.

R5 is a risk-based requirement type. It focuses upon preventative actions to be taken by the Transmission Owner for the mitigation of Sustained Outage risk when temporarily constrained from performing vegetation maintenance. The intent of this requirement is to deal with situations that prevent the Transmission Owner from performing planned vegetation management work and, as a result, have the potential to put the transmission line at risk. Constraints to performing vegetation maintenance work as planned could result from legal injunctions filed by property owners, the discovery of easement stipulations which limit the Transmission Owner's rights, or other circumstances.

This requirement is not intended to address situations where the transmission line is not at immediate risk and the work event can be rescheduled or re-planned using an alternate work methodology. For example, a land owner may prevent the planned use of chemicals on non-threatening, low growth vegetation but agree to the use of mechanical clearing. In this case the Transmission Owner is not under any immediate time constraint for achieving the management objective, can easily reschedule work using an alternate approach, and therefore does not need to take interim corrective action.

However, in situations where transmission line reliability is potentially at risk due to a constraint, the Transmission Owner is required to take an interim corrective action to mitigate the potential risk to the transmission line. A wide range of actions can be taken to address various situations. General considerations include:

- Identifying locations where the Transmission Owner is constrained from performing planned vegetation maintenance work which potentially leaves the transmission line at risk.
- Developing the specific action to mitigate any potential risk associated with not performing the vegetation maintenance work as planned.
- Documenting and tracking the specific action taken for each location.
- In developing the specific action to mitigate the potential risk to the transmission line the Transmission Owner could consider location specific measures such as modifying

the inspection and/or maintenance intervals. Where a legal constraint would not allow any vegetation work, the interim corrective action could include limiting the loading on the transmission line.

- The Transmission Owner should document and track the specific corrective action taken at each location. This location may be indicated as one span, one tree or a combination of spans on one property where the constraint is considered to be temporary.

Requirement R6

R6. *Each Transmission Owner shall perform a Vegetation Inspection of all applicable transmission lines at least once per calendar year*

M6. *Each Transmission Owner has evidence that it conducted Vegetation Inspections at least once per calendar year for applicable transmission lines. Examples of acceptable forms of evidence may include work orders, invoices, or inspection records.*

Rationale
The requirement is for once per calendar year because that seems to be reasonable length of time for a majority of situations. Transmission Owners should consider local and environmental factors that could warrant more frequent inspections that may affect reliability.

R6 is a risk-based requirement type. It focuses upon the preventative action of vegetation inspections to be conducted by the Transmission Owner for the mitigation of Sustained Outage risk. This requirement sets a minimum vegetation inspection frequency of once per calendar year. A once per calendar year frequency is reasonable based upon average growth rates across North America and common utility practice. Transmission Owners should consider local and environmental factors that could warrant more frequent inspections that may affect reliability.

This requirement sets a minimum time period for the Vegetation Inspections. More frequent inspections may be needed to maintain reliability levels, depending upon such factors as anticipated growth rates of the local vegetation, length of the growing season for the geographical area, limited Active Transmission ROW width, and rainfall amounts. Therefore some lines may be designated with a higher frequency of inspections.

The VSL for Requirement R6 has VSL categories ranked by the percentage of the required ROW inspections completed. To calculate the percentage of inspection completion, the Transmission Owner lines may choose units such as: line miles or kilometers, circuit miles or kilometers, pole line miles, ROW miles, etc.

For example, when a Transmission Owner operates 2,000 miles of 230 kV transmission lines this Transmission Owner will be responsible for inspecting all 2,000 miles of 230 kV transmission lines at least once during the calendar year. If one of the included lines was 100 miles long, and if it was not inspected during the year, then the amount inspected would be 1900/2000 = 0.95 or 95%. The "Lower VSL" for R6 would apply in this example.

The standard allows Vegetation Inspections to be performed in conjunction with general line inspections as per the definition.

Requirement R7

R7. *Each Transmission Owner shall execute a flexible annual vegetation work plan to ensure no vegetation encroachments occur within the MVCD.*

M7. *Each Transmission Owner has evidence that it executed a flexible annual vegetation work plan. Examples of acceptable forms of evidence may include work orders, invoices, or inspection records.*

Rationale
This requirement sets the expectation that the work identified in the annual work plan will be completed as planned. A flexible annual vegetation work plan allows for work to be deferred into the following calendar year provided it does not have the potential to become an imminent threat.

This is a risk-based requirement type. R7 focuses upon implementation of the annual vegetation work plan to diminish risk of vegetation encroachments within the MVCD. This requirement sets the expectation that the work identified in the annual vegetation work plan will be completed as planned.

The flexibility to adjust the annual vegetation work plan must always ensure the reliability of the electric Transmission system. Flexibility is meant to address changing conditions of the vegetation on the Active Transmission Line ROW, emergencies, and other significant changing conditions.

This standard requires that the annual vegetation work plan be flexible to allow the Transmission Owner to change priorities during the year as conditions or situations dictate. For example, weather conditions (drought) could make herbicide application ineffective during the plan year. Other conditions may also result in adjustments to the annual vegetation work plan:

- Environmental conditions such as excessive rainfall, infestation, disease, fire, etc.
- Work-management related conditions such as revised work plan priorities, rescheduled work to another time or selection of an alternative vegetation control method.
- Changes in land usage made by a property owner, such as timber clearing.
- Redirection of local resources away from planned maintenance to render assistance due to major storms, i.e., complying with mutual assistance agreements.

The work plan is not intended to be a "span-by-span" detailed description of all work to be performed. It is intended to require the Transmission Owner to annually plan and schedule vegetation work to prevent encroachment into the MVCD.

The Transmission Owner is required to implement the annual vegetation work plan to accomplish the purpose of this standard. This means that maintenance should be performed to the extent of the Transmission Owner's easement, fee simple or other legal right. A comprehensive approach that exercises the full extent of legal rights is superior to incremental management in the long term by reducing overall encroachments. This approach emphasizes the importance of maintaining all locations on the Active Transmission Line ROWs for reliability purposes in lieu of making special exceptions.

Property owners, agencies and other interested parties occasionally request special considerations to leave undesirable vegetation conditions. Historically, such special considerations have led to outages (some of which became Cascading events) and can lead to violations of the standard.

Documentation or other evidence of the work performed typically consists of signed off work orders, signed contracts, printouts from work management systems, spreadsheets of planned versus completed work, timesheets, work inspection reports, or paid invoices. Other evidence may include photographs, work inspection reports and walk-through reports.

When the annual vegetation work plan is adjusted or otherwise not completely implemented as originally planned, the Transmission Owner is encouraged to document the change. The reasons for the deferrals or changes and the expected completion date of postponed work should also be documented.

When developing the annual vegetation work plan the Transmission Owner should allow time for procedural requirements to obtain permits to work on federal, state, provincial, public, tribal lands. In some cases the lead time for obtaining permits may necessitate preparing work plans more than a year prior to work start dates. Transmission Owners may also need to consider those special landowner requirements as documented in easement instruments.

Appendix One: Clearance Distance Derivation by the Gallet Equation

The Gallet Equation is a well-known method of computing the required strike distance for proper insulation coordination, and has the ability to take into account various air gap geometries, as well as non-standard atmospheric conditions. When the Gallet Equation and conservative probabilistic methods are combined, i.e. deterministic design, sparkover probabilities of 10^{-6} or less are achieved. This approach is well known for its conservatism and was used to design the first 500 kV and 765 kV lines in North America [1]. Thus, the deterministic design approach using the Gallet Equation is used for the standard to compute the minimum strike distance between transmission lines and the vegetation that may be present in or along the transmission corridor.

Method Explanation (Gallet Equation)

In 1975 G. Gallet published a benchmark paper that provided a method to compute the critical flashover voltage (CFO) of various air gap geometries [4]. The Gallet Equation uses various "gap factors" to take into account various air gap geometries. Various gap factor values are provided in [1]. If the vegetation in a transmission corridor, e.g. a tree, is assumed electrically to be a large structure then the CFO of such an air gap geometry can be computed for dry or wet conditions using a well established equation proposed by Gallet [1],[2],[4],

$$CFO_A = k_w \cdot k_g \cdot \delta^m \cdot \frac{3400}{1+\frac{8}{D}} \qquad (1)$$

Where:

k_w is defined as the factor that takes into account wet or dry conditions (dry = 1.0 and wet = 0.96) and phase arrangement (multiply by 1.08 for outside phase), e.g. outside phase and wet conditions = (0.96)(1.08) = 1.037

k_g is defined as the gap factor (1.3 for conductor to large structure)

D is the strike distance (m)

CFO_A is the CFO for the relative air density (kV)

δ is defined as the relative air density and is approximately equal to (2) where A is the altitude in km

$$\delta = e^{-\frac{A}{8.6}} \qquad (2)$$

$$m = 1.25G_0\left(G_0 - 0.2\right) \qquad (3)$$

$$G_0 = \frac{CFO_s}{500 \cdot D} \qquad (4)$$

$$CFO_s = k_w \cdot k_g \cdot \frac{3400}{1+\frac{8}{D}} \qquad (5)$$

where CFO_S is the CFO for standard atmospheric conditions (kV). Using (1)-(5), the required CFO_A can be computed using an iterative process.

Once the CFO_A is known, deterministic methods can be used to determine the required clearance distance. If we let the maximum switching overvoltage be equal to the withstand voltage of the air gap (CFO_A - 3σ) then the CFO_A can be written as (6).

$$CFO_A = \frac{V_m}{1-3\left(\frac{\sigma}{CFO_A}\right)} \qquad (6)$$

Where:

V_m is equal to the maximum switching overvoltage, i.e. the value that has a 0.135% chance of being exceeded

σ is the standard deviation of the air gap insulation

CFO_A is the critical flashover voltage of the air gap insulation under non-standard atmospheric conditions

The ratio of σ to the CFO_A given in (6) can be assumed to be 0.05 (5%) [1]. Thus, (6) can be written as (7).

$$CFO_A = \frac{V_m}{0.85} \qquad (7)$$

Substituting (7) into (1) we arrive at (8).

$$V_m = 0.85 \cdot k_w \cdot k_g \cdot \delta^m \cdot \frac{3400}{1+\frac{8}{D}} \qquad (8)$$

Equation 8 relates the maximum transient overvoltage, V_m, to the air gap distance, D. Using (8) to compute the required clearance distance for the specified air gap geometry (conductor to large structure) results in a probability of flashover in the range of 10^{-6}.

Transient Overvoltage

In general, the worst case transient overvoltages occurring on a transmission line are caused by energizing or re-energizing the line with the latter being the extreme case if trapped charge is present. The intent of FAC-003 is to keep a transmission line that is *in service* from becoming de-energized (i.e. tripped out) due to sparkover from the line conductor to nearby vegetation. Thus, the worst case scenarios that are typically analyzed for insulation coordination purposes (e.g. line energization and re-energization) can be ignored. For the purposes of FAC-003-2, the worst case transient overvoltage then becomes the maximum value that can occur with the line energized. Determining a realistic value of transient overvoltage for this situation is difficult because the maximum transient overvoltage factors listed in the literature are based on a switching operation of the line in question. In other words, these maximum overvoltage values (e.g. the values listed in [2], [3] and [5]) are based on the assumption that the subject line is being energized, re-energized or de-energized. These operations, by their very nature, will create the largest transient overvoltages. Typical values of transient overvoltages of in-service lines, as such, are not readily available in the literature because the resulting level of overvoltage is negligible compared with the maximum (e.g. re-energizing a transmission line with trapped charge). A conservative value for the maximum transient overvoltage that can occur anywhere along the length of an in-service ac line is approximately 2.0 p.u.[2]. This value is a conservative estimate of the transient overvoltage that is created at the point of application (e.g. a substation) by switching a capacitor bank without a pre-insertion device (e.g. closing resistors). At voltage levels where capacitor banks are not very common (e.g. 362 kV), the maximum transient overvoltage of an "in-service" ac line are created by fault initiation on adjacent ac lines and shunt reactor bank switching. These transient voltages are usually 1.5 p.u. or less [2]. It is well known that these theoretical transient overvoltages will not be experienced at locations remote from the bus at which they were created; however, in order to be conservative, it will be assumed that all nearby ac lines are subjected to this same level of overvoltage. Thus, a maximum transient overvoltage factor of 2.0 p.u. for 242 kV and below and 1.4 p.u. for ac transmission lines 362 kV and above is used to compute the required clearance distances for vegetation management purposes.

The overvoltage characteristics of dc transmission lines vary somewhat from their ac counterparts. The referenced empirically derived transient overvoltage factor used to calculate the minimum clearance distances from dc transmission lines to vegetation for the purpose of FAC-003-2 will be 1.8 p.u.[3].

Example Calculation

An example calculation is presented below using the proposed method of computing the vegetation clearance distances. It is assumed that the line in question has a maximum operating voltage of 550 kV_{rms} line-to-line. Using a per unit transient overvoltage factor of 1.4, the result is a peak transient voltage of 629 kV_{crest}. It is further assumed that the line in question operates at a maximum altitude of 7000 feet (2.134 km) above sea level.

The required withstand voltage of the air gap must be equal to or greater than 629 kV_{crest}. Since the altitude is above sea level, (1) - (5) have to be iterated on to achieve the desired result. Equation (9) can be used as an initial guess for the clearance distance.

$$D_i = \frac{8}{\dfrac{3400 \cdot k_w \cdot k_g}{\left(\dfrac{V_m}{0.85}\right)} - 1} \qquad (9)$$

For our case here, V_m is equal to 629 kV, k_w = 1.037 and k_g = 1.3. Thus,

$$D_i = \frac{8}{\dfrac{3400 \cdot k_w \cdot k_g}{\left(\dfrac{V_m}{0.85}\right)} - 1} = \frac{8}{\dfrac{3400 \cdot 1.037 \cdot 1.3}{\left(\dfrac{629}{0.85}\right)} - 1} = 1.535m \qquad (10)$$

Using (2)-(5) and (8) the withstand voltage of the air gap is next computed. This value will then be compared to the maximum transient overvoltage.

$$CFO_S = k_w \cdot k_g \cdot \frac{3400}{1+\frac{8}{D}} = 1.037 \cdot 1.3 \cdot \frac{3400}{1+\frac{8}{1.535}} = 737.7kV \quad (11)$$

$$\delta = e^{-\frac{A}{8.6}} = e^{-\frac{2.134}{8.6}} = 0.78 \quad (12)$$

$$G_O = \frac{CFO_S}{500 \cdot D} = \frac{737.7}{(500)\cdot(1.535)} = 0.961 \quad (13)$$

$$m = 1.25 \cdot G_O(G_O - 0.2) = 1.25 \cdot 0.961(0.961 - 0.2) = 0.915 \quad (14)$$

$$V_m = 0.85 \cdot k_w \cdot k_g \cdot \delta^m \cdot \frac{3400}{1+\frac{8}{D}} = (0.85)(1.037)(1.3)(0.78)^{0.915}\left(\frac{3400}{1+\frac{8}{1.535}}\right) = 499.8kV \quad (15)$$

The calculated V_m is less than 629 kV; thus, the clearance distance must be increased. A few iterations using (2)-(5) and (8) are required until the computed $V_m \geq 629$ kV. For this case it was found that D = 1.978 m (6.49 feet) yielded $V_m = 629.3$ kV. Using this clearance distance the following values were computed for the final iteration.

$$CFO_S = k_w \cdot k_g \cdot \frac{3400}{1+\frac{8}{D}} = 1.037 \cdot 1.3 \cdot \frac{3400}{1+\frac{8}{1.978}} = 908.5kV \quad (16)$$

$$\delta = e^{-\frac{A}{8.6}} = e^{-\frac{2.134}{8.6}} = 0.78 \quad (17)$$

$$G_O = \frac{CFO_S}{500 \cdot D} = \frac{908.5}{(500)\cdot(1.978)} = 0.919 \quad (18)$$

$$m = 1.25 \cdot G_O(G_O - 0.2) = 1.25 \cdot 0.919(0.919 - 0.2) = 0.825 \quad (19)$$

$$V_m = 0.85 \cdot k_w \cdot k_g \cdot \delta^m \cdot \frac{3400}{1+\frac{8}{D}} = (0.85)(1.037)(1.3)(0.78)^{0.825}\left(\frac{3400}{1+\frac{8}{1.978}}\right) = 629.3kV \quad (20)$$

Therefore, the minimum vegetation clearance distance for a maximum line to line ac operating voltage of 550 kV at 7000 feet above sea level is 1.978 m (6.49 feet). Table 1 provides calculated distances for various altitudes and maximum system operating ac voltages.

TABLE 1 — Minimum Vegetation Clearance Distances (MVCD)
For Alternating Current Voltages

(AC) Nominal System Voltage (kV)	(AC) Maximum System Voltage (kV)	MVCD feet (meters) Sea level	MVCD feet (meters) 3,000ft (914.4m)	MVCD feet (meters) 4,000ft (1219.2m)	MVCD feet (meters) 5,000ft (1524m)	MVCD feet (meters) 6,000ft (1828.8m)	MVCD feet (meters) 7,000ft (2133.6m)	MVCD feet (meters) 8,000ft (2438.4m)	MVCD feet (meters) 9,000ft (2743.2m)	MVCD feet (meters) 10,000ft (3048m)	MVCD feet (meters) 11,000ft (3352.8m)
765	800	8.06ft (2.46m)	8.89ft (2.71m)	9.17ft (2.80m)	9.45ft (2.88m)	9.73ft (2.97m)	10.01ft (3.05m)	10.29ft (3.14m)	10.57ft (3.22m)	10.85ft (3.31m)	11.13ft (3.39m)
500	550	5.06ft (1.54m)	5.66ft (1.73m)	5.86ft (1.79m)	6.07ft (1.85m)	6.28ft (1.91m)	6.49ft (1.98m)	6.7ft (2.04m)	6.92ft (2.11m)	7.13ft (2.17m)	7.35ft (2.24m)
345	362	3.12ft (0.95m)	3.53ft (1.08m)	3.67ft (1.12m)	3.82ft (1.16m)	3.97ft (1.21m)	4.12ft (1.26m)	4.27ft (1.30m)	4.43ft (1.35m)	4.58ft (1.40m)	4.74ft (1.44m)
230	242	2.97ft (0.91m)	3.36ft (1.02m)	3.49ft (1.06m)	3.63ft (1.11m)	3.78ft (1.15m)	3.92ft (1.19m)	4.07ft (1.24m)	4.22ft (1.29m)	4.37ft (1.33m)	4.53ft (1.38m)
161*	169	2ft (0.61m)	2.28ft (0.69m)	2.38ft (0.73m)	2.48ft (0.76m)	2.58ft (0.79m)	2.69ft (0.82m)	2.8ft (0.85m)	2.91ft (0.89m)	3.03ft (0.92m)	3.14ft (0.96m)
138*	145	1.7ft (0.52m)	1.94ft (0.59m)	2.03ft (0.62m)	2.12ft (0.65m)	2.21ft (0.67m)	2.3ft (0.70m)	2.4ft (0.73m)	2.49ft (0.76m)	2.59ft (0.79m)	2.7ft (0.82m)
115*	121	1.41ft (0.43m)	1.61ft (0.49m)	1.68ft (0.51m)	1.75ft (0.53m)	1.83ft (0.56m)	1.91ft (0.58m)	1.99ft (0.61m)	2.07ft (0.63m)	2.16ft (0.66m)	2.25ft (0.69m)
88*	100	1.15ft (0.35m)	1.32ft (0.40m)	1.38ft (0.42m)	1.44ft (0.44m)	1.5ft (0.46m)	1.57ft (0.48m)	1.64ft (0.50m)	1.71ft (0.52m)	1.78ft (0.54m)	1.86ft (0.57m)
69*	72	0.82ft (0.25m)	0.94ft (0.29m)	0.99ft (0.30m)	1.03ft (0.31m)	1.08ft (0.33m)	1.13ft (0.34m)	1.18ft (0.36m)	1.23ft (0.37m)	1.28ft (0.39m)	1.34ft (0.41m)

*As designated by the Planning Coordinator

TABLE 1 (CONT.) — Minimum Vegetation Clearance Distances (MVCD)
For **Direct Current** Voltages

(DC) Nominal Pole to Ground Voltage (kV)	MVCD feet (meters) sea level	MVCD feet (meters) 3,000ft (914.4m) Alt.	MVCD feet (meters) 4,000ft (1219.2m) Alt.	MVCD feet (meters) 5,000ft (1524m) Alt.	MVCD feet (meters) 6,000ft (1828.8m) Alt.	MVCD feet (meters) 7,000ft (2133.6m) Alt.	MVCD feet (meters) (8,000ft (2438.4m) Alt.	MVCD feet (meters) 9,000ft (2743.2m) Alt.	MVCD feet (meters) 10,000ft (3048m) Alt.	MVCD feet (meters) 11,000ft (3352.8m) Alt.
±750	13.92ft (4.24m)	15.07ft (4.59m)	15.45ft (4.71m)	15.82ft (4.82m)	16.2ft (4.94m)	16.55ft (5.04m)	16.9ft (5.15m)	17.27ft (5.26m)	17.62ft (5.37m)	17.97ft (5.48m)
±600	10.07ft (3.07m)	11.04ft (3.36m)	11.35ft (3.46m)	11.66ft (3.55m)	11.98ft (3.65m)	12.3ft (3.75m)	12.62ft (3.85m)	12.92ft (3.94m)	13.24ft (4.04m)	(13.54ft 4.13m)
±500	7.89ft (2.40m)	8.71ft (2.65m)	8.99ft (2.74m)	9.25ft (2.82m)	9.55ft (2.91m)	9.82ft (2.99m)	10.1ft (3.08m)	10.38ft (3.16m)	10.65ft (3.25m)	10.92ft (3.33m)
±400	4.78ft (1.46m)	5.35ft (1.63m)	5.55ft (1.69m)	5.75ft (1.75m)	5.95ft (1.81m)	6.15ft (1.87m)	6.36ft (1.94m)	6.57ft (2.00m)	6.77ft (2.06m)	6.98ft (2.13m)
±250	3.43ft (1.05m)	4.02ft (1.23m)	4.02ft (1.23m)	4.18ft (1.27m)	4.34ft (1.32m)	4.5ft (1.37m)	4.66ft (1.42m)	4.83ft (1.47m)	5ft (1.52m)	5.17ft (1.58m)

List of Acronyms and Abbreviations

ANSI	American National Standards Institute
IEEE	Institute of Electrical and Electronics Engineers
IVM	Integrated Vegetation Management
NERC	North American Electric Reliability Corporation

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