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Engineering the Multiple Use of the Right of Way

2006 Progress Report

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Engineering the Multiple Use of the Right-of-Way

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Technical Update, November 2006

EPRI Project Manager

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ABSTRACT

Transmission line owners and operators are under increasing pressure to share the use of their rights-of-way with other systems and for other activities. The objective of the "Engineering the Multiple Use of the Right of Way" project is to develop a guide for the design and maintenance of transmission lines so that the systems can operate reliably and activities can be carried out safety on these shared rights-of-way. It is a multi-year project conducted from 2004 to 2007.

The first task of the project started in 2004 was to conduct a survey on the shared use of rights-of-way in order to identify the current range of concerns faced by the utilities. Following that, a workshop was held to provide information on shared use of rights-of-way to the attendees as well as to collect feedbacks from them about their concerns. In addition, a thorough review of literature available in this area was conducted. The effort cumulated into the publication of the first Technical Update for this project in December 2004.

The concept of the guide was developed in 2005. The strategy here is to provide a state-of-the-art Universal Guide (GUIDE) to the utility members for the development of their own internal guide. In August 2005, a proposed outline for the GUIDE was published and circulated for comments. In December 2005, a progress report was published which summarized the current issues and concerns of shared right-of-way uses, identified and prioritized research projects needed to address information gaps, results of investigations in 2005, and two examples of shared-use cases to be included in the final GUIDE.

This progress report summarized the:

- Results of investigations in 2006, and
- Four examples of shared-use cases to be included in the final GUIDE i.e. Wireless Communication Systems on Transmission Line Structures; Electronic, Communication & Navigation Equipment; Agricultural Activities and Railroads. This is in addition to the two examples on Parking Facilities and Pipelines given in the 2005 Progress Report.

The GUIDE will be fully developed in 2007.

Keywords
Right-of-Way Guide
Multiple Uses
ROW Issues
Transmission Lines
Co-existence

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1 BACKGROUND

Transmission line owners and operators are under increasing pressure to share the use of their rights-of-way (ROW) with other systems and for other activities. These systems include pipelines, railroads, cellular phone repeater stations, fiber-optic repeaters, distribution systems, etc. Other activities include agricultural, recreational, residential and commercial uses etc. The effects of the transmission lines on the safety and performance of these systems and on the safety of these activities are of concern to the affected parties. As well, the effects of these systems and activities on the transmission line cannot be ignored.

The objectives of the Engineering Multiple Use of Rights-of-Way project are to:

- Address the safety and reliability of all the users of the right-of-way and the associated systems,
- Develop guidelines to help utility engineers make decisions on whether to allow this cohabitation, and
- Provide guidance on design and maintenance rules for these systems to ensure their safe and reliable operation.

The project investigates issues from a range of perspectives, including the influence of steady-state conditions, transient conditions, fault conditions, installation, and the influence of maintenance operations on both the transmission line and the other systems. Issues such as vegetation management, electromagnetic fields, inspection and assessment are addressed where appropriate.

This project was initiated in 2004. The first task was to conduct a survey on the shared use of rights-of-way with an aim of identifying the current range of concerns faced by the utilities. Following that, a workshop was held to provide information on shared use of rights-of-way to the funding members as well as to collect feedbacks from the utilities about their concerns. The workshop provided a forum for members to share information, to learn from each other's experience, and to guide the project. In addition, a thorough literature survey on publications available in this area was conducted. The effort cumulated into the publication of the first Technical Update under this project in December 2004. The Technical Update entitled "Engineering the Multiple Use of Rights-of-Way: Current Issues and Knowledge" (Product ID 1008743) prioritized issues according to the transmission line owners and operators and identified gaps that required further investigations and research.

The current issues and concerns related to the shared use of rights-of-way were further discussed and prioritized at the Task Force meeting held in March, 2005. These issues and concerns are related to two major categories of shared uses of the right of way: secondary uses for recreation, agriculture or real estate purposes, and co-existence with other utilities such as pipelines, railroads or communication facilities. Identified issues and concerns, research gaps and needs related to shared uses of rights-of-way were summarized and prioritized in the December 2005 Progress Report (Product ID 1010240).

The concept of the guide was developed in 2005 (Appendix A of Technical Update, August 2005, Product ID 1010239). This concept recognizes that utilities are subjected to the same regulations and standards imposed on them and yet adopt different buffers according to their own needs and judgments that could vary significantly from utilities to utilities. Thus, it is impossible and impractical to produce a single ROW guide that is suitable for all electric utilities when dealing with ROW issues. The strategy here is to provide a state-of-the-art Universal Guide (GUIDE) to the utility members for the development of their own internal guide.

The GUIDE will first be written in a universal template format that is suitable for most of the ROW issues. Using this universal template, an individual guide for each ROW issue (or a category of ROW issues) will be developed. At the completion of the project, it is likely that about ten individual guides will be written covering ten categories of ROW issues (Technical Update, August 2005, Product ID 1010239). A member utility can subsequently select and adapt the individual guides for its own use. This is the ultimate objective of the project which is to develop a guide for transmission line owners and operators in the design and maintenance of shared use of rights-of-way.

Using this universal template, two guides were written for two ROW issues in 2005. They were for Parking Facilities and Pipelines. Further improvements to these two 2005 guides and four additional guides for four more ROW issues were completed in 2006. The four new guides were for Wireless Communication Systems on Transmission Line Structures; Electronic, Communication & Navigation Equipment; Agricultural Activities and Railroads.

The GUIDE will be fully developed in 2007.

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ACCOMPLISHMENTS IN 2006

This project "Engineering the Multiple Use of the Right-of-Way" along with three other projects forms Project Set 35C "Overhead Transmission Design for Optimized Life Cycle Costs." The objective of this Project Set is to provide clients with tools to make informed decisions when designing and constructing new transmission lines or when upgrading existing transmission lines. These tools will help clients make cost-effective decisions while maintaining a high level of reliability and a known life expectancy. Tools include research results, techniques, equations, methodologies, guides and software.

The other projects under this Project Set are:

- Compaction of Overhead Lines
- Transmission Line Design Tools
- Vibration Management of Overhead Transmission Lines

An Overhead Transmission Design task force was formed for Project Set 35C in 2005. The purpose of the task force is to review progress and direction of this group of projects and to ensure that each project achieves its objective.

In 2005, two task force meetings were held: March 21 - 22 in Palo Alto, CA and November 3 - 4 in Charlotte, NC. In addition, two Webcasts were held: June 20 and August 22. In 2006, the two task force meetings were held on April 4 & 5 in Dallas, TX and on September 18 & 19 in Atlanta, GA. The two Webcasts were held on July 11 and October 24. Projects were reviewed and discussed, and input was sought at these task force meetings and Webcasts.

Following the outline of the guide document discussed in the next section, the universal template plus two examples of the administrative and technical guides were developed for two ROW issues in 2005. These issues were related to Parking Facilities and Pipelines.

In 2006, more utility practices were collected and improvements were made to the guides prepared in 2005. In addition, four more examples of the administrative and technical guides were developed. They were Wireless Communication Systems on Transmission Line Structures; Electronic, Communication & Navigation Equipment; Agricultural Activities and Railroads. These examples can be found in Appendices A to L.

Outline of Guide Document

The concept of the guide was developed in 2005 (See Appendix A of Technical Update, August 2005, Product ID 1010239). This concept recognizes that utilities are subjected to the same regulations and standards imposed on them and yet adopt different buffers according to their own needs and judgments that could vary significantly from utilities to utilities.

Technical analyses are often used in the development of criteria that govern a right-of-way (ROW) issue, e.g., separation distance between an overhead conductor and a vehicle. Some of these analyses are based on two sets of criteria: "hard" and "soft" criteria. Hard criteria are those imposed by national and/or regional standards, codes, regulations etc. and are considered to be the minimum requirements; while soft criteria are additional requirements determined by the utilities based on operating experience, research reports etc. and are considered as "buffers" for increasing the reliability of the transmission line, improving the safety and minimizing the annoyance for the general public. Because of the buffer, soft criteria produce requirements that are beyond the minimum requirements.

Although most of hard criteria are the same for all the utilities (e.g., the flashover criterion), the soft criteria (e.g., additional allowance for survey error, final sag, grade change, plans in the future such as higher operating temperature and underbuilt facilities) vary from utility to utility. Thus, it is impossible and impractical to produce a single ROW guide that is suitable for all electric utilities when dealing with ROW issues. The strategy here is to provide a state-of-the-art Universal Guide (GUIDE) to the utility members for the development of their own internal guide. The purposes of the GUIDE are:

- For developing each utility's own internal state-of-the-art guidelines on engineering the multiple use of the ROW.
- For comparing with existing internal guidelines to see if anything has been missed.
- For identifying ROW issues.
- For better management of multiple use of ROW (engineering issues only).
- For eliminating the bulk of the work that a utility needs to write its own internal guidelines.

When addressing the ROW issues, both non-technical/less technical professionals (e.g., real property agents, ROW administrators) and technical professionals (e.g., design engineers, technical specialists) are involved. The GUIDE will therefore be written in two parts, one for each type of professionals.

The GUIDE will first be written in a universal template format that is suitable for most of the ROW issues. Using this universal template, an individual guide for each ROW issue (or a category of ROW issues) will be developed. At this stage of the project, it is likely that about ten individual guides will be written covering ten categories of ROW issues (see Technical Update in August 2005, EPRI report 1010239). A member utility can subsequently select and adapt the individual guides for its own use.

The first part of the GUIDE is an administrative component for the non-technical professionals. It provides a relatively easy to follow procedure/guidance on how to deal with requests for different types of ROW usage and issue. The goal of the administrative guide is to adequately address most of the requests by identifying and classifying the request into one of the three categories: a) Approved (minor or no impacts), b) Not Approved, or c) Further Review (complicated cases that require engineering evaluations). A final recommendation is made at the end of the review process.

The second part is a technical component that addresses the "Further Review" category identified in the administrative component. It provides technical details and explains (where applicable) how the rules or criteria in the administrative component are established. If applicable, it identifies evaluation methods, mitigation procedures and methods, and risks and concerns of various options. References to technical reports, guides and standards (such as IEEE) are given as needed.

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FUTURE WORK

The development of the GUIDE will continue. Additional individual guides covering different categories of ROW issues will be prepared. Some of the proposed categories are Building, Structures and Fences; Ground Potential Rise. Common Utility Practices providing information on criteria used by various utilities will also be prepared. At the completion of the project, it is likely that about ten individual guides will be written.

The study on pipelines will continue to improve on the guide prepared in 2005. A four volume set on pipeline electromagnetic compatibility, EMC (EL-3106) was published by EPRI in 1983. Significant advances in the field have been made since then. As well, Volume 2 is a handbook using graphical analysis and is over 400 pages long. A study using computer simulations will be carried out to accomplish the following two primary goals:

- Simplify the graphical analysis to make it much simpler for the users, and
- Incorporate advances in modeling, mitigation and standards.

Due to budget limitation, the computer simulations will not be covered under this project. Instead, it will be funded separately under a supplemental project.

Along with the other projects in Project Set 35C, two task force meetings are scheduled, one on March 27 & 28 in Palo Alto, CA and one on September 18 & 19 in Washington, DC. Two Webcasts will be held on May 30 and November 6. Further input from the advisors will be sought at the task force meetings before the final document is published.

The ultimate objective of this project is to develop a GUIDE for transmission line owners and operators in the design and maintenance of shared use of rights-of-way. The GUIDE will be fully developed in 2007. A member utility can subsequently select and adapt the individual guides for its own use.

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CONCLUSION AND RECOMMENDATION

The final GUIDE will consist of two parts, namely the Administrative Guide and the Technical Guide. The administrative guide is for the non-technical professionals. It provides a relatively easy to follow procedure/guidance on how to deal with requests for different types of right-of-way usage and issue. The goal of the administrative component is to adequately address most of the requests by identifying and classifying the request into one of the three categories: a) Approved (minor or no impacts), b) Not Approved, or c) Further Review (complicated cases that require engineering evaluations). A final recommendation is made at the end of the review process.

The technical guide is for technical professionals and addresses the "Further Review" category identified in the administrative component. It provides technical details and explains how the rules or criteria in the administrative component are established. If applicable, it identifies evaluation methods, mitigation procedures and methods, and risks and concerns of various options. References to technical reports, guides and standards are given as needed.

Some examples of utility practices for different right-of-way issues will be included in the GUIDE. These examples on shared use of right-of-way practices will provide valuable reference for a utility in the preparation of its own guide.

This progress report summarized the:

- Results of investigations in 2006, and
- Four examples of shared-use cases to be included in the final GUIDE, namely, Wireless Communication Systems on Transmission Line Structures; Electronic, Communication & Navigation Equipment; Agricultural Activities and, Railroads. This is in addition to the two examples on Parking Facilities and Pipelines given in the 2005 Progress Report.

The GUIDE will be fully developed in 2007.

A

ADMINISTRATIVE GUIDE – WIRELESS COMMUNICATION SYSTEMS ON TRANSMISSION LINE STRUCTURES

Scope

This guide outlines the activities required for evaluating requests for installing wireless communication systems on transmission line structures on rights-of-way (ROW). It outlines the conditions under which the proposal may or may not be approved, and the administrative approval process.

Purpose

- Ensure public safety.
- Ensure safe working conditions for electric utility and third party personnel.
- Ensure a uniform review, evaluation and approval process.
- Ensure power system reliability and safe operation of the transmission circuits.
- Ensure access for transmission maintenance and future expansions and modifications.
- Ensure plant security.
- Ensure uncompromised power transmission capability.
- Ensure compliance with all applicable codes, standards and regulations, laws and ordinances.
- Protect the property rights of the power company.
- Protect the electric utility's ability to construct future works.
- Protect the natural environment, habitat and wildlife.
- Promote positive public image by allowing multiple use of the ROW for compatible public activities.

Policy

Requests for installing wireless communication systems on structures on rights-of-way shall be processed through an established procedure to ensure that all affected groups have the opportunity to review and approve or disapprove the proposal.

The office receiving the inquiry will determine, with appropriate consultation, whether the proposal has a significant impact and follow the administrative procedure in this document, or the proposal is classified by the power company as non-compatible use on the ROW and is therefore rejected without further review.

If the proposal is considered by the power company as having a significant impact, it needs approval on a site-specific basis. Detailed construction drawings are to be submitted to the power company for approval, at least __(lead time)__ in advance of construction. The power company will arrange for Engineering, Legal, Operational and others as appropriate to review the proposal. No work shall proceed until approval has been granted. This procedure ensures that all affected departments have the opportunity to review and approve or disapprove the proposal.

Responsibilities

Here is an example showing the responsible functions which may be assigned in the review and approval process:

- Civil Design - foundations, structural or geotechnical concerns.
- Station Design - impacts to substation.
- Cable Design - impacts to underground works.
- Electrical Design - studies related to induction, grounding, clearance, conductor thermal rating.
- System Planning - anything affecting future plant.
- Environmental Services - environmental compatibility concerns.
- Survey and Photogrammetry - detailed field measurements and mapping.
- Property/Real Estate/Legal Services - land rights, liabilities and legal information, maintaining records and correspondence with applicants.
- Field resources - site-specific information.

Requirements

- Maintain property rights of the power company. The ROW agreement held by the electric utility may not include commercial communication rights, in which case the potential applicant should obtain the necessary property rights for its equipment from the owners. Assure that the property rights of the power company take precedence.
- Compliance with local and national codes (e.g., fire and electrical codes).
- Personal safety.
  - Assure that training is provided to line workers for work in the area of radio frequency (RF) and microwave facilities.

- Assure that training is provided to communications workers for work around transmission line structures.
- Monitor exposure of line workers to RF and microwave. It may be necessary to take antennae out of service for line and structure maintenance work.
- Safe working distance from transmission line conductors.

- All communications installations must be reviewed and approved by the electric utility or its contractor to assure the additional structural and electrical impacts maintain the structural and electrical operational integrity of the transmission facilities.
- Applicant's facilities on the ground must have adequate grounding, appropriate equipotential zones and electrical shielding to assure its personnel are safe in the event of a lightning strike or fault at the structure.
- The power supply to the applicant's facilities must be adequately isolated from the transmission line ground to avoid dangerous and damaging power surges propagating onto the power distribution system (the neutral of the distribution system is of particular concern).
- Only the electric utility's line workers and its approved contractors are allowed to install and maintain the communications facilities on transmission line structures. Installations and modifications to structures must meet the electric utility's requirements.
- Applicant assumes all responsibility and repairs for damage to transmission property resulting from use of the ROW.
- Precautions to be taken when working near the transmission line
  - Maximum height of vehicles, including load and reach, not to exceed ___ ft (e.g., 13.5').
  - No refueling of vehicles or equipment on ROW.
- The applicant is responsible for repair or replacement of its own equipment in the event of damage from an electrical fault and/or structural failure.
- ROW and access roads to be restored to their original condition following any construction, at applicant's expense.
- Plant security and maintenance
  - Access to transmission line structures must be unobstructed at all times.
  - No grade changes to facilitate the disposal of overburden will be allowed.
  - No deterioration of drainage patterns or soil stability.
  - Landscaping, trees, shrubs and plants must not exceed _____ ft (e.g., 10') in height at maturity on ROW.
  - No storage of materials on ROW unless approved by the power company.
  - No temporary or permanent structures larger than _(size and height)_ are allowed on the ROW unless approved by the power company.

- In the event of outages and damage at a communication installation site, the repair and return to service of the line takes precedence over restoration of the communication facility.

- Special construction requirements (such as grounding, bonding and isolation) and safety procedures for installing and maintaining the wireless communication systems must be firmly established within the power company. They must be followed to ensure that these special requirements and procedures are not overlooked and forgotten with time.

Related Guidelines, Standards and Documents

Internal guidelines should be established and used for all installation on power company ROWs. The following is a list of relevant internal guidelines covering topics such as:

- General conditions
  - Contact the power company at least ______ days prior to working on ROW.
  - Power company not responsible for damage to works caused by normal activities.
  - Power company reserves the right to terminate consent.
  - Applicant responsible for all costs for plant alterations/protection.
  - Below ground works designed to withstand heavy loads.
  - "As constructed" drawings required within ____ days.
  - Survey plan of works is required showing relation to ROW boundaries and transmission line structures.
  - Remove or relocate works upon issue of ____ months' written notice from the power company.
  - Works must not be enlarged, moved or added to without the consent of the power company.
  - Metal fences must be grounded according to the power company guidelines.
- Personal safety
  - Where plant is installed on transmission line structures and ROW, assure
    - There is provision for training of power company line crews and contractors crews to deal with the installation.
    - There is provision for training and approved work methods for licensee workers working around transmission line facilities.
    - Adequate grounding, bonding and shielding are provided for the installation and for workers at the site.
    - Rules for access to the installation are clear (i.e. only power company approved climbers or bucket operators are allowed above (____) ft. on any power company facilities.

  - Safe working distance from transmission line conductors (e.g., 20' for 500 kV lines).
  - Maximum height of vehicles, including load and reach, not to exceed _____ ft.
  - Levels of induction in objects near transmission lines.
  - No refueling of vehicles within the ROW.
- Plant security and maintenance
  - Access to be maintained.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - Trees, shrubs and plants not to exceed _____ ft (e.g., 10') in height at maturity.
  - Temporary or permanent structures larger than __(size and height)__ are not allowed on ROW.

Relevant transmission maintenance and construction standards covering topics such as:

- Working clearances from energized conductors.
- Minimum operating line to ground clearances.
- Grounding of fences, buildings and objects on or near transmission facilities.
- Isolation and protection of power supply lines.

National, state and local relevant industry standards and codes covering topics such as:

- National Electric Safety Code.
- Fire and electrical codes.
- Work regulations or electric safety code for working near energized conductors and communications systems.
- International Telecommunication Union – Telecommunication Standardization Sector Recommendation publications.

Other references:

- See Technical Guide for other references.

Administrative Procedure

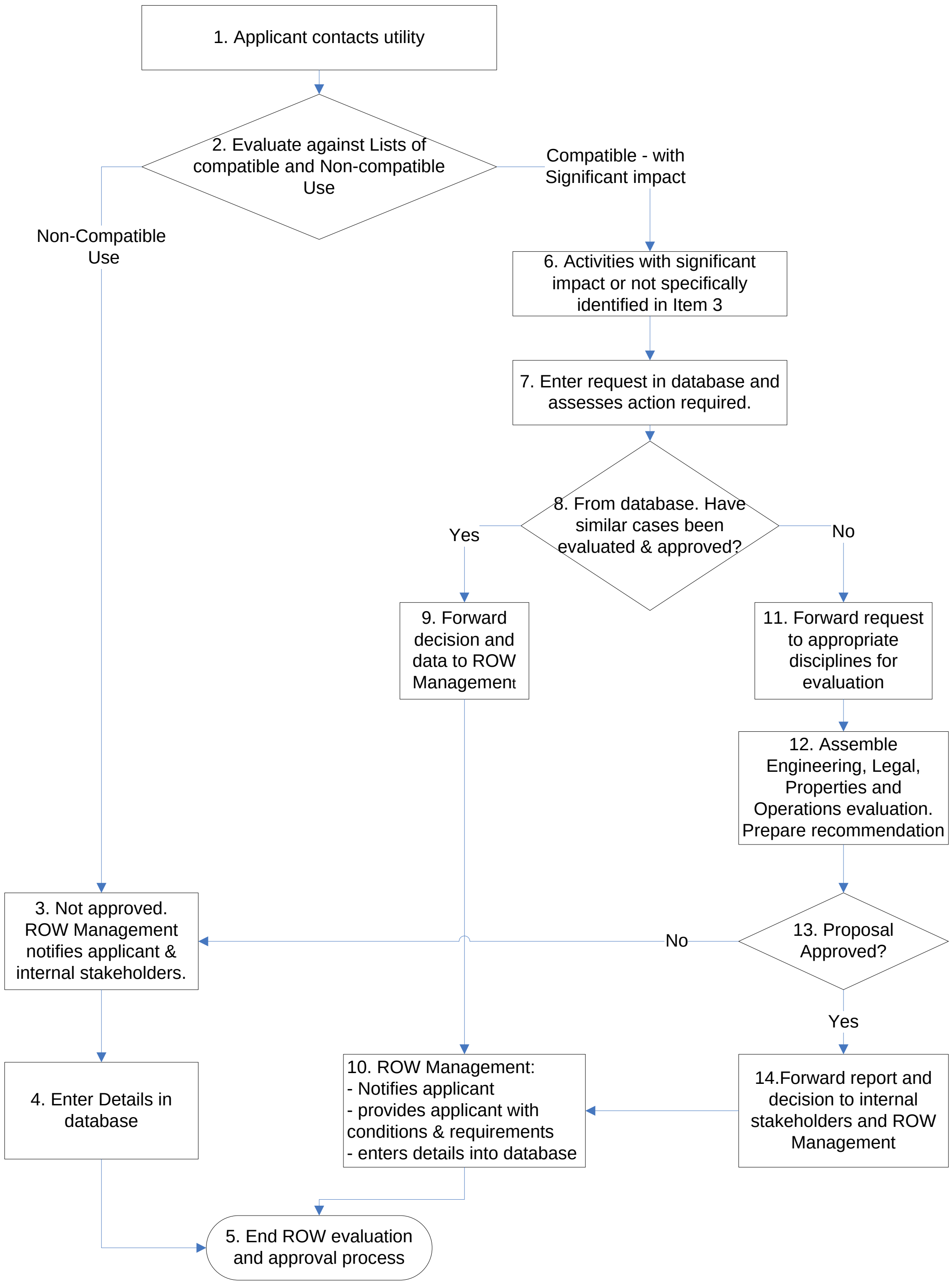
If the proposal is considered by the power company as having a significant impact and not a non-compatible usage, it needs approval on a site-specific basis. The request must be referred to various departments for review and approval. See Flowchart for evaluation and approval process.

- Receive application, enter into log book and data base recording the following minimum information:
  - Property contact.
  - Engineering contact.
  - Type of use.
  - Applicant.
  - Landowner.
  - Location.
  - Transmission circuits.
- Assign request
  - Determine level of complexity.
  - Determine other stakeholders.
  - Determine need for other information from Applicant.
- Determine type of use
  - Access previous similar requests in database.
  - Confirm development on ROW.
  - Confirm civil engineering impact (e.g., foundation, roadwork, soil effects); transmit request to Civil Design.
  - Confirm property impact (e.g., future expansion); transmit request to System Planning.
  - Confirm development on station property, transmit request to Station Design.
  - Confirm significant environmental impact; transmit request to Environmental Services.
- Prepare engineering (technical) evaluation (See Technical Guide for details)
- Assemble responses and engineering evaluation (See Technical Guide for details)
- Prepare engineering report (See Technical Guide for details)
- Review report (See Technical Guide for details)
- File report
  - File hard copies of report, original request, departmental responses, marked location maps, profiles and other related documents.
  - Log completed report into ROW database with a case number.
  - Enter email correspondence, requests and all electronic documents into ROW database.
  - The approved cases can be kept for future reference.

Attachments

- Frequently asked questions.
- Definitions/glossary.
- Terms of reference.

Flowchart for Evaluation and Approval Process for Wireless Communication Systems on Transmission Line Structures



Notes for Flowchart:

1. Applicant contacts utility and seeks approval for using the ROW.

2. The office receiving the request evaluates the type of use and classifies the request into one of two categories:

   a) **Activities that are non-compatible** with multiple use of the ROW are not approved. A utility sets its own criteria and its own list of activities under this category, for example:

      - Anything that is too close to structures or conductors.
      - Storage of flammable, explosive or environmentally unfriendly materials or conditions.
      - Any land use that extinguishes the utility rights.
      - Anything that impacts the utility's flexibility to install future plant.
      - Some utilities may consider the installation of wireless communication systems on transmission line structures as non-compatible use. Not Approved (non-compatible usage).

   b) Further review (significant impact, require technical evaluation).

3. Requests for non-compatible use of the ROW are not approved. Forward case details to the ROW Management Department. Notify applicant.

4. ROW Management enters details into the database for record keeping, future reference and information retrieval (e.g., property contact, type of use, applicant, landowner, location, transmission circuits, final decision.)

5. End of the evaluation and approval process.

6. **Significant impact** refers to those activities that may affect items like the environment, future use, safety, plant security and accessibility. All other activities that do not fall under the non-compatible use or minor/no impact categories belong to this category. Activities belonging to this category require a technical and impact evaluation process.

7. ROW Management enters details of the request details into the database (e.g., property contact, type of use, applicant, landowner, location, transmission circuits), evaluates the request, obtains additional information from the applicant (if necessary), determines who are the stakeholders, evaluates the level of complexity, and assigns the request for Engineering evaluation and other disciplines as required.

8. Engineering determines if similar cases exist in the database and if the decision made in a former case are applicable today. Please note that a decision made previously may not be valid today due to possible changes in the evaluation criteria and/or company policies.

9. If the decision made in a former case is applicable today, no further technical evaluation is required. Forward the decision from a former case to ROW Management.

10. ROW Management notifies the applicant of its decision and enters details into the database for record keeping, future reference and information retrieval.

11. If no similar cases exist in the database or if the decision made in a former case is not applicable today, Engineering confirms the needs for technical evaluation and prepares a referral package containing details of

the application and background information (e.g., reference to the former cases, correspondence with the applicant). Forward the referral package to the appropriate departments for technical evaluation. See “Responsibilities” Section in the Administrative Guide for an example showing the responsibilities of the departments assigned in the evaluation and approval process.

12. Engineering and other departments prepare technical evaluations (e.g., check operating clearances, electrical parameters, industry work standards, future line criteria, plant protection and internal policies and standards). If estimate is required, refer to Transmission Project/Construction.

13. The responsible department assembles and compiles responses from all departments. Prepare engineering decision report and recommendation using analysis criteria that include standards of acceptance as a minimum. See “Technical Evaluation” Section in the Technical Guide for more details.

14. Forward report to internal stakeholders and ROW Management. File all relevant materials. See “Administrative Procedure” in the Administrative Guide for more details.

B

TECHNICAL GUIDE - WIRELESS COMMUNICATION SYSTEMS ON TRANSMISSION LINE STRUCTURES

Scope

This guide outlines the activities required for evaluating the technical compatibility of requests for installing wireless communication systems on transmission line structures on rights-of-way (ROW). It outlines the conditions under which the proposal may or may not be approved, and the technical evaluation process.

Purpose

- Ensure public safety.
- Ensure safe working conditions for electric utility and third party personnel.
- Ensure a uniform review, evaluation and approval process.
- Ensure power system reliability and safe operation of the transmission circuits.
- Ensure access for transmission maintenance and future expansions and modifications.
- Ensure plant security.
- Ensure uncompromised power transmission capability.
- Ensure compliance with all applicable codes, standards and regulations, laws and ordinances.
- Protect the property rights of the power company.
- Protect the electric utility's ability to construct future works.
- Protect the natural environment, habitat and wildlife.
- Promote positive public image by allowing multiple use of the ROW for compatible public activities.

Policy

Request for installing wireless communication systems on transmission line structures on rights-of-way shall be processed through the procedure established in this document to ensure that all affected groups have the opportunity to review and approve or disapprove the proposal.

Requirements

- Maintain property rights of the power company. The ROW agreement held by the electric utility may not include commercial communication rights, in which case the potential applicant should obtain the necessary property rights for its equipment from the owners. Assure that the property rights of the power company always take precedence.
- Compliance with local and national codes (e.g., fire and electrical codes).
- Personal safety
  - Assure that training is provided to line workers for work in the area of radio frequency (RF) and microwave facilities.
  - Assure that training is provided to communications workers for work around transmission line structures.
  - Monitor exposure of line workers to RF and microwave (See Technical Background Section). It may be necessary to take antennae out of service for line and structure maintenance work.
  - Safe working distance from transmission line conductors (e.g., 20' for 500 kV lines).
- All communications installations are to be reviewed and approved by the electric utility or its contractor to assure the additional structural and electrical impacts maintain the structural and electrical operational integrity of the transmission facilities.
- Applicant's facilities on the ground must have adequate grounding, appropriate equipotential zones and electrical shielding to assure its personnel are safe in the event of a lightning strike or fault at the structure (Section 12.6.3, Red Book; ITU-T Recommendation K.57).
- The power supply to the applicant's facilities must be adequately isolated from the transmission line ground to avoid dangerous and damaging power surges propagating onto the power distribution system (the neutral of the distribution system is of particular concern).
- Only the electric utility's line workers and its approved contractors are allowed to install and maintain the communications facilities on transmission structures. Installations and modifications to structures must meet the electric utility's requirements.
- Applicant assumes all responsibility and repairs for damage to transmission property resulting from use of the ROW.
- Precautions to be taken when working near the transmission line
  - Maximum height of vehicles, including load and reach, not to exceed ___ ft (e.g., 13.5').
  - No refueling of vehicles or equipment on ROW.
- The applicant is responsible for repair or replacement of its own equipment in the event of damage from an electrical fault and/or structural failure.
- ROW and access roads to be restored to their original condition following any construction, at applicant's expense.
- Plant security and maintenance

- Access to transmission structures must be unobstructed at all times.
- No grade changes to facilitate the disposal of overburden will be allowed.
- No deterioration of drainage patterns or soil stability.
- Landscaping, trees, shrubs and plants must not exceed _____ ft (e.g., 10') in height at maturity on ROW.
- No storage of materials on ROW unless approved by the power company.
- No temporary or permanent structures larger than _(size and height)_ are allowed on the ROW unless approved by the power company.
- In the event of outages and damage at a communication installation site, the repair and return to service of the line takes precedence over restoration of the communication facility.

- Special construction requirements (such as grounding, bonding and isolation) and safety procedures for installing and maintaining the wireless communication systems must be firmly established within the power company. They must be followed to ensure that these special requirements and procedures are not overlooked and forgotten with time.

Common Utility Practices

- No utility practices were made available at the time of preparation of this document.
- Some utilities may consider the installation of wireless communication systems on transmission structures as non-compatible use on the ROW and is therefore rejected without further review.

Technical Background

Introduction (Section 12.6.1, Red Book)

In recent years, communications antennas have been installed on high-voltage transmission-line towers, such as those shown in Figure WCS-1. Because of this, several issues have been raised. The first is whether the transmission line or its supporting towers has any influence on the performance of the antenna. The second is whether there are any special problems related to the low-voltage source used to supply power to the communications equipment. Finally, transmission-line workers (and the public) are exposed not only to the expected 50/60-Hz electric and magnetic fields, but also to radio frequency (RF) electromagnetic fields from the antennas. As a result, concern about how to properly evaluate worker (and public) safety in the combination of extremely-low-frequency (ELF) and RF electromagnetic fields has been raised.

Figure WCS-1
A typical installation of communication antennas on a transmission-line tower
(Figure 12.6-1, Red Book)

Influence of the Power Line on the Antenna (Section 12.6.2, Red Book)

Questions have been raised about whether transmission-line towers might influence the radiation pattern of the antennas and/or whether high-power-frequency electric fields might cause corona at the tips of communication antennas. Neither has been reported to be a major problem. The main beams of directional antennas (e.g., panel antennas), such as typically used for cellular telephone installations, are normally directed away from the tower and hence are only minimally influenced by the tower. Non-directional antennas mounted on the tower may experience modified patterns in the direction through the tower, but this appears to be a problem that the antenna's operator can accept. Finally, while corona could possibly occur on the sharp tips of RF antennas, no reports of either corona-related material degradation or electromagnetic interference with reception have been given.

Issues Relating to Grounding and Low-Voltage Feeds (Section 12.6.3, Red Book)

When a communications antenna is installed on a high-voltage transmission-line tower, a cable (usually coaxial) is mounted on the tower to carry the RF signals from the communications hut on the ground to the antenna. The "grounding" of this cable is of concern to electric utilities since fault currents can have a significant effect on the potential of different parts of the "ground" with respect to "remote earth." Since grounding practices appear to vary among utilities, a typical practice will be outlined here. First, in this typical practice, the cable shield is bonded to the tower as close to the antenna location as possible using a commercially available grounding kit. In addition, the cable shield is connected to ground at the point near the earth just before it enters the communications hut. Here, it is connected to a small ground plate that is, in turn, connected to a large-diameter wire (typically 00 or 0000 wire) that surrounds the hut and is buried approximately 0.6 m (2 ft) in the ground. This wire is usually connected to between two and four ground rods that are typically 2.4 m (8 ft) in length and driven into the earth. The wire then runs underground from the hut to the transmission tower and is typically bonded to each of the four tower legs.

Because the wire is usually made of copper, and towers are usually made of galvanized steel, there is concern about galvanic action at the junction between these two metals. For this reason, an anticorrosion cell may be required.

Another issue that should be considered is the fact that power is provided to the communications hut from the low-voltage electric distribution system. If the transmission and distribution system grounds are connected together, ground potential rise (possibly thousands of volts), due to fault currents on the transmission line, may be carried to the distribution system via its "ground" and, hence, adversely affect any device connected to the distribution system. Although designs for isolation transformers to eliminate this problem have been developed by the Bonneville Power Administration, none are known to be commercially available at this time. Thus, in most systems known to the authors at this time, the transmission and distribution grounds are simply connected. The safety issue raised as a result of this connection needs to be investigated.

Finally, because of concerns about the effect of ground potential rise (GPR) on their equipment, telephone companies generally do not install copper telephone wires within the "zone of influence" of a transmission-line tower. The "zone of influence" is defined by them as any point within approximately 150 m (500 ft) of a transmission-line tower. The communications operator is then responsible for installing the last section of the communications line with nonmetallic (usually fiber optic) medium.

Protection measures for radio base stations sited on power line towers are covered extensively in a recommendation by the Telecommunication Standardization Sector of the International Telecommunication Union (ITU-T Recommendation K.57, 2003). This Recommendation specifies measures to be taken with respect to safety and risk of damage to equipment through GPR. It also covers a special lightning protection scheme for this type of installation and different options for feeding power from a distribution network to the telecommunication hut.

Exposure to RF Electromagnetic Fields (Section 12.6.4, Red Book)

Utility employees who must work close to RF antennas will be exposed to RF electromagnetic fields that may exceed government standards for human exposure to these fields (FCC 1997; IEEE 1999; ICNIRP 1998). Since there are now numerous antennas located on electric power transmission-line towers, acceptable RF exposure limits and work practices must be developed for utility employees working near these antennas (EPRI 2002). One of the tools used to evaluate the environment is an instrument called an RF survey meter, which is used to measure RF field levels. An example of one of these meters is shown in Figure WCS-2.

Figure WCS-2
A typical RF survey meter
In this photograph, the probe (upper left) is connected to a preamplifier (center) and then to a readout unit in the operator's hand. The probe elements are contained within a "radome" structure to protect them from physical damage (Figure 12.6-2, Red Book).

It has been noted, however, that erroneous meter indications of the RF electromagnetic field strength occur when RF survey meters are exposed to strong ELF (e.g., 50/60-Hz) electric fields near power transmission lines (Aslan 1985; Mantiply 1988; Mantiply 1995). This phenomenon usually results in significantly higher indications of RF electric field strength than those which actually exist. More specifically, they may indicate that RF fields exceed RF safety standards when, in fact, they do not. Although this situation errs on the safe side, it requires needlessly the RF equipment to be shut down before the workers are permitted to work on the RF equipment.

To consider this issue more carefully, a study of the EMC of RF survey meters and 50/60 Hz electromagnetic fields was carried out by EPRI (EPRI 2003; Olsen and Yamazaki 2004). This work showed that special care must be used in making RF electromagnetic field measurements whenever strong ELF fields are present. More specifically, broadband instruments commonly used to assess RF fields for safety purposes can be substantially interfered with when used in the presence of 50/60-Hz electric fields typical of those found in the electric power industry. While it can take considerable effort to conclusively identify whether an instrument is malfunctioning when used in strong 50/60-Hz fields, the following practical observations can be made by the user to gauge the likelihood of such problems.

If measurements are being made in a known, high-level 50/60-Hz field environment, the observer should be alert to the possibility of artifactual readings and focus more than casual attention on whether the indications on the instrument seem to make sense. In this regard, strong electric fields are potentially more suspect than strong magnetic fields.

The meter readout should be observed as the probe shaft is oriented from horizontal to vertical and back to horizontal while keeping the probe sensor itself at approximately the same location. If the meter reading increases significantly in one orientation or the other, this is an indication that low-frequency interference may be present. The orientation of the probe shaft for the greatest reading will suggest the polarization of the interfering low-frequency field. At ground level under power lines and away from structures, poles, and other objects, the principal electric-field component is usually vertical. Hence, most 50/60-Hz interference is observed when the probe shaft is vertical such that the electric field is aligned with the direction of the shaft.

If the RF meter reading appears to continue to increase in value as the probe is elevated above ground, without decreasing at some height, it can be inferred that low-frequency fields may be interfering with proper measurement of the intended RF field.

If 50/60-Hz electric field interference is suspected, the most accurate measurement will be accomplished by isolating the probe, meter, and cable from the observer by mounting it on a nonconductive stand. Figure WCS-3 illustrates this technique for an older-style probe and meter. The cable should be formed into a small-diameter coil and taped to the side of the meter, while the probe should be positioned at the same height as the meter on the stand. In this fashion, the instrumentation components (i.e., probe, cable, and meter readout) are placed as close as possible to the same low-frequency space potential, which will result in the least amount of pickup. If the meter reading increases noticeably when touching the meter, while it is supported on the nonconductive stand, then this is a definite indication that the probe is responding to low-frequency artifact. Under this condition, RF field readings obtained when directly holding the meter should be considered suspect.

Another type of meter that may be used is an RF exposure monitor. These are compact RF field sensors carried by workers that are designed to warn them if they enter RF electromagnetic fields close to, or in excess of, RF safety standards. Concern has been expressed about whether these sensors are also susceptible to 50/60-Hz electric or magnetic fields. Two studies of these meters indicate that meters designed to be "ELF immune" by coating the inside of their cases with a conducting material work well in electric fields even up to 120 kV/m (Johnson 1999; EPRI 2004). This level of field is higher than that experienced by workers passing by phase conductors as they climb 500-kV transmission-line towers.

Figure WCS-3
Older-style probe, meter, and cable placed on nonconductive support for measurement of medium-frequency RF fields near AM radio station
Placement of the entire measurement system at essentially the same space potential helps reduce the magnitude of low-frequency interference due to induction of common-mode currents on cabling (Figure 12.6-3, Red Book).

Technical Evaluation

See Flowchart for Evaluation and Approval Process in the Administrative Guide.

Solicit inputs on issues and concerns from all impacted departments.

Prepare Engineering Evaluation

- Check operating clearances
  - Check impact on structure.
  - Determine line voltage.
  - Determine location, span, structure numbers.
  - Get design profile / mapping.
  - Get detailed structure drawings
  - Evaluate mechanical (weather) loadings of the proposed installation on the structure and structure members. Design structure reinforcements to maintain structural integrity.
  - Check to assure operating clearances to conductors are not violated.
- Check electrical parameters

- Extensive information on engineering protective arrangements for communications equipment on transmission towers is provided by the International Telecommunication Union – Telecommunication Standardization Sector (ITU-T) Recommendation K.57.
- Assure safety and protection of the equipment by the design of an appropriate grounding, shielding and bonding system:
  - Bond metallic parts of the antenna to the coaxial cable shield and metallic parts of the transmission structure.
  - Connect the coaxial cable to the grounding system of the equipment cabinet.
  - A grounding system for the equipment cabinet which is appropriate for the anticipated fault levels and control of step and touch voltages.
  - Bond the equipment cabinet grounding system to the structure grounding network.
  - Assure any telecommunications link to the installation is either via radio, fiberoptic cable or microwave.
- Protection of the low voltage (LV) connecting line (<1 kV) feeding power to the equipment cabinet. The concerns are induction and exposure of the distribution line to voltage surges due to ground potential rise (GPR) that causes a differential voltage with respect to the remote ground of the distribution neutral.
  - Assure that the distribution feed does not parallel the transmission line within the range where magnetic or electric field induction would impact the distribution line voltage.
  - The LV connecting line from the point of connection to the distribution network to the communications equipment at the tower must be protected (IEC 61643-1, IEC 61643-12 and ITU-T Rec. K.31). This protection scheme would need to be designed for the following typical installations:
    - The LV connecting line supplying the communications base station is protected from GPR initiated surges by a combination of specially insulated cable, isolating transformer and surge protective devices. (ITU-T Rec. K.57, paragraph 5, Power Supply).
    - Distribution transformer located within the zone of ground potential rise (GPR) (see paragraph 5.1.4 of ITU-T Rec. K.57).
    - Distribution transformer located outside the zone of GPR and serving only the radio base station (see paragraph 5.1.5 of ITU-T Rec. K.57).
    - Distribution transformer located in or on the base station equipment hut (see paragraph 5.2 of ITU-T Rec. K.57).
- Plot encroachment on profile.
- Measure conductor to ground clearance.
- Add tolerance.
- Compare to minimum operating clearance.

- Check industry work standards
  - Determine line voltage.
  - Refer to industry/electrical safety regulations for minimum working clearance to transmission conductors.
- Check future line criteria
  - Review electric system plan for future lines on ROW.
  - Contact System Planning for updated information.
- Check plant protection and internal policies and standards
  - Specify structure protection if necessary (e.g., secure fencing of the equipment box).
  - Environmental/social acceptability.
  - Compliance with local and national codes (e.g., fire and electrical codes).
  - Review induction and grounding concern.
- If estimate required – refer to Transmission Project/Construction.

Assemble Responses and Engineering Evaluation

- Assemble responses from all departments and assure all pertinent technical issues are addressed.
- Select applicable general conditions.
- Compile all findings.

Prepare Engineering Report and Recommendations

Analysis criteria shall include standards of acceptance and the following as a minimum:

- Clearance from conductors, structures and related plant.
- Local, national and internal standards.
- Work safety regulations.
- Access for maintenance.
- Provision for future plant.
- Environmental protection.
- Public image.
- Assessment of technical risk issues.
- All relevant information received from others.
- Engineering evaluation of the mechanical and electrical issues identified above.

Review Report

- Review report for accuracy, consistency and coverage.
- Transmit report to Property Services with copies to appropriate internal stakeholders.

Related Guidelines, Standards and Documents

Internal guidelines should be established and used for all installation on power company ROWs. The following is a list of relevant internal guidelines covering topics such as:

- General conditions
  - Contact the power company at least ______ days prior to working on ROW.
  - Power company not responsible for damage to works caused by normal activities.
  - Power company reserves the right to terminate consent.
  - Applicant responsible for all costs for plant alterations/protection.
  - Below ground works designed to withstand heavy loads.
  - "As constructed" drawings required within ____ days.
  - Survey plan of works is required showing relation to ROW boundaries and transmission structures.
  - Remove or relocate works upon issue of ____ months' written notice from the power company.
  - Works must not be enlarged, moved or added to without the consent of the power company.
  - Metal fences must be grounded according to the power company guidelines.
- Personal safety
  - Where plant is installed on transmission line structures and ROW, assure
    - There is provision for training of power company line crews and contractors crews to deal with the installation.
    - There is provision for training and approved work methods for licensee workers working around transmission line facilities.
    - Adequate grounding, bonding and shielding are provided for the installation and for workers at the site.
    - Rules for access to the installation are clear (i.e. only power company approved climbers or bucket operators are allowed above (____) ft. on any power company facilities.
  - Safe working distance from transmission line conductors (e.g., 20’ for 500 kV lines).
  - Maximum height of vehicles, including load and reach, not to exceed _____ ft.

- No refueling of vehicles within the ROW.
- Levels of induction in objects near transmission lines.

- Plant security and maintenance
  - Access to be maintained.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - Trees, shrubs and plants not to exceed _____ ft (e.g., 10') in height at maturity.
  - Temporary or permanent structures larger than __(size and height)__ are not allowed on ROW.

Relevant transmission maintenance and construction standards covering topics such as:

- Working clearances from energized conductors.
- Minimum operating line to ground clearances.
- Grounding of fences, buildings and objects on or near transmission facilities.
- Isolation and protection of power supply lines.

National, state and local relevant industry standards and codes covering topics such as:

- National Electric Safety Code.
- Fire and electrical codes.
- Work regulations or electric safety code for working near energized conductors and communications systems.
- International Telecommunication Union – Telecommunication Standardization Sector Recommendation publications.

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Attachments

- Frequently asked questions.
- Definitions/glossary.
- Terms of reference.

C
ADMINISTRATIVE GUIDE - ELECTRONIC, COMMUNICATION & NAVIGATION EQUIPMENT

Scope

This guide outlines the activities required for evaluating the use of electronic, communication and navigation equipment (other than wireless communication systems on transmission structures) on rights-of-way (ROW) or fee-owned land. It outlines the conditions under which the proposal may or may not be approved, and the administrative approval process.

For wireless communication systems on transmission line structures, refer to administrative guide written for this topic.

Purpose

- Ensure public safety.
- Ensure safe working conditions for electric utility and third party personnel.
- Ensure a uniform review, evaluation and approval process.
- Ensure power system reliability and safe operation of the transmission circuits.
- Ensure access for transmission maintenance and future expansions and modifications.
- Ensure plant security.
- Ensure uncompromised power transmission capability.
- Ensure compliance with all applicable codes, standards and regulations, laws and ordinances.
- Protect the property rights of the power company.
- Protect the electric utility's ability to construct future works.
- Protect the natural environment, habitat and wildlife.
- Promote positive public image by allowing multiple use of the ROW for compatible public activities.

Policy

Requests for using electronic, communication and navigation equipment on rights-of-way or fee owned land shall be processed through a procedure established in this document to ensure that all affected groups have the opportunity to review and approve or disapprove the proposal.

The department receiving the inquiry will determine, with appropriate consultation, whether the proposal has a minor or significant impact and follow the administrative procedure in this document, or the proposal is classified by the power company as non-compatible use on the ROW and is therefore rejected without further review.

Minor impact refer to those items that meet the electric company's standards, guidelines and terms of the ROW agreement and do not need more in-depth review or formal approval. All minor impact uses of the electric company's fee owned land require review by the appropriate department so that appropriate agreements and documentation can be completed.

Here are some examples of non-compatible uses of the ROW:

- Permanent buildings and structures.
- Anything that is too close to structures or conductors.
- Most low voltage electrical wiring.
- Any land use that extinguishes the utility rights.
- Anything that impacts the utility's flexibility to install future plant.

For encroachment that needs approval on a site-specific basis, detailed construction drawings are to be submitted to the power company for approval, at least __(lead time)__ in advance of construction. The power company will arrange for Engineering, Legal, Operational and others as appropriate to review the proposal. No work shall proceed until approval has been granted. This procedure ensures that all affected departments have the opportunity to review and approve or disapprove the proposal.

Responsibilities

Here is an example showing the responsible functions which may be assigned in the review and approval process:

- Civil Design - foundations, structural or geotechnical concerns.
- Station Design - impacts to substation.
- Cable Design - impacts to underground works.
- Electrical Design - studies related to induction, grounding, clearance, conductor thermal rating.
- System Planning - anything affecting future plant.

- Environmental Services - environmental compatibility concerns.
- Survey and Photogrammetry - detailed field measurements and mapping.
- Property/Real Estate/Legal Services - land rights, liabilities and legal information, maintaining records and correspondence with applicants.
- Field resources - site-specific information.

Requirements

- Maintain property rights of the power company.
- Compliance with local and national codes (e.g., fire and electrical codes).
- Personal safety.
- Safe working distance from transmission line conductors (e.g., 20' for 500 kV lines).
- Applicant assumes all responsibility and repairs for damage to transmission property resulting from use of the ROW.
- Maximum height of vehicles, including load and reach, not to exceed _____ ft (e.g., 13.5').
- Uses not permitted in the ROW, for example:
  - Buildings or other permanent structures.
  - Flammable or explosive materials.
  - Fueling of vehicles or equipment.
- Plant security and maintenance
  - Access to transmission structures must be unobstructed at all times; temporary interruptions to the applicant's activities may be necessary.
  - Grade elevation changes not to exceed _____ ft (e.g., 1.5').
  - Ensure the ROW use/encroachment is a minimum of _____ ft (e.g., 30') horizontally from any transmission structure.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - Landscaping, trees, shrubs and plants must not exceed _____ ft (e.g., 10') in height at maturity on the ROW.
  - No storage of materials on ROW unless approved by the power company.
  - No temporary or permanent structures larger than _(size and height)_ are allowed on the ROW unless approved by the power company.

Related Guidelines, Standards and Documents

Internal guidelines should be established and used for all installation on power company ROWs. The following is a list of relevant internal guidelines covering topics such as:

- General conditions
  - Contact the power company at least ______ days prior to working on ROW.
  - Power company not responsible for damage to works caused by normal activities.
  - Power company reserves the right to terminate consent with a clear communication of the time for removal of licensee equipment.
  - Applicant responsible for all costs for plant alterations/protection.
  - Works must not approach within ______ ft of the utility facilities.
  - "As constructed" drawings required within ____ days.
  - Survey plan of works is required showing relation to ROW boundaries.
  - Remove or relocate works upon issue of ____ days' written notice from the power company.
  - Works must not be enlarged, moved or added to without the consent of the power company.
  - Metal fences must be grounded according to the power company guidelines.
- Personal safety
  - Safe working distance from transmission line conductors (e.g., 20' for 500 kV lines).
  - Maximum height of vehicles, including load and reach, not to exceed _____ ft.
  - Levels of induction in objects near transmission lines.
- Plant security and maintenance
  - Access to be maintained.
  - Grade elevation changes not to exceed _____ ft.
  - Encroachment is a minimum of _____ ft horizontally from any transmission structure.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - Trees, shrubs and plants not to exceed _____ ft in height at maturity.
  - Temporary or permanent structures larger than __(size and height)__ are not allowed on ROW.

Relevant transmission maintenance and construction standards covering topics such as:

- Working clearances from energized conductors.
- Minimum operating line to ground clearances.

- Grounding of fences, buildings and objects near transmission lines.

National, state and local relevant industry standards and codes covering topics such as:

- National Electric Safety Code.
- Fire and electrical codes.
- Work regulations or electrical safety code for working near energized conductors.

Other references:

See Technical Guide for other references.

Administrative Procedure

Approval without review can be granted when there are no violations in the requirements. Otherwise, the request must be referred to various departments for review and approval. See Flowchart for evaluation and approval process.

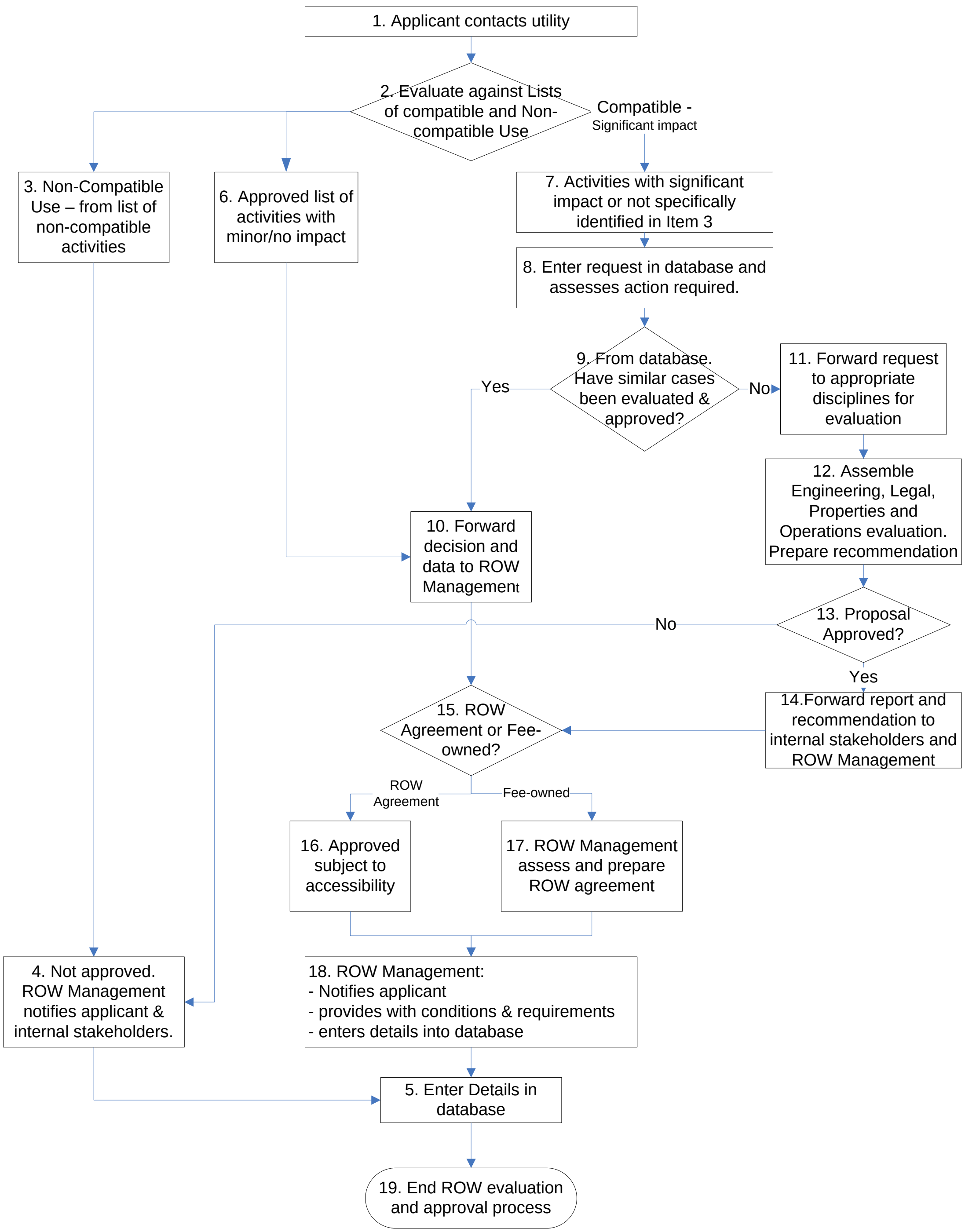
- Receive application, enter into log book and data base recording the following minimum information:
    - Property contact.
    - Engineering contact.
    - Type of use.
    - Applicant.
    - Landowner.
    - Location.
    - Transmission circuits.
- Assign request
    - Determine level of complexity.
    - Determine other stakeholders.
    - Determine need for other information from Applicant.
- Determine type of use
    - Access previous similar requests in database.
    - Confirm development on ROW.
    - Confirm civil engineering impact (e.g., foundation, roadwork, soil effects); transmit request to Civil Design.
    - Confirm property impact (e.g., future expansion); transmit request to System Planning.
    - Confirm development on station property, transmit request to Station Design.

  - Confirm significant environmental impact; transmit request to Environmental Services.
- Prepare engineering (technical) evaluation (See Technical Guide for details)
- Assemble responses and engineering evaluation (See Technical Guide for details)
- Prepare engineering report (See Technical Guide for details)
- Review report (See Technical Guide for details)
- File report
  - File hard copies of report, original request, departmental responses, marked location maps, profiles and other related documents.
  - Log completed report into ROW database with a case number.
  - Enter email correspondence, requests and all electronic documents into ROW database.
  - The approved cases can be kept for future reference.

Attachments

- Frequently asked questions.
- Definitions/glossary.
- Terms of reference.

Flowchart for Evaluation and Approval Process for Electronic, Communication & Navigation Equipment



Notes for Flowchart:

1. Applicant contacts utility and seeks approval for using the ROW.

2. The office receiving the request evaluates the type of use and classifies the request into one of the three categories: a) Not Approved (non-compatible usage), b) Approved (minor or no impact), and c) Further Review (significant impact, require technical evaluation).

3. **Activities that are non-compatible** with multiple use of the ROW are not approved. A utility sets its own criteria and its own list of activities under this category, for example:

   - Permanent buildings and structures.
   - Anything that is too close to structures or conductors.
   - Storage of flammable, explosive or environmentally unfriendly materials or conditions.
   - Installation of most low voltage electrical wiring.
   - Any land use that extinguishes the utility rights.
   - Anything that impacts the utility's flexibility to install future plant.

4. Requests for non-compatible use of the ROW are not approved. Notify applicant.

5. ROW Management enters details into the database for record keeping, future reference and information retrieval (e.g., property contact, type of use, applicant, landowner, location, transmission circuits, and final decision.)

6. **Minor/no impact on non fee-owned property** refers to those activities that meet the utility's standards, guidelines and terms of the ROW agreement and do not require further review. A utility sets its own criteria and its own list of activities under this category, paying attention to concerns such as:

   - Maintain property rights of the power company and the owners.
   - Compliance with local/national fire and electrical code.
   - Personal safety:
   - Plant security and maintenance

   Activities falling under the approved list of activities with minor/no impact on non fee-owned property are approved without technical review provided access to utility facilities is maintained.

   Minor/no impact on fee-owned property refers to those activities that meet the utility's standards, guidelines and terms of the ROW agreement and require only assessment by the ROW Management Department so that the appropriate ROW amendments and documentation are prepared. A utility sets its own criteria and its own list of activities under this category. The approved list of activities or criteria for this category may or may not be the same as those listed for minor/no impact on non fee-owned property. In addition, the administrative procedure requires the involvement of the ROW Management Department in the approval process for requests on fee-owned property.

7. **Significant impact** refers to those activities that may affect items like the environment, future use, safety, plant security and accessibility. All other activities that do not fall under the non-compatible use or minor/no impact categories belong to this category. Activities belonging to this category require a technical evaluation process.

8. ROW Management enters details of the request details into the database (e.g., property contact, type of use, applicant, landowner, location, transmission circuits), evaluates the request, obtains additional information from the applicant (if necessary), determines who are the stakeholders, evaluates the level of complexity, and assigns the request to a technical individual in the Engineering department accordingly.

9. Determine if similar cases exist in the database and if the decision made in a former case applicable today. Please note that a decision made previously may not be valid today due to possible changes in the evaluation criteria and/or company policies.

10. If the decision made in a former case is applicable today, no further technical evaluation is required. Forward the decision from a former case to ROW Management.

11. If no similar cases exist in the database or if the decision made in a former case is not applicable today, Engineering confirms the needs for technical evaluation and prepares a referral package containing details of the application and background information (e.g., reference to the former cases, correspondence with the applicant). Forward the referral package to the appropriate departments for technical evaluation. See "Responsibilities" Section in the Administrative Guide for an example showing the responsibilities of the departments assigned in the evaluation and approval process.

    Engineering and other departments prepare technical evaluations (e.g., check operating clearances, electrical parameters, industry work standards, future line criteria, plant protection and internal policies and standards). If underground, refer to Cables Design. If estimate required, refer to Transmission Project/Construction.

12. Assemble and compile responses from all departments. Prepare engineering decision report and recommendation using analysis criteria that include standards of acceptance as a minimum. See "Technical Evaluation" Section in the Technical Guide for more details.

14. Engineering reviews report for accuracy, consistency and coverage. Forward report to internal stakeholders and ROW Management. File all relevant materials. See "Administrative Procedure" in the Administrative Guide for more details.

15 to 18. ROW Management prepares the appropriate ROW amendments and documentation appropriate to non-fee owned or fee-owned situations, notifies the applicant of its decision and enters details into the database for record keeping, future reference and information retrieval.

Activities falling under the approved list of activities with minor/no impact on fee-owned property are approved by the ROW Management Department without technical review provided access to utility facilities is maintained. Notify applicant.

19. End of the evaluation and approval process.

D
TECHNICAL GUIDE - ELECTRONIC, COMMUNICATION & NAVIGATION EQUIPMENT

Scope

This guide outlines the activities required for evaluating the technical compatibility of using electronic, communication and navigation equipment on rights-of-way (ROW) or fee-owned land. It outlines the conditions under which the proposal may or may not be approved, and the technical evaluation process.

For wireless communication systems on transmission line structures, refer to its own technical guide.

Purpose

- Ensure public safety.
- Ensure safe working conditions for electric utility and third party personnel.
- Ensure a uniform review, evaluation and approval process.
- Ensure power system reliability and safe operation of the transmission circuits.
- Ensure access for transmission maintenance and future expansions and modifications.
- Ensure plant security.
- Ensure uncompromised power transmission capability.
- Ensure compliance with all applicable codes, standards and regulations, laws and ordinances.
- Protect the property rights of the power company.
- Protect the electric utility's ability to construct future works.
- Protect the natural environment, habitat and wildlife.
- Promote positive public image by allowing multiple use of the ROW for compatible public activities.

Policy

Requests for using electronic, communication and navigation equipment on rights-of-way or fee-owned land shall be processed through a procedure established in this document to ensure that all affected groups have the opportunity to review and approve or disapprove the proposal.

Requirements

- Maintain property rights of the power company.
- Compliance with local and national codes (e.g., fire and electrical codes).
- Personal safety.
- Safe working distance from transmission line conductors (e.g., 20' for 500 kV lines).
- Applicant assumes all responsibility and repairs for damage to transmission property resulting from use of the ROW.
- Maximum height of vehicles, including load and reach, not to exceed _____ ft (e.g., 13.5').
- Plant security and maintenance
  - Access to transmission structures must be unobstructed at all times, temporary interruptions to the applicant's activities may be necessary.
  - No grade changes to facilitate the disposal of overburden will be allowed.
  - Grade elevation changes not to exceed _____ ft (e.g., 1.5').
  - Ensure ROW use/encroachment is a minimum of _____ ft (e.g., 30') horizontally from any transmission structure.
  - No deterioration of drainage patterns or soil stability.
  - ROW and access roads to be restored to transmission specifications or to their original condition following any construction, at applicant's expense.
  - No landscaping, trees, shrubs and plants must exceed _____ ft (e.g., 10') in height at maturity on ROW.
  - No refueling of vehicles or equipment on ROW.
  - No storage of materials on ROW unless approved by the power company.
  - No temporary or permanent structures larger than _(size and height)_ are allowed on the ROW unless approved by the power company.

Common Utility Practices

No common utility practices available at the time of writing this guide.

Technical Background

Interference with the Operation of Power Line Communication Systems (Section 12.4, Red Book)

Power Line Carrier (Section 12.4.1, Red Book)

For many years, power line carrier (PLC) systems have used power lines as a communications medium at frequencies between 40 and 490 kHz. Most of these systems have been used for utility applications such as relaying, automatic meter reading, load control, and distribution automation (ANSI/IEEE 1980; Tengdin 1987; Diamanti 1996; Hagmann 1989). The systems are economical (especially in mountainous areas where microwave systems are not easy to construct and operate successfully) and reliable, and can be used over long distances. Generally, however, they operate only at very slow speeds.

The primary compatibility concern about PLC systems is that they must satisfy limits on the amplitude of electromagnetic fields associated with them. In the United States, these regulations are written in Part 15 of the Federal Communications Commission regulations (FCC 1998). More specifically, according to Sections 15.109 and 15.209 of these regulations, the measured electric field strength using a CISPR quasi-peak receiver (ANSI 2001) at 300 m from the power line must not exceed 2400/f µV/m, where f is the operating frequency of the PLC system in kHz. Calculations of the electromagnetic fields associated with PLC can be easily made (Madge and Hatanaka 1992; Sarto 1998).

Over the years, PLC systems have caused interference to the operation of LORAN-C navigation systems that operate at 100 kHz (Arnstein 1986; Last and Bian 1993). This issue has declined in importance recently as the use of LORAN-C has decreased. Another concern has been raised is the potential for interference with receivers using the Nationwide Differential Global Positioning System (NDGPS) network. But this potential has been shown to be small and can be resolved easily by frequency separation if it becomes a problem (Silva and Whitney 2002).

Because PLC systems are often used for communicating information to relays, it is essential that they operate properly at all times. One issue is that the normal background noise from transmission-line corona and switching devices (e.g., FACTS facilities) should not degrade the PLC performance. Although corona has not been reported to cause problems, anecdotal information and measurements suggest that wideband noise from FACTS facilities may interfere with PLC communication (EPRI 2003). During the occurrence of a fault, there may be additional noise generated by the impulsive voltages and currents associated with the fault. Generally the power of the PLC transmitter is set so that communication is maintained during these faults.

High-Speed Communications (Section 12.4.2, Red Book)

More recently, PLC systems (e.g., in-home networks) have been developed that can operate at relatively high speed. For example, low-cost, short-range systems designed around the wireless RF standard 802.11b (i.e., "homeplug" devices), with 12 Mbps (megabits per second) data rates have been offered recently by several suppliers of networking products (O'Neal 1986; Radford 1996). These systems, however, are found only on secondary distribution systems and are limited in their range to distances comparable to the size of a small neighborhood.

In the last few years, the possibility of using power lines for high-speed internet access has been seriously discussed (EPRI 2001; Brown 1996; Sanderson 2000a; Sanderson 2000b; Hansen 2001). Such systems must utilize a broad range of frequencies (i.e., a broad bandwidth), and will be designated here as "broadband power line" (BPL) communication systems. Utilities have expressed interest because they can receive revenue from the sale of services and also have a system that can be used for their own communication needs. BPL systems are an attractive alternative to their wired competition (e.g., digital subscriber lines [DSL] and cable modem) because: (1) little new infrastructure is needed - the wires go nearly everywhere; (2) utilities own the wires and thus control the communication medium; and (3) the regulatory and licensing strictures on PLC are relatively minimal, providing it does not cause interference.

To date, BPL systems have only been used on low- and medium-voltage power lines. Nevertheless, they are discussed in the Red Book because they can, in principle, be used on higher-voltage transmission lines (e.g., in rural areas).

To realize these systems, it will be necessary to operate them over a long distance (i.e., multiple kilometers), and at high speed (i.e., tens of megabits per second). Because of this high data rate, the bandwidth required for these systems extends to tens of megahertz. Such systems have been developed only within the last few years. To be successful, these PLC products must: (1) operate as designed and meet the needs of the intended application; (2) be built, sold, and installed at a price that makes it commercially successful; and (3) satisfy all government regulations on EMC with licensed systems that use the same spectrum.

It is important to note that power lines were not designed to be operated at frequencies in the tens of megahertz range. As a result, they do not necessarily have the desired characteristics at these frequencies. More specifically, unshielded and unbalanced low-and medium-voltage distribution lines are not primarily designed for communication purposes like DSL. Examples of problems with the power system architecture are: capacitors used for power factor correction, transitions from overhead to underground powerlines, multiple taps, and multiple grounds and transformers (EPRI 2001; Tesche et al. 2003; Tesche 1993). Each of these has a purpose and works well at 50/60 Hz, but causes deterioration in system performance (i.e., results in higher attenuation and/or additional radiation due to unbalanced currents) at tens of megahertz. In addition, time-dependent loads, as well as EMI filters that block high-frequency signals, present difficulties for evenly distributing radio frequency (RF) energy on secondary distribution systems and within buildings.

Because of this, the most serious technical challenges to BPL systems have been found to be

- attenuation due to junctions such as taps, connected elements such as transformers, and the lack of matched transmitter/receiver impedances; and
- legal limits on electromagnetic emissions from these unlicensed systems.

Together, the first challenge listed above, which causes the attenuation rate for high-frequency signals to be quite high (Tesche et al. 2003), and the second challenge, which limits the input power, result in possibly unacceptable limits on the range of the system.

Recent experience with BPL systems installed on overhead distribution lines with relatively few (i.e., fewer than roughly one per 100 m) devices such as transformers, capacitors, taps, and underground risers suggests typical attenuation rates on the order of 3 dB/100 m. For the same lines, the maximum distance between repeaters is approximately 600 m for a communication rate of at least 10 Mbps. Note that the communication rate available to any one user may be smaller than this since the transmission system is shared by all of its users. Overhead distribution lines with a larger density of attached devices may exhibit similar attenuation rates and maximum distances between repeaters, but there can be no guarantee of this. Underground distribution lines typically exhibit attenuation rates that are three times as high as those for overhead lines. However, this is often compensated for by the substantially lower noise levels on most underground lines, since they do not tend to pick up radio broadcasts.

Experiments on sub-transmission lines (i.e., 69 kV) have shown that repeaters may be spaced as far as 1200 m or more apart for a communication rate of 10 Mbps. It can be inferred from this result that attenuation rates on higher-voltage lines may be even lower. The reason for this is likely related to the smaller number of attachments, and more uniform dimensions, of higher-voltage lines.

It should be emphasized here that one of the more difficult issues for BPL systems to deal with is the noise that is induced on the system from a variety of unconnected RF sources such as commercial radio stations. This occurs because the overhead power lines act as good receiving antennas for these signals. Such noise can be mitigated by the use of systems that adaptively select spectrum that maximizes the data rate for given interference conditions.

Of greatest concern here is the potential for meeting the legal limits on electromagnetic emissions. These vary from country to country and are much more liberal in the United States than other countries (EPRI 2001; Olsen 2002a). In the United States, the FCC is responsible for governing the emission of electromagnetic fields. According to FCC Part 15 regulations, the measured electric-field strength from a BPL system operating in the range 1.705-30 MHz must not exceed 30 μV/m. The measurements are made using a CISPR quasi-peak receiver (ANSI/IEEE 2001) at 30 m from the power line (EPRI 2001). In addition, since BPL systems are unlicensed, they must not cause harmful interference to authorized users of the spectrum. It is this part of the regulation that may be the most difficult to satisfy since there are numerous users of the spectrum (e.g., amateur radio operators and government users) who are concerned about interference.

In Section 15.3m of the FCC regulations, harmful interference is defined as “any emission, radiation, or induction that endangers the functioning of a radio navigation service or other safety services or seriously degrades, obstructs or repeatedly interrupts a radiocommunications service in accordance with this chapter.” The FCC requires that such devices employ good engineering practices to minimize the risk of harmful interference. If harmful interference does occur, the operator of the incidental radiator must take all necessary steps to correct the interference. In the case of power lines, the operator is not responsible for radio frequency noise generated by devices connected to the electric power system (e.g., motors, welding machines, manufacturing plants, etc).

In the early part of 2004, the FCC issued a notice of proposed rulemaking in which they identified BPL as a new technology that could “play an important role in providing additional competition in the offering of broadband services to the American home and consumers, and in bringing Internet and high speed broadband access to rural and underserved areas (FCC 2004).” In this document, the FCC proposed new rules to mitigate harmful interference and new rules to clarify how measurements to determine compliance with Part 15 regulations should be conducted. It remains to be seen how these new regulations will affect the BPL industry.

Interference with the Operation of Optical Fiber Communications (section 12.5, Red Book)

Introduction (Section 12.5.1, Red Book)

In recent years it has become common for utilities to locate optical-fiber communication systems on their transmission-line towers. The need for internal utility communications (to replace inadequate microwave links) and, for some utilities, the desire for revenue from leased fibers has driven this activity. Of the variety of cable options available (EPRI 1997; Austin et al. 1984), three are most common: the first is optical ground wires (OPGW) in which the fibers are installed in the center of shield wires normally used for lightning protection. The second (WRAP) is an all-dielectric cable that is wrapped around phase conductors on lower-voltage lines or shield wires on higher-voltage lines. The third is all-dielectric self-supporting (ADSS) cable, which is usually attached on a tower below the phase conductors.

This section first compares the advantages and disadvantages of each type. In doing so, several of the criteria that involve electromagnetic compatibility with the power line are noted with a “*”. These topics are discussed in more detail later in the section.

Comparison of OPGW, ADSS, and WRAP (Section 12.5.2, Red Book)

OPGW Advantages

- For new installations with ground wires, OPGW requires only that a different type of ground wire be specified.
- For new installations with ground wires, the additional cost of OPGW is minimal.

- OPGW is less susceptible to vandalism than ADSS.
- Operating experience with OPGW has been good (EPRI 2000).

OPGW Disadvantages

- OPGW is difficult, if not impossible, to install while the transmission line is energized.
- It is usually necessary to request extended outages to install or repair OPGW.
- There have been a number of lightning-related failures.*
- It may not be possible to retrofit OPGW on existing towers without ground wires due to loading limits.
- Ground potential rise is a concern for telecommunications terminal equipment.*
- OPGW is more expensive than ADSS for retrofit installations.
- In some cases, OPGW must be removed near substations due to fault current considerations.*
- OPGW in high lightning areas should be inspected periodically for strand breakage.
- For transmission lines that use segmented shield wires, special optical isolators will be needed at towers where shield wire segments are isolated.

WRAP Advantages

- Material cost of WRAP is smaller than ADSS or OPGW.
- WRAP is relatively easy to install and repair on energized circuits, although permission to work on the fiber while the line is energized is not always easily obtained or available.
- It is not necessary to request extended outages to install or repair WRAP, unless installed on energized conductors.

WRAP Disadvantages

- WRAP is more vulnerable to bird damage and vandalism than OPGW.
- WRAP cables can only be installed on conductors that have surface gradients less than approximately 10 kV/cm. On high-voltage transmission lines, this limits their installation to the shield wires since most high-voltage phase conductors have surface gradients that exceed 10 kV/cm.
- Care must be taken not to damage WRAP sheath during installation or re-sagging of conductors.
- Some utilities have experienced problems with loosening of WRAP cable over time.

ADSS Advantages

- Material cost of ADSS for retrofits or new designs without ground wires is smaller than OPGW.

- Fault and lightning protection is not an issue since ADSS is usually located below phase conductors.
- ADSS is much easier to install and repair on energized circuits.
- It is not necessary to request extended outages to install or repair ADSS.
- Recent operating experience with properly designed ADSS installations has generally been very good (EPRI 2000).

ADSS Disadvantages

- ADSS is susceptible to excessive stretching due to icing (EPRI 1999a).
- ADSS is more vulnerable to vandalism (e.g., gunshots) than OPGW.
- Some ADSS cables have failed in the high-electric-field environment of transmission lines.*
- Although operating experience has been good, it is not clear whether or not the expected life of ADSS will be as long as OPGW (EPRI 1999b).*
- It is not clear to utilities if the ADSS should be considered a dielectric or a conductor for deciding which work practices are appropriate.*
- ADSS cannot be used on spans longer than approximately 1000 m due to limited strength.
- Care must be taken not to damage ADSS sheath during installation.

Experience with WRAP (Section 12.5.3, Red Book)

Operating experience with WRAP installations has generally been mixed. Experience in Europe has generally been reported to be positive. However, in North America, problems that include fiber pinching during re-sagging and loosening of WRAP cable from the conductor around which it is wrapped have caused interest in WRAP to decline. For this reason, the emphasis here will be placed on the OPGW and ADSS options.

OPGW EMC Issues (Section 12.5.4, Red Book)

Considerations for Fault Currents

As for any other ground wire, it is important to evaluate the importance of fault currents. However, the OPGW case is different because the limiting factor is the protection of the temperature-sensitive fibers in the center of the cable. Normally, manufacturers supply OPGW with a specification on the maximum value of i^2t (where i is the rms fault current on the ground wire and t is the time until relay operation) that the cable can withstand without damage to the fibers. The user should determine that this value is not exceeded for any fault on the system. In some cases, it may be necessary to limit installation of OPGW at some distance from a substation since the value of i^2t at points closer to the substation may exceed the manufacturer's limit.

Lightning

Even if the OPGW is sized correctly for the expected fault current, lightning protection may still be an issue. This is a critical issue because it is known that lightning can have a serious effect on OPGW, as shown in Figure ECN-1, and utilities often must guarantee the availability of communication circuits.

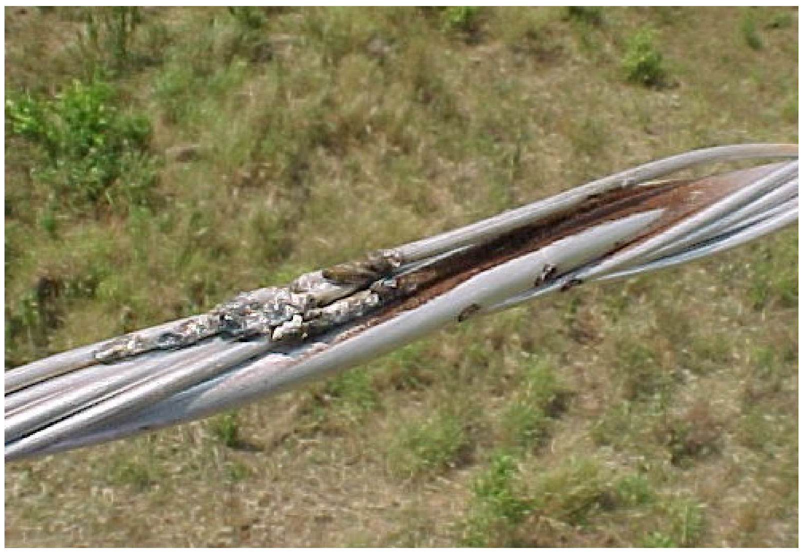


Figure ECN-1
Observed lightning damage to OPGW in Brazil
Note that several strands have been damaged, leading to reduced strength, and the central aluminum buffer tube has been punctured. Photo credit: Silverio Visacro. (Figure 12.5.1, Red Book).

The procedure for ensuring that OPGW will withstand lightning strikes in any given area of the world is not completely understood. Given this, it is appropriate to summarize what is known about lightning failures from research, a detailed analysis of several operating failures, and interviews with utilities and companies that repair failures.

The procedure for selecting an OPGW that will withstand lightning strikes in any given area of the world has some uncertainties. The greatest of these are the local ground flash density N_g, the local fraction of negative-to-positive flashes and the statistical distributions of the total charge (Berger et al. 1975; Eriksson 1987; Section 6.2 of the Red Book). In cases where little is known, Applet G2 (of the Red Book) provides an estimate of ground flash density based on observations of overall lightning transient density, and the ratio of 5% positive to 95% negative flashes can also be assumed. This information may be used to predict the probability of damage to OPGW (Section 6.2.16 of the Red Book).

- OPGW damage and/or failure rates range from 0.02 to 0.08 cases/100 km/year (Yokoya et al. 1994; Zischank and Wiesinger 1997).

- Distribution conductor damage rates tend to match OPGW damage rates, once corrected for the number of flashes to the line (using Equation 6.2-27 of the Red Book).
- Low-amplitude (≅ 400 A), long-duration (≅ 500 ms) continuing currents rather than short impulsive currents cause damage to ground wires. The larger the transferred charge (typically on the order of 100 coulombs or greater), the more destructive the stroke (Bonicel et al. 1995; Nourai 1992; Carter et al. 1984).

Figure ECN-2 illustrates that the short impulsive component of a lightning current (i.e., the IEC Standard 60794 Component "A" impulse) does not transfer enough energy to the OPGW to generate serious damage to the cable strands. In contrast, the lower-amplitude, long-duration current pulses characteristic of lightning "continuing currents" (i.e., the IEC Standard 60794 Component "C") can cause considerable damage, as illustrated in Figure ECN-3 for negative polarity current and in Figure ECN-4 for a positive polarity current.

Figure ECN-2
Effect of 160-kA 30/150 μs IEC Standard 60794 Component "A" impulse on OPGW
$I^2t = 2x10^6 A^2s$. Photo credit: Jody Levine, Kinectrics. (Figure 12.5-2, Red Book).

Figure ECN-3
Effect of negative IEC Standard 60794 Component "C" (500 ms x 400 A = 200 coulomb)
Photo credit: Jody Levine, Kinectrics. (Figure 12.5-3, Red Book).

Figure ECN-4
Effect of positive IEC Standard 60794 Component "C" (670 ms x 418 A = 280 coulomb)
Photo credit: Jody Levine, Kinectrics. (Figure 12.5-4, Red Book).

Perhaps the best guidance that can be developed is from the ground wire or distribution conductor damage rates at locations near the new installation. Generally, if there is a history of conductor damage or the local overhead ground wire life is less than 30 years, extraordinary measures such as large (>3 mm) strands and large overall OPGW diameter may be warranted. In extraordinary cases, one might consider "lightning-resistant OPGW" (Yokoya et al. 1994; Kuboto 1983). However, the most effective scheme is the use of lightweight OPGW in a protected, underbuilt location beneath the phase conductors. In this location, the OPGW cable will also improve the transmission-line backflashover rate by increasing the common-mode electromagnetic coupling of lightning surges to the phase conductors, reducing the insulator voltage by as much as 25%. OPGW position in underbuilt locations relative to phase conductors can be controlled using lightweight, non ceramic insulator spacers similar to interphase spacers used for conductor galloping control.

Safety of Working on OPGW on Energized Circuits

It is not unusual for utilities to conduct splicing operations on OPGW while the transmission line on which it is installed is energized. Given the possibility of faults occurring on the transmission line during this maintenance, there is concern about worker exposure to transferred potentials caused by ground potential rise during the flow of fault current to earth. This problem has been studied by Olsen and Meliopoulis (2002b). Their general conclusion was that grounding mats were needed to provide a safe working environment for this activity.

ADSS EMC Issues (Section 12.5.5, Red Book)

Background

There have been a number of catastrophic failures of ADSS cable around the world, some within a year of installation (EPRI 1996; EPRI 2000; Keller et al. 1997). One example of a failed cable is shown in Figure ECN-5. A few failures have occurred in environments previously thought to be benign (Kaidanov et al. 2000). As a result, some people have suggested a severely restricted lifespan for ADSS cables on high-voltage transmission lines (Carter 1998). Despite this pessimistic prediction, ADSS cables installed in North America have been in use near 345-kV transmission lines for more than 15 years and on 500-kV lines for more than 8 years without incident. It appears that these disparate reports can be reconciled by recognizing that significant advances have been made in the development of ADSS cables with tracking-resistant jackets (Wheeler et al. 1998) and in the procedures used to design ADSS installations. Thus more recent experience with properly designed ADSS cable installations has been significantly better than earlier experience.

At least two reasons for ADSS cable failures are related to the fact that the cable is suspended in a strong electric field. First, metallic hardware is used to attach the cable to a tower that is at ground potential. Electric fields are increased around the grounded hardware, and corona and/or microsparks may occur near hardware tips that are close to the cable sheath. These corona and/or microsparks have been shown to affect the long-term integrity of the cable sheath (Karady et al. 1999). Second, the midspan electrical potential of the cable is approximately that of the space potential at the cable position. At the tower, however, the cable is held at ground potential. Over time, all cables become contaminated and hydrophilic. When these cables are wet from rain or dew, the pollution layer on the cable sheath becomes conducting, and small electric currents can flow. As the cable dries, “dry bands” can form on the pollution that has a voltage across it approximately equal to the midspan space potential. If the pollution resistance is low enough, dry-band arcing can lead to cable sheath damage that may affect the cable sheath’s long-term integrity (Carter 1993; Wheeler et al. 1988; Carter and Waldron 1992).

Figure ECN-5
An ADSS cable that has failed due to dry-band arcing
Note the heavy contamination on the cable and attachment hardware.
Photo credit: Wayne Kincheloe. (Figure 12.5-5, Red Book).

Corona Damage

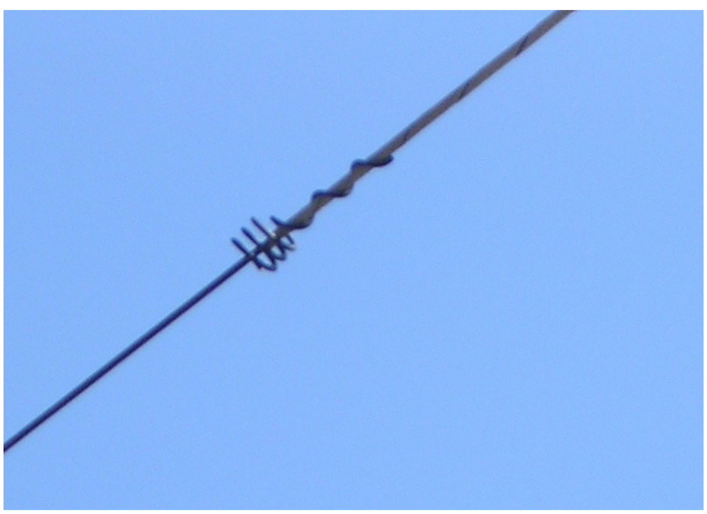


Figure ECN-6
A "Corona Coil"® for suppressing corona on ADSS mounting hardware
Photo credit: R. G. Olsen. (Figure 12.5-6, Red Book).

Three-dimensional electric-field modeling has been used successfully to understand the conditions under which corona can occur and to develop techniques to suppress it (Tuominen 1996). Based on this research, commercial devices such as the one shown in Figure ECN-6 are now available to suppress corona by essentially shielding critical areas (such as tips of armor rods). In most cases it is not necessary to use the full three-dimensional electric-field modeling when designing a new ADSS system. Rather, the two-dimensional space potential, calculated using the cross section of the transmission line at the tower location, can be used to indicate the need for corona-suppressing hardware.

Dry-Band Arcing Damage

Electrical design parameters that are useful for predicting dry-band arcing on ADSS cable in a high-voltage environment have been identified. These include contamination level and hydrophobicity of the ADSS cable, space potential, dry-band voltage, current available to an arc, and arc models (Tuominen and Olsen 2000). Of these, current available to the arc, available dry-band voltage, and contamination/hydrophobicity level appear to be the most useful predictors of performance. In fact, preliminary tests indicate that for a 26-kV dry-band voltage, available arc currents of 1.5 and 5 mA are sufficient to cause damage to nontracking-resistant and tracking-resistant ADSS cable sheaths, respectively (Carter and Waldron 1992; Johnson and Lo 1999; EPRI 1999b). Under normal conditions, these levels cannot be reached unless the resistance per unit length of the cable sheath under wet conditions (a measure of the contamination level) is less than approximately 10^6 Ω/m (i.e., moderate contamination).

Two computer models (shown to be equivalent) have been developed that can be used to predict values of current available to a dry-band arc and available dry-band voltage (EPRI 2000; Olsen 1998; Olsen 1999a; Tuominen and Olsen 2000). As mentioned above, these values are critically dependent upon the (generally unknown) level of contamination. For unknown contamination levels (the normal case), a typical contamination level, such as 10^6 Ω/m, or a range of contamination levels, such as 10^5 Ω/m to 10^7 Ω/m, can be used in the computer models mentioned above to evaluate the possibility of dry-band arcing. More specifically, there will not generally be a problem with dry-band arcing if the current available to a dry-band arc is less than 1 mA and tracking-resistant cable is used.

Simpler Method for Designing ADSS Installations

For those who do not have access to either contamination measurements or computer programs to predict the probability of dry-band arcs, a less precise but generally adequate method can be used (Tuominen and Olsen 2000). A description of this method follows.

ADSS cables are normally placed 3-6 m below phase wires. The determination of the specific location, however, is a much more complicated issue. This is especially true for transmission lines with voltages above 138 kV. As mentioned earlier, one measure of the induced currents and voltages on the cable is the space potential at midspan. It should be noted, however, that the electric field, not the space potential, is the driving force behind both dry-band arcing and corona activity. Nevertheless, space potential is often used as a surrogate because it is the integral of the electric field from the tower to midspan.

For calculation of the space potential, towers are neglected, and it is normally assumed that the transmission line is two dimensional. Here this potential will be designated V_{SP}(2D). Software such as Applet EMF-2 (of the Red Book), can be used for this calculation.

Generally, ADSS cable placements have been successful in environments for which the space potential is less than approximately 12 kV. Above 12 kV (which is more common on transmission lines of 138 kV and above), manufacturers' recommendations differ. At least one is willing to install cables with tracking-resistant sheaths in space potentials of up to 25 kV. For space potentials in this range, dry-band arcing can occur if the contamination is sufficient and a more careful analysis is suggested. With such an analysis, ADSS cable has been successfully installed and operated on transmission lines with voltages of up to 500 kV. While above 25-kV space potential, the use of ADSS cable is not generally recommended, at least one utility has installed ADSS near 45 kV by employing extensive 3D electric-field analysis to design electric-field-reducing hardware.

Longevity of ADSS Cable

Since their introduction, questions about the longevity of ADSS cables have been studied (Alcoa 1995). As mentioned earlier, some have predicted dramatically reduced lifetimes for ADSS cable on high-voltage lines (Carter 1998). Nevertheless, as mentioned above, ADSS cables have been operated successfully in high-voltage environments for more than 15 years. Because the question of how long ADSS cable will last is important to utilities, EPRI conducted accelerated aging tests at its Lenox, MA laboratory using a test that simulates field conditions (EPRI 2000). Their conclusion was that tracking-resistant ADSS cables installed in severe climatic conditions have expected lives greater than 17 years when used in a space potential equal to 25 kV.

Safety of Working on ADSS Cable on Energized Circuits

In a recent survey of utilities, it was found that approximately half consider ADSS to be an insulator for the purpose of assigning work rules, and the other half consider it to be a conductor. In order to resolve this issue, a method has been developed for calculating the contact current through a grounded worker touching the ADSS cable while the power line is energized (Olsen 1999b). The model is valid for cable resistances between 10^5 and 10^7 Ω/m (typical of wet/polluted cables). Very close to the tower, the contact current is $V_{SP}(2D)/Z_0$, and a crude upper limit is $2V_{SP}(2D)/Z_0$. Here V_{SP}(2D) is the two-dimensional space potential near the tower (typically 10s of kilovolts), and Z_0 is the characteristic impedance of the ADSS cable above ground (typically 5–50 MΩ for wet/contaminated cables). More explicit results indicate that for cable resistances less than 10^6 /m, workers within 25 m of structures could be exposed to contact currents in excess of the IEEE standard for contact currents in controlled (occupational) environments: maximum permissible exposure not to exceed 3.0 mA for grasp contacts and 1.5 mA for touch contacts (IEEE 2002a).

Since the above analysis is based on theory, some field tests were done at the Bonneville Power Administration to further study the question of worker safety (Edwards and Olsen 2002). In the limited set of conditions examined in this work, the short-circuit current through a worker touching ungrounded hardware while it was drying after rain could exceed the maximum permissible exposure defined in the IEEE standard (IEEE 2002a). Clearly, more study of worker safety is needed for ungrounded workers on wood poles in contact with grounded and ungrounded hardware in a variety of weather conditions.

Recommended Maintenance

As mentioned earlier, the variable that is both critical and least well known is the contamination level on the ADSS sheath. If there is concern about dry-band arcing, it is recommended that periodic checks of the contamination level be done using the method outlined in Edwards et al. (2003). Such tests at the Bonneville Power Administration have indicated that contamination levels in their territory are not as severe as might have been thought (Edwards et al. 2003). The lowest level measured was 10^7.7 ohm/m at Bandon, Oregon, one mile from the Pacific Ocean, on ADSS exposed to the local climate for about six years (Tuominen 2004).

Alternative Mitigation Techniques

Other mitigation devices have been proposed and tested (Carter 1993). These include insulating the ADSS cable from the tower and the use of a semiconducting rod in parallel with the ADSS cable. The latter technique is the most promising and has been used in the United Kingdom.

Interference with the Operation of Telephone Systems (Section 12.8, Red Book)

Telephone Lines (Section 12.8.1, Red Book)

Over the years, there have been many cases of interference between electric power lines and telephone lines that parallel the power lines. These problems led to an IEEE standard that can be used both to design compatible systems and assist in the diagnosis of these “inductive coordination” problems (IEEE 1992). Although many of the problems have involved distribution lines because there are so many more of these, there have also been issues with transmission lines. For this reason, these problems will be reviewed briefly here. Further, with the improvement in communication technology over the years (e.g., microwave systems and fiber optics), the number of inductive coordination problems has decreased. Nevertheless, inductive coordination remains an issue and does arise from time to time (Jewell et al. 2000).

The mechanisms by which coupling between these systems occurs are essentially identical to those for railroads (Section 12.2.1, Red Book). But, because communications lines are physically different from railroad tracks, some of the details are different. The most important difference is that communications lines are often closely spaced wires that are twisted together. Because of this, there is very little direct induction of a differential-mode current between the two wires (i.e., the mode for which the entire current on one of the wires returns on the other). Rather, essentially all of the induction on the communication wire is common mode for which the return current is through the earth. Interference, however, usually occurs because some of the common-mode current is converted into differential-mode current via unbalances in the system (Section 12.2.7, Red Book).

The Canadian Electrical Association published a comprehensive guide for power and telecommunications engineers to help prevent and solve electrical interference problems between power and telecommunications systems (CEA 1989). It describes the interaction between power and telecommunications systems at fundamental and harmonic frequencies under both normal and fault conditions. For each system, the guide covers the applicable calculations, measurements, and mitigation methods. The guide further discusses the administration of electrical coordination work and suggests a cooperative agreement with provisions for sharing costs.

Cordless Phones (Section 12.8.2, Red Book)

A cordless phone operates like a radio receiver and a mini radio station in one unit. Radio signals are transmitted and received between the base unit and the handset. Both the base unit and the handset can be the transmitter and receiver at any one time. Cordless phones first appeared around 1980 with an operating frequency in the 27 MHz range. Later in the mid 1980s, the 43-50 MHz band was used to improve the sound quality but was still unsatisfactory due to its very limited range between the base station and the handset. These two types of cordless phones are no longer sold in stores, and very few units are probably still being used.

Today, cordless phones sold in stores operate in the 900-MHz and 2.4-GHz (gigahertz) range, with some newer units in the 5.8-GHz range. The useful range is about 0.5 km between the base unit and the handset, with some units reaching as high as 3 km. Modern cordless phones use digital spread spectrum (DSS) technology, which improves sound quality, provides security against eavesdropping and immunity against interference, and increases the usable range of the telephone when compared to older analog technology.

Like any electronic equipment, cordless phones contain electronic components that may be sensitive to radio interference. If the telephone does not have built-in interference protection, its performance may be affected by nearby radio communications or electrical noise. Telephones with more features contain more electronic components and need greater interference protection. A better quality telephone or one that uses a higher frequency is less likely to have interference problems.

Considering the high frequency of operation (900 MHz, 2.4 and 5.8 GHz) and the use of digital technology, it is highly unlikely that transmission-line radio frequency (RF) noise will interfere with the operation of cordless phones in the vicinity of transmission lines. In the unlikely event that an interference complaint occurs, an economical solution to resolve the complaint is to replace the older cordless phone with a newer and better quality unit.

Cell Phones (Section 12.8.3, Red Book)

A cell phone is a mobile phone that sends and receives radio signals to and from low-power transmitters and receivers located within defined service areas called cells. Each cell ranges from a few to tens of kilometers. Each cell site is connected to one or more cellular switching exchanges. As the phone moves out of the service range of one cell and enters the adjacent cell, the signal carrying the conversation is transferred to the transmitter and receiver in the adjacent cell and the connection is switched to the new cell site by the switching exchange. Communication between cell sites and the public switched telephone network can be by optic fibers, microwave radio links, or copper wires connected with telephone exchanges.

The older cell phones use analog technology, whereas the newer units use digital technology, which is suitable for both voice and data communications. The digital technology allows a greater number of users within the available bandwidth and is more immune to interference. Different digital technologies in use include time division multiple access (TDMA), code division multiple access (CDMA), and Global System for Mobile communication (GSM). In North America, the older analog units operate only in the 800-MHz (800- to 900-MHz) band, while the newer digital units operate in both the 800-MHz and 2-GHz bands. Phones operating in the 2-GHz band are sometimes called PCS (Personal Communications Services) phones.

For cell phone systems in the 800-MHz band, the reliable service area of a cell is defined as having a signal strength of 35 dBµV/m at the cell perimeter (Industry Canada 2003). This standard is technology neutral, and supports analog cell systems and digital systems based on different technology platforms (e.g., TDMA, CDMA, GSM) as well as digital packet data (CDPD). For the purpose of protecting stations operating in adjacent service areas from co-channel interference, a base station is not allowed to generate a field strength exceeding 35 dBµV/m outside the operator's service area unless agreed by the affected operator. The 35-dBµV/m field level may be used as a rough guide for cell phone signal level in this frequency band. The channel bandwidth is 30 kHz.

For land mobile and fixed radio services in the 800-MHz band, the geographic separation between co-channel systems (Industry Canada 1999) is calculated based on a nonoverlap of the 40-dBµV/m service contour (i.e., usually calculated based on a probability of service of 50% of the time for 90% of the locations at edge of contour) of the existing station and the 22-dBµV/m interference contour (i.e., calculated using the probability that the signal level used is below the threshold 90% of the time for 90% of the locations) of the proposed station. The difference between the service and interference contours is 18 dB (40-22 dBµV/m), which may be used as a rough guideline for the required signal-to-noise ratio for satisfactory reception of mobile phone signal.

For the purpose of protecting stations operating in adjacent service area from co-channel interference for PCS phone systems in the 2-GHz range, a base station is not allowed to generate a field strength exceeding 47 dBµV/m outside the operator's service area unless agreed by the affected operator. The 47-dBµV/m field level may be used as a rough guide for cell phone signal level in this frequency band.

Many cell antennas are currently operating on top of transmission-line structures. The proper functioning of these cell antennas over the years gives a very good indication that perceptible interference from transmission lines with cell phones is a highly unlikely event. Because of the high operating frequency (above 800 MHz), the use of digital technology in the newer phones, and years of successful operation of cell antennas on transmission-line towers, it is highly unlikely that transmission-line radio noise will interfere with cell phone systems.

It should be noted that specific concerns about the consequences of locating cell phone system base stations on transmission-line towers are considered in Section 12.6 of the Red Book and in a companion ROW guide on wireless communication systems. The interested reader is referred there for further information.

Interference with the Operation of Radio Navigation Systems (Section 12.10, Red Book)

LORAN-C (Section 12.10.1, Red Book)

Long-range navigation systems such as LORAN-C operate in the very-low-frequency (VLF) range near 100 kHz. One of the factors that limits the absolute positional accuracy of the LORAN-C system (i.e., approximately 0.25 nautical miles) is signal-to-noise degradation due to atmospheric noise generated by lightning (U.S. Coast Guard 2002). Since the system was primarily designed to be used for the navigation of ships in U.S. coastal waters, man-made noise sources do not usually add to this atmospheric noise. However, when LORAN-C is used on rivers or channels crossed by high-voltage power lines or on land near high-voltage power lines, radio noise due to corona can degrade its performance.

LORAN-C is also subject to errors caused by electromagnetic scattering of its ground waves by nearby large objects, such as bridges, power lines, and other large structures (e.g., petroleum refineries, steel mills) (U.S. Coast Guard 2002). The distance from the structure where LORAN-C position information becomes unusable varies among structures. In Coast Guard track line surveys, it was noted that some power lines caused noticeable errors, when as much as 500 m distant from the receiver, and distance errors up to 200 m, when directly under the power line (U.S. Coast Guard 1982; Olsen and Aburwein 1982).

Over the years, PLC systems operating near 100 kHz have also caused interference to the operation of LORAN-C navigation systems (Arnstein 1986; Last and Bian 1993). This problem can be mitigated by an appropriate choice of PLC operating frequency.

While all of these problems remain, LORAN-C systems have been generally supplanted by the global positioning system (GPS) and the future of LORAN-C is in doubt. Since GPS operates in the microwave frequency range, it is much less vulnerable to interference from power transmission lines. As a result, there will be no further discussion here of low-frequency navigation systems.

Instrument Landing Systems (Section 12.10.2, Red Book)

The Instrument Landing System (ILS) is a radio navigation system that provides a pilot with accurate guidance for the final approach in landing. It consists of three subsystems: localizer (LOC), glide slope (GS) or glide path, and marker (MKR) beacon. Each system is composed of: transmitters, transmitter antennas, receiver antennas, receivers, and indicators. The approach path is given by the intersection of the localizer beam (for horizontal guidance) and the glide slope beam (for vertical guidance). These beams activate a course deviation indicator in the aircraft that contains a horizontal needle sensitive to deviations from the glide slope and a vertical needle sensitive to deviations from the localizer. By keeping both needles centered, the pilot can guide the aircraft down to the centerline of the runway. False guidance can result from distortion of the radio beam by nearby buildings or mountains. Newer systems using microwave beams overcome most of these limitations. For example, the microwave landing system (MLS) uses frequencies in the 5.030 and 5.150 GHz range.

The localizer operates in a frequency band from 108 to 118 MHz. Within this band, there are 200 channels, each occupying 50 kHz. The carrier is modulated with audio tones of 90, 150, and 1020 Hz. The first two tones are for horizontal guidance, and the difference in tone characteristics results in a deviation on the course deviation indicator. The third tone is for identifying the facility. The minimum ICAO (International Civil Aviation Organization) performance standard requires a signal level of -77 dBm/m^2.

The glide slope or glide path operates in a frequency band from 329 to 335 MHz. Within this band, there are 40 channels, each occupying 150 kHz. Like the localizer, the carrier is modulated with 90 and 150 Hz tones, which are used for vertical guidance. The minimum ICAO performance standard requires a signal level of -65 dBm/m^2.

Marker beacons are installed at several locations along the approach path to inform the pilot of the plane's location along the approach path. These beacons operate near 75 MHz (74.8 to 75.2 MHz). Depending on the location of the marker beacon, the carrier is modulated with a 400-, 1300-, or 3000-Hz tone. The minimum ICAO performance standard requires a signal level of -52 dBm/m^2.

According to a 1985 report, there are two major interference mechanisms affecting ILS receivers: automatic gain-control (AGC) capture and tone-filter capture (CEA 1985). AGC capture occurs when an extraneous signal is detected and causes the AGC to reduce gains in the first mixer and IF (intermediate frequency) stages, and the output level of the desired signal (or tones) is therefore reduced. Tone-filter capture occurs when the envelope of an undesired signal contains spectral components at or near the tone-filter frequencies. The report concluded that the flag deviation currents in the GS and LOC receivers degraded as a function of the average power of the interfering noise, and that both indicators were easier to measure than the AGC voltage. The sharpness of the tone filters in the ILS receivers varies among manufacturers, and receivers with "sloppy" filters degrade much more rapidly than those with sharp ones.

In the Canadian Electrical Association (CEA) project cited above, limited measurements of ILS receiver performance were made in the field near a 500-kV power line and within the perimeter of a distribution substation of a major power company. The antenna used for capturing noise was a pole-mounted, half-wave dipole tuned to 110 MHz, and located ~30 ft from the outside phase of a 500-kV line. The actual noise level, however, was not reported. Additional measurements were made in the laboratory using recorded power-line noise and independent, controllable noise sources. All measurements confirmed the theoretical premises that ILS receiver degradation occurs as a function of the average power level of power-line noise, and that the LOC receiver is the most susceptible element of the three ILS receivers (LOC, GS, and MKR).

The conservative EMI zoning criteria for electrical power systems established by Transport Canada require power lines with voltages greater than 100 kV be located no closer than 1.8 km from the runway centerline and no closer than 3.2 km from the ends of the runway; and AC electrical substations with voltages greater than 100 kV be located no closer than 3.2 km from the runway centerline and no closer than 16 km from the ends of the runway (Transport Canada 2004). Only Stage 1 of a three-stage project was completed by CEA and Transport Canada in 1985. Stage 2 (actual airborne radio noise measurements) and Stage 3 (more realistic EMI zoning criteria for airports under all weather conditions) were never carried out. Consequently, the Canadian utilities must continue to use the conservative EMI zoning criteria for airports, which results in added costs for routing and locating electric power facilities near airports.

There are no recorded incidences of ILS interference from power systems. This is probably because most, if not all, of the utilities are using unrealistically large separation distance between airports and electric power facilities, as dictated by their respective EMI zoning criteria near airports. Given this operating experience, it is highly unlikely that ILS interference from power systems will occur in the future as long as the same separation distances are maintained.

Although there is no recorded airborne radio noise data from power systems, it is possible to do a crude prediction on the likelihood of ILS interference with power systems by making the assumption that airborne radio noise from power systems are similar in characteristics to those measured near ground level, except possibly for a slower attenuation rate with distance from the power system. Using this assumption and the above technical information on ILS, one can estimate the likelihood of ILS interference from a transmission line by using a "postulated" 13-dB signal to noise degradation threshold, with noise measured in a bandwidth of 100 kHz, as given in the 1985 CEA report.

Global Positioning System (Section 12.10.3, Red Book)

Global Positioning System (GPS) is a satellite-based radio navigation system that has many civilian applications for the position, velocity, and time information it can provide (Parkinson and Spilker 1996). At present, 28 GPS satellites are in place (Enge and Misra 1999). Each satellite, at an altitude of about 20,200 km, is moving at about 4 km/s and completes an orbit of the earth in approximately 12 hours. Precise determination of the transit time for a radio wave to travel from a GPS satellite with a known position in space to the user's receiver on earth is the basis for all GPS applications. For 3-D navigation, the GPS receiver requires range information from at least four satellites; the fourth satellite is needed to adjust for receiver clock errors. The position is given as latitude, longitude, and elevation, usually with respect to a reference ellipsoid model of the earth, such as the World Geodetic System (Kremer et al. 1990; Pietraszewski 1990).

Each GPS satellite broadcasts very weak, uniquely identifiable signals, using spread spectrum technology (Parkinson and Spilker 1996). Each satellite transmits its carrier signals on two different radio frequencies in the L-Band of the frequency spectrum: Link 1 (L1) at 1,575.42 MHz, and Link 2 (L2) at 1,227.60 MHz; each has a bandwidth of 20.46 MHz (Parkinson and Spilker 1996).

One issue that is sometimes raised is the potential for degraded performance of GPS receivers when they are used near electric power facilities. Of specific interest is the reception of GPS satellite-based microwave signals under or near power line conductors. At the surface of the earth, the satellite microwave signals are weak, and any reduction of signal intensity due to scattering by conductors or noise due to corona and/or gap discharges could degrade receiver performance or cause loss of signal lock.

The potential effects of EMI from transmission-line corona and/or signal scattering from overhead conductors have been evaluated analytically by Silva and Olsen (2002). More specifically, their analysis shows that scattering is unlikely to lead to significantly reduced signal strength, and that corona and gap noise are small enough at 1200-1500 MHz to be neglected. These conclusions have been supported by a small number of practical measurements made under transmission lines with GPS receivers. It is thus unlikely that power line conductors will interfere with use of the GPS satellite signals.

Differential Global Positioning System (Section 12.10.4, Red Book)

There are a number of error sources for GPS receiver operation, including: satellite clock and orbit errors, ionosphere and troposphere delay, multipath, receiver noise, and errors due to satellite constellation geometry. There are also a number of applications (such as harbor navigation, positive train control, and precision agriculture) that require accuracies of 5-10 m or better (Enge and Misra 1999). Since the accuracy of the GPS system is not sufficient for these applications, the system is being improved with augmentations such as differential GPS (DGPS). With DGPS, corrections are provided to users to improve accuracy by compensating for some of the errors inherent in autonomous GPS use. More specifically, with DGPS, two GPS receivers are used: a reference unit and a mobile or rover unit. The reference receiver is placed at a stationary location with a position previously determined to a high degree of accuracy by surveying. This reference receiver determines its position using GPS signals, and a computer derives the position error and calculates differential corrections that can be applied by the rover to yield a more accurate position. Users with mobile GPS receivers that are equipped to receive and process these corrections in real time can realize significant improvements in accuracy improvements—in some cases, to the 1-3 m range or better (Parkinson and Spilker 1996; Enge and Misra 1999).

The DGPS correction messages can be made available by various methods (including commercial satellites and FM radio), but the focus here is the network of broadcast stations operated in the 283.5-325 kHz band by the United States and many other governments. The reason for this focus is that EMI fields from corona on transmission lines can be quite strong in this frequency range. In fact, anecdotal reports by agricultural users of coastal DGPS stations indicate that power line electromagnetic noise can be a problem for DGPS receivers if it exceeds the background atmospheric noise. Some GPS receiver manuals also mention the potential for noise/interference problems near to electric power lines.

The DGPS messages are modulated onto the low-medium frequency carrier wave by minimum shift keying (MSK) with transmission rates that are presently 100 and 200 bits per second (USDOT 1998). The 99% power containment bandwidth of the MSK modulated signal is equal to 1.17 times the transmission rate (USDOT 1998). This means the DGPS broadcast information is contained in a relatively small bandwidth (i.e., 117 or 234 Hz).

The specified minimum field strength for coverage of the DGPS broadcast signal is usually 75 μV/m or 37.5 dBμV/m. Many DGPS sites with a 200-bit per second transmission rate have a specified minimum field strength of 100 μV/m (or 40 dBμV/m).

As an example, consider a calculation of the minimum signal-to-noise ratio (See Chapter 9 of the Red Book) needed for a DGPS receiver to properly operate in corona noise. It will be assumed here that that the DGPS receiver has a bandwidth of 234 Hz. It will be further assumed that the electromagnetic noise is 58 dBμV/m as measured by a CISPR receiver (i.e., at a bandwidth of 9 kHz). This figure is typical of the interference measured near a 387-kV transmission line in average measurable rain, as quoted in Table 9.5-4 (of the Red Book). This noise can be converted to rms noise (see Section 9.3.1 of the Red Book) by subtracting 8 dB and to the bandwidth of the DGPS receiver by adding $10 \log_{10}(234/9000) = -15.8$ dB. The resulting noise level is 34.2 dBμV/m. If the signal strength is 100 μV/m or 40 dBμV/m, the receiver must operate properly with a signal-to-noise ratio of 5.8 dB. If a receiver has a minimum signal-to-noise ratio for proper operation less than 5.8 dB, it will work properly. Given typical minimum signal-to-noise ratios for digital receivers, it would be no surprise that this noise level could cause the receiver to malfunction. It should be noted here that the calculation reported above assumed a minimum signal strength for the DGPS signal. In most cases, the signal strength will be significantly above this level.

It has been shown (Silva 2002) that DGPS receivers, operated close to 345- to 765-kV transmission lines, could experience a decreased SNR that may degrade receiver performance.

The practical consequences of poor DGPS signal reception are illustrated by the results of measurements taken using a GPS-equipped vehicle driven slowly across a multiple transmission-line easement (double-circuit 120- and 345-kV transmission lines). The high-end GPS receiver carried by the vehicle was augmented with DGPS and used a roof-mounted, shielded H-field antenna for both GPS and DGPS signal detection. As the vehicle was driven, its position, as reported by the GPS receiver, was logged at 1-s intervals. The data were taken on two different days while driving along the same route under the transmission lines (at midspan) in fair weather and in light steady rain when corona would be more prevalent. The data collection route across the easement started about 100 m south of the 120-kV line and proceeded laterally on a straight line to traverse the easement by crossing first under the 120-kV line and then, in succession, under each of the two double-circuit 345-kV transmission lines. The results are shown in Figures ECN-7 and ECN-8 (Figures 12.10-1 and 12.10-2 of the Red Book) for fair weather and rain, respectively.

The plot of positions approximates a straight line in Figure ECN-7 during fair weather as expected since the vehicle traverse was not exactly a straight line and the position accuracy was within 1 m or less. As Figure ECN-8 indicates, the SNR was reduced by the corona noise until it went below the minimum required to maintain lock on the DGPS beacon. At this point, the DGPS receiver experienced a loss of the DGPS differential correction messages and suddenly reverted to the standard positioning service with the associated lack of accuracy. Without DGPS, the reported position suddenly jumped to a different position with significant error. As the measurement vehicle continued to traverse the easement, DGPS operation was intermittently resumed, albeit with some aging of corrections, which is representative of marginal or suboptimum receiver performance. Near the edge of the easement, DGPS corrections were again received on a timely basis, and the final few positions shown in Figure ECN-8 were close to the correct values.

Note that in this particular experiment, the signal from the closest DGPS transmitter was significantly reduced by scattering from the power line ground wire and tower combination because the angle of arrival of the DGPS signal was almost parallel to the transmission line. The next closest DGPS transmitter (used by the receiver when the first was unavailable) was significantly further away, hence its signal was very small. This combination of conditions was unusual.

It should also be noted that the measurements reported in Figures ECN-7 and ECN-8 were taken before the “selective availability” option was removed by the U.S. government. This option intentionally reduced the position accuracy for the nonaugmented GPS system. After this option was removed, data taken when the DGPS corrections were unavailable would not have errors as large as those shown in Figure ECN-8.

These measurements demonstrate that, even with a very high quality digital GPS/DGPS receiver and antenna, corona noise can degrade DGPS receiver performance in the region near transmission lines. There was no apparent effect on the GPS microwave signal reception quality. However, the DGPS low-medium frequency signals could not be used at some locations close to the 345 kV lines, even with the closest DGPS broadcast beacon only about 20 miles away.

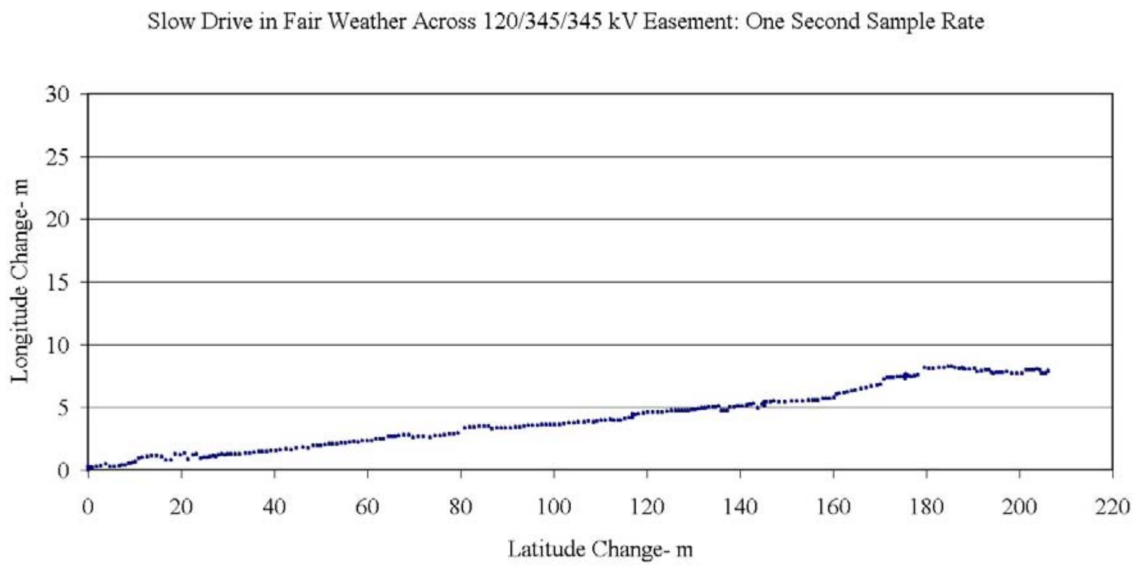


Figure ECN-7
Plot of positions logged using digital GPS unit (augmented with DGPS), taken while driving across 120/345/345-kV easement during fair weather
(Figure 12.10-1, Red Book)

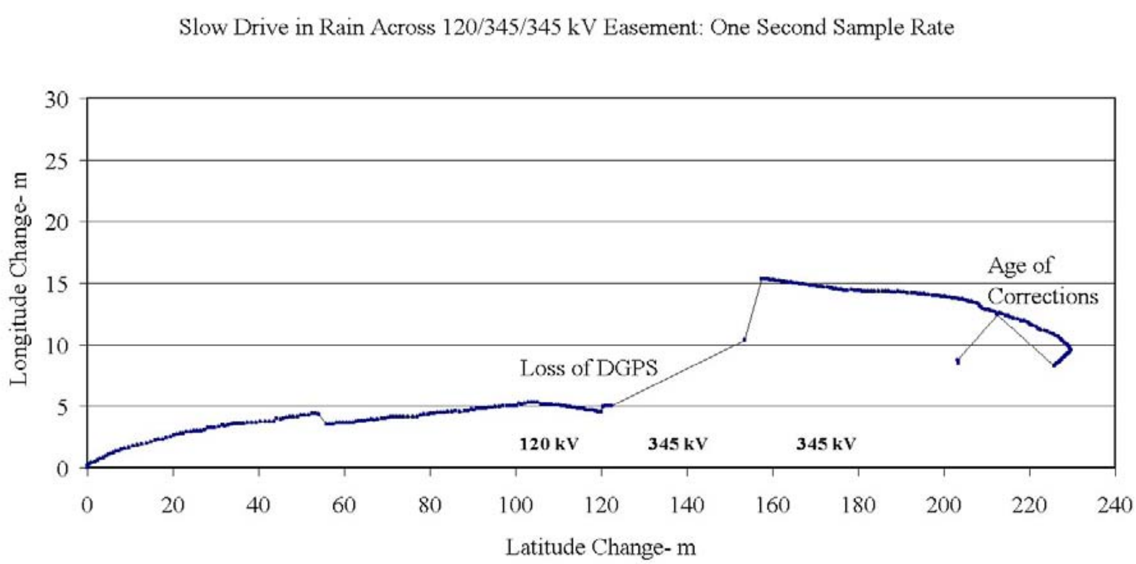


Figure ECN-8
Plot of positions logged using digital GPS unit (augmented with DGPS), taken while driving across 120/345/345-kV easement during fair weather
(Figure 12.10-1, Red Book)

Gap discharge sources on power lines can also generate radio frequency noise in the DGPS band. These potential RF noise sources are most commonly associated with ubiquitous distribution lines but can be found on transmission lines as well. It has been shown by Silva (2002) that gap discharge RF noise can significantly raise the noise floor in the DGPS band. It is thus possible under certain conditions that DGPS receiver performance may be degraded to suboptimal levels by gap discharge noise sources. Of course this will depend on many factors, such as DGPS receiver and antenna design, signal strength, noise level, distance from source, and weather (gap sources are often quiet during wet weather). Since most gap sources are associated with distribution lines and most of them can be eliminated by transmission maintenance, this type of interference is of a less concern than corona interference.

Interference with the Operation of Communication Receivers (Section 12.11, Red Book)

It is well known that transmission lines can interfere with AM/FM/TV receivers, amateur radio receivers, aircraft communication receivers, and specialized devices such as radio astronomy antennas. At frequencies below approximately 10 MHz, corona noise may dominate during foul weather. Above 10 MHz, however, gap discharges will be the primary source of interference. (See Chapter 9 of the Red Book for further information.)

A satellite TV reception system consists of a dish antenna, a low noise amplifier/converter and an integrated receiver/decoder (IRD). The satellite signal is focused by the dish onto a probe that is connected to the low noise amplifier/converter. After the signal is amplified and down-converted to a lower carrier frequency, it is sent to an integrated receiver/decoder for channel selection (note, the received satellite signal contains many TV channels). Following which, the outputs of the receiver are sent to the input terminals of a TV set. Since the received satellite signal is in the C-band (~4 GHz range) or K_u-band (~12 GHz range), it is highly unlikely that transmission line radio noise will interfere with satellite TV reception systems.

Citizens' band (CB) or other land mobile radio operates like a radio receiver and a mini radio station in one unit, and provides a simple, low-cost, short-range two-way radiocommunication service. The coverage range varies: typically 5 to 15 km for car-to-car use, 12 to 25 km for car-to-base station use, and 20 to 40 km between base stations. For even greater coverage, a fixed base station or repeater can also be employed.

Ontario Hydro has carried out several extensive field and laboratory studies to evaluate the influence of noise from a 500 kV line on land mobile communications covering FM mobile receivers from 25 to 470 MHz and CB receivers from 26.96 to 27.28 MHz (Ontario Hydro 1977, 1979). The results indicate that receiver degradation can generally be expected close to a power line when operating at the threshold of the receiver. For FM mobile receivers in the low VHF band from 25 to 88 MHz, the degradation near the edge of the right-of-way can be appreciable, and becomes negligible beyond about 1,000 m from the line. For FM mobile receivers in the high VHF band from 132 to 174 MHz, the degradation is less, and becomes insignificant beyond about 200 m from the line. For FM mobile receivers in the UHF band from 400 to 570 MHz, there is no noticeable effect at any separation. For CB receivers, the degradation depends on the effective length of the receiving antenna. For a typical commercial one-meter base loaded whip antenna, the influence is limited to within 400 m of the line.

The results also suggest that in some cases, the base station coverage can be reduced considerably when a mobile receiver is operating at its threshold close to a 500 kV transmission line under extreme foul weather conditions. These extreme foul weather conditions occur only for a small percentage of time during a year. Performance in fair weather is generally better than that in foul weather because of the lower repetition rate of fair weather corona.

As described in Section 9.1 of the Red Book, the source of interference that causes more than 90% of the electromagnetic interference (EMI) complaints received by utilities are gap discharges, which are also called gaps or sparks and sometimes microsparks. Gap discharges are complete electrical discharges across two electrodes of two dissimilar dielectrics. The main source of gap discharges is loose hardware, and they can be found on lines of every voltage classification. They tend to be found the most often on wood pole structures where hardware has a greater probability of becoming loose as the wood poles and wood crossarms dry out. Lattice steel structures, concrete poles, and tubular steel poles are much better structures from an EMI standpoint than wood because the hardware on the structure usually stays very tight, and the weight of the long spans tends to keep hardware well bonded.

Corona can be a source of severe EMI in the AM broadcast band, particularly during foul weather when the corona can be as much as 10 times greater than in dry weather. However, over the past 20 or so years, electric utilities have received very few EMI complaints in this frequency band that were due to corona. This trend is primarily because of the popularity of the FM broadcast band, which is not affected by power line EMI and the fact that the AM broadcast band tends to have a lot of static due to atmospheric EMI, especially where the signal strengths are not very strong.

Overhead structures and buildings can cause passive interference. In the AM broadcast band, metal transmission line structures can reradiate broadcast signals that can change the propagation pattern of the radio station that has the license from FCC. This is especially true for directional antennas. The license given to the radio station not only specifies the transmitting power of the antenna, but also specifies the propagation pattern that the station must maintain. If the pattern is changed or distorted, the utility could be responsible for fixing the problem.

The other type of passive interference of great concern to customers living near metal transmission and substation structures is ghosting and blocking of TV signals.

Outside the electric utility industry, there is the mistaken impression that EMI increases with line voltage. This is not true, as will be explained in Chapter 9 of the Red Book. Gap discharges are the main source of EMI complaints, and they are pretty much independent of the voltage of the line. In fact, distribution lines are a much larger source of gap discharges than transmission lines.

EMI can be calculated using the following simple software applications provided in the electronic version of the Red Book.

- Applet RN-1: "Electromagnetic Interference up to 30 MHz." This applet may be used to calculate either the conductor corona EMI measured with either a rod or loop antenna versus the distance from a transmission line of given characteristics in different weather conditions.

This applet uses the wideband analytical method (WBNOISE) developed by Olsen and his coworkers and described in Chapter 9 of the Red Book.

- Applet RN-2: "Radio Noise." This applet may also be used to calculate conductor corona EMI but is based on the empirical Corona and Field Effects method developed by Chartier at the Bonneville Power Administration. Although it will not give exactly the same results as RN-1, it will usually be within a few dB, since it has been slightly modified to be in agreement with the same long-term experiments as has RN-1. Both RN-1 and RN-2 produce results that are valid at arbitrary distances from the transmission line and at frequencies up to 30 MHz.
- Applet RN-3: "Radio Noise Base Case Curves." This applet is a calculation of the EMI using the analytical method described in the second edition of this reference book. In some cases, the results may be significantly different than either RN-1 or RN-2 because it uses laboratory measured generation functions rather than generation functions that have been calibrated using long-term measurements on operating lines.
- Applet RN-4: This applet may be used to calculate the EMI measured at a reference location and the effect of individual line parameters—such as conductor diameter, number of conductors, phase spacing, and height above ground—for a large number of base case line voltages and configurations.

Although the number of wireless communication devices is growing, the use of digital technology instead of analog technology, and the use of higher UHF (ultra high frequencies) and microwave frequencies instead of lower VHF (very high frequencies) will make the newer communication devices less susceptible to interference from transmission lines. The reasons being:

- Unlike analog technology, digital data are less sensitive to interference and transmission errors can often be recovered easily.
- The amount of corona noise generated by a transmission line decreases with increasing frequency. Therefore, communications equipment using a higher operating frequency will likely be less susceptible to corona interference.

Interference with Computer Monitors (Appendix 7.4, Red Book)

Magnetic fields at power frequency (50 or 60 Hz) may interfere with the image displayed by computer monitors that utilize a cathode ray tube (CRT). The interference manifests itself as rapidly moving or wiggling characters or images on the display - called "jitter." The level of interference depends not only on the value of the magnetic field but also on the monitor design. Monitor design has changed over time. Some changes, such as the use of longer electron beam paths and lower electron gun acceleration voltages for larger screens, have resulted in monitors that are less immune than older and smaller monitors (Baishiki et al. 1990). Manufacturers of computer monitors have done little to decrease the immunity to external magnetic fields, even fields that are present in common environments. In fact, the most typical situations where complaints about monitor jitter are made do not involve high-voltage transmission lines, but rather proximity to an electrical panel, appliance, or building wires. On the other hand, the steady growth in usage of flat-panel liquid crystal displays (LCD), which are not affected by external magnetic fields, may some day render this issue irrelevant.

Cathode Ray Tubes for Computer Monitors

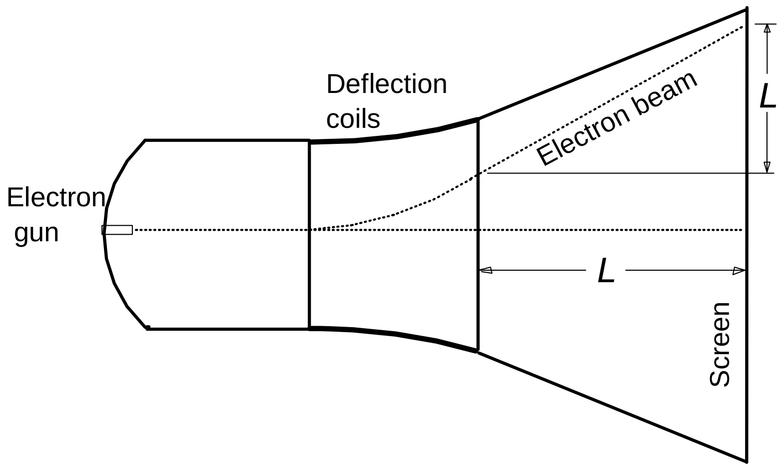


Figure ECN-9
Cathode ray tube for computer monitor
(Figure A7.4.1, Red Book)

Cathode ray tubes (see Figure ECN-9) utilize an electron gun at one end of the tube that sends a beam of electrons to the other end of the tube, consisting of a screen covered by a phosphorous layer. The phosphorous layer emits light when the beam hits the screen. The electron beam is accelerated inside the gun and exits the gun in the axial direction with a velocity dependent on the characteristics of the gun. The electrons maintain their axial velocity inside the vacuum tube, but are accelerated horizontally and vertically by the magnetic field generated by the deflection coils. The beam then proceeds in a straight line until it reaches the phosphorous screen. The deflection coils are controlled in such a way that the electron beams constantly scan the phosphorous screen creating the image on the monitor. The electron beam starts from the upper left-hand edge of the screen, moves horizontally across the screen to the end of the line, and moves back to the beginning of the next line, and so on until the entire screen is traced. The number of times that this process is performed in a second is called the "refresh rate" or "vertical scan rate." Typically, refresh rates for standard monitors range from about 50 to 120 Hz. To the human eye, however, the image on the screen appears steady. Jitter occurs whenever the external power frequency magnetic field is of sufficient strength to change the deflection of the electron beam in an appreciable way. The deflection caused by the power-frequency magnetic field varies in intensity during the cycle, and it is superimposed on the deflection caused by the deflection coils. The result is an apparent movement of the image at a frequency equal to the difference between the refresh rate and the power frequency.

Jitter Characteristics

A jitter is characterized by its magnitude, frequency, and mode. The *magnitude* of the jitter is defined as the maximum displacement (mm) of one character on the screen. The displacement occurs because, under the action of a magnetic field, an electron is accelerated by a force proportional to the magnetic field and to the component of the velocity of the electron orthogonal to the magnetic field. The force is orthogonal both to the field and to the electron velocity. For instance, consider the electrode beam hitting the center of the screen. An external magnetic field horizontal and parallel to the screen will accelerate the electrons in a vertical direction (perpendicular both to the velocity of the electrons and to the magnetic field).

This acceleration will create a vertical deflection, d, during the time of flight, T, of the electrons from the area of the deflection coils (which is shielded from the action of an external field) to the screen. The time T is very short in comparison to the period of the power frequency. Therefore, the field b may be considered constant during the travel time of the electrons.

If the frequency of the magnetic field is different from the frequency of vertical scanning, the deflection will be different for each scanning period. The deflection will change at a frequency equal to the difference between magnetic field frequency and scanning frequency. The maximum displacement of a character on the screen (jitter, J) is proportional to the peak-to-peak value of the magnetic field.

When the magnetic field is horizontal and parallel to the screen, the jitter will be approximately the same throughout the screen.

A vertical magnetic field will accelerate the electrons in a horizontal direction. The jitter will occur in a different mode, as described below.

A magnetic field perpendicular to the screen will not deflect the beam that hits the center of the screen, but it will deflect the beam that reaches other points. For a corner of the screen, where the jitter is the largest, the velocity of the beam has a component parallel to the screen.

The maximum jitter for this situation is less than the maximum jitter when the field is parallel to the screen in proportion to the ratio between half the screen diagonal and the length of the tube from the deflection coils to the screen.

In summary, when the magnetic field is parallel to the screen, the jitter sensitivity (mm/mG) is proportional to the square of the length, L, of the tube. When the magnetic field is perpendicular to the screen, the jitter is zero in the center and maximum in the corners of the screen where it is proportional to the product of the length of the tube and the half diagonal ($G/2$) and is therefore considerably lower than when the field is parallel to the screen.

Smaller (14- or 15-inch) monitors have jitter sensitivity equal to 0.008 - 0.011 mm/mG for a magnetic field parallel to the screen and 0.004 - 0.008 mm/mG for a magnetic field perpendicular to the screen. The sensitivity increases with monitor size: 17-inch monitors have jitter sensitivity equal to 0.014 - 0.017 mm/mG for a magnetic field parallel to the screen and 0.006 - 0.011 mm/mG for a magnetic field perpendicular to the screen. Large (21-inch) monitors have jitter sensitivity of about 0.019 mm/mG for a magnetic field parallel to the screen and about 0.013 mm/mG for a magnetic field perpendicular to the screen.

The *frequency* of the jitter is equal to the difference between the power frequency and the refresh rate. The same jitter is perceived differently depending on the frequency. When the refresh rate is equal to the power frequency the jitter frequency is zero. In this case, the image is distorted, but it does not move and the distortion is perceived only when it becomes very large. As the jitter frequency increases, the jitter is perceived more easily. The minimum jitter is perceived at a frequency of 4 - 15 Hz. As the frequency is further increased, jitter perception becomes more difficult. Above 30 Hz, the jitter becomes a blur and can be perceived only by increasing its level.

Jitter may occur in different *modes* depending on the direction of the power frequency field relative to the cathode ray tube. Figure ECN-10 presents a sample of the magnetic field interference displayed on the monitor when the external magnetic field is perpendicular to the path of the electron beam (parallel to the screen) and is aligned horizontally. In this orientation, the image displacement will result in the vertical squeezing and enlarging of the characters. Figure ECN-11 presents a sample of the magnetic field interference displayed on the monitor whenever the external magnetic field is perpendicular to the path of the electron beam (parallel to the screen) and is aligned vertically. In this orientation, the image displacement will result in a horizontal oscillating motion. Figure ECN-12 presents a sample of the magnetic field interference displayed on the monitor whenever the external magnetic field is aligned in the direction of the path of the electron beam (perpendicular to the screen). In this orientation, the image will be displaced both horizontally and vertically, and the image will shift in a rotational pattern.

The human sensitivity to jitter is greatest when the magnetic field is vertical and the image has a horizontal oscillating motion (Figure ECN-11). In this mode, the threshold of observed jitter for a large group of people had a mean value of 0.127 mm, with a standard deviation of 13% when the jitter frequency was 4 Hz, and a mean value of 0.142 mm with a standard deviation of 11% when the jitter frequency was 12 Hz (Banfai et al. 2000). When the magnetic field is horizontal and parallel to the screen (Figure ECN-10), the vertical squeezing and enlarging of the characters are perceived less readily, and the minimum observed jitter is somewhat larger (20 – 50% larger) (Baishiki and Deno 1987). When the magnetic field is perpendicular to the screen (Figure ECN-12), the minimum detected jitter is considerably larger.

Other orientations will create a combination of different image displacements, depending upon the angle of orientation between the monitor and the external magnetic field. When the magnetic field is elliptically polarized, as is often the case for transmission lines, more than one mode of jitter will be present.

In summary, the most easily detectable jitter occurs when the field is vertical. The jitter sensitivity (mm/mG), the minimum observable jitter (mm), and the corresponding minimum field (mG) are presented in Table ECN-1.

Figure ECN-10
Jitter caused by a power-frequency magnetic field horizontal and parallel to the screen
(Figure A7.4.2, Red Book)

Figure ECN-11
Jitter caused by a power-frequency magnetic field vertical and parallel to the screen
(Figure A7.4.3, Red Book)

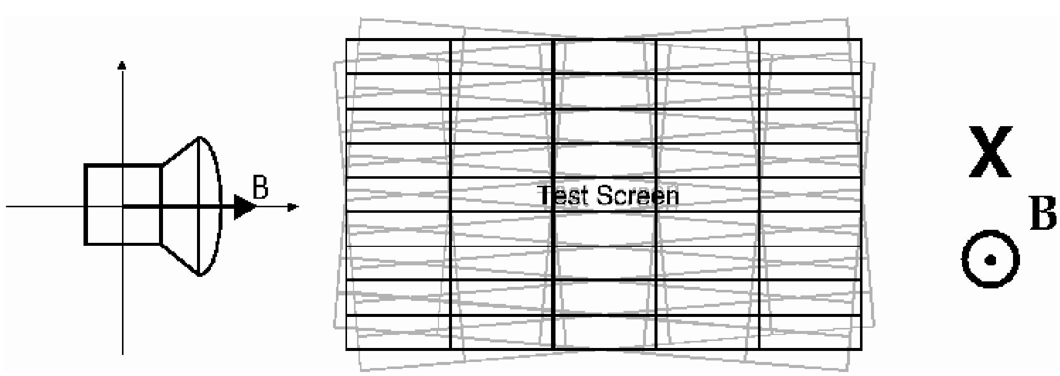


Figure ECN-12
Jitter caused by a power-frequency magnetic field perpendicular to the screen
(Figure A7.4.4, Red Book)

Table ECN-1
Minimum Magnetic Field for Perceptible Jitter
(Table A7.4-1, Red Book)

Monitor Size	Jitter Sensitivity	Minimum Observable Jitter		Minimum Field for Perceptible Jitter	
		Jitter Frequency = 4 Hz			
		Mean Value	5% of People	Mean Value	5% of People
(inch)	(mm/mG)	(mm)	(mm)	(mG)	(mG)
14” – 15”	0.008 - 0.011	0.127	0.10	11.5 - 16	9 - 12.5
17”	0.014 - 0.017	0.127	0.10	7.5 - 9	6 - 7
21”	0.019	0.127	0.10	7	5
		Jitter Frequency = 12 Hz			
14” – 15”	0.008 - 0.011	0.142	0.12	13 - 18	11 - 15
17”	0.014 - 0.017	0.142	0.12	8.5 - 10	7 - 8.5
21”	0.019	0.142	0.12	7.5	6

Color Monitors

A color monitor has three electron guns, and the three beams converge into three adjacent dots, having the phosphor corresponding to the three basic colors: red, green, and blue. A color picture is made by varying the intensity of each beam and achieving the proper mixture of the basic colors. The color purity of an image is obtained when the proper phosphors are excited. This occurs only when the alignment is properly adjusted and the necessary magnetic field free region is maintained inside the CRT. A power-frequency magnetic field may cause the loss of color purity, which can be seen as mottled or incorrect colors, and color fringes at edges of characters or graphics. These phenomena are difficult to detect at the magnetic field levels corresponding to the threshold of jitter.

Mitigation Options

A number of options can be employed to reduce or eliminate computer monitor jitter:

- Adjust the monitor refresh rate to be as close to the power frequency as possible. However, the tendency today is to increase the refresh rate well above the power frequency in order to reduce flicker, which is a temporal variation in character or background luminance independent of power frequency magnetic field. When jitter is more objectionable than flicker, making the refresh rate equal to the power frequency may be an acceptable solution.

- Increase the refresh rate so that the jitter frequency becomes greater than 30 Hz. At this frequency the jitter is not perceptible. The image, however, becomes blurred and may create eye fatigue for long-term usage of the monitor. Also the necessary change in refresh rate is not always possible and depends on the graphic card and monitor.
- Adjust the orientation of the monitor to minimize effects. This is possible if the interfering field is horizontal and the monitor can be turned until the field becomes perpendicular to the screen. This is equivalent to a field reduction by a factor of 1.5 - 2.
- Install a magnetic field shield around the monitor. Shields made of high-permeability materials may achieve significant field reduction and are commercially available.
- Use active shielding (Mellik 1996). This is accomplished with external coils that generate a magnetic field that cancels all or part of the interfering field.
- Replace the CRT monitor with an LCD monitor.

Technical Evaluation

See Flowchart for Evaluation and Approval Process in the Administrative Guide.

Solicit inputs on issues and concerns from all impacted departments.

Prepare Engineering Evaluation

- Check operating clearances
  - Determine type of ROW use or encroachment.
  - Determine line voltage.
  - Determine location, span, structure numbers.
  - Get design profile / mapping.
  - Plot encroachment on profile.
  - Measure conductor to ground clearance.
  - Add tolerance.
  - Compare to minimum operating clearance.
  - If clearance is marginal, refer to Electrical Design for conductor thermal study.
  - If clearance is insufficient, suggest alternative location, lower ground elevation, raise conductors.
- Check industry work standards
  - Determine line voltage.

- Refer to industry/electrical safety regulations for minimum working clearance to transmission conductors.

- Check future line criteria
  - Review electric system plan for future lines on ROW.
  - Contact System Planning for updated information.
- Check plant protection and internal policies and standards
  - Ensure ROW use/encroachment is a minimum of _____ ft horizontally from any transmission structure.
  - Specify structure protection if necessary.
  - Review power company policies (e.g., refer EMF concerns to EMF Project Manager).
  - Good engineering practice.
  - Environmental/social acceptability.
  - Compliance with fire and electrical codes.
  - Review induction and grounding concern.
- If estimate required – refer to Transmission Project/Construction.

Assemble Responses and Engineering Evaluation

- Assemble responses from all departments and assure all pertinent technical issues are addressed.
- Select applicable general conditions.
- Compile all findings.

Prepare Engineering Report and Recommendations

Analysis criteria shall include standards of acceptance and the following as a minimum:

- Conductor to ground clearances.
- Horizontal clearance from conductors, structures and related plant.
- Local, national and internal standards.
- Work safety regulations.
- Access for maintenance.
- Provision for future plant.
- Environmental protection.
- Public image.
- Assessment of technical risk issues.

- All relevant information received from others.

Review Report

- Review report for accuracy, consistency and coverage.
- Transmit report to Property Services with copies to appropriate internal stakeholders.

Related Guidelines, Standards and Documents

Internal guidelines should be established and used for all installation on power company ROWs. The following is a list of relevant internal guidelines covering topics such as:

- General conditions
  - Contact the power company at least ______ days prior to working on ROW.
  - Power company not responsible for damage to works caused by normal activities.
  - Power company reserves the right to terminate consent.
  - Applicant responsible for all costs for plant alterations/protection.
  - Works must not approach within ______ ft of power company plant.
  - "As constructed" drawings required within ____ days.
  - Survey plan of works is required showing relation to ROW boundaries.
  - Remove or relocate works upon issue of ____ days' written notice from the power company.
  - Works must not be enlarged, moved or added to without the consent of the power company.
  - Metal fences must be grounded according to the power company guidelines.
- Personal safety
  - Where plant is installed on transmission line structures and ROW, assure
    - There is provision for training of power company line crews and contractors crews to deal with the installation.
    - There is provision for training and approved work methods for licensee workers working around transmission line facilities.
    - Adequate grounding, bonding and shielding are provided for the installation and for workers at the site.
    - Rules for access to the installation are clear (i.e. only power company approved climbers or bucket operators are allowed above (____) ft. on any power company facilities.
  - Safe working distance from transmission line conductors (e.g., 20' for 500 kV lines).
  - Maximum height of vehicles, including load and reach, not to exceed _____ ft.

  - Levels of induction in objects near transmission lines.
- Plant security and maintenance
  - Access to be maintained.
  - Grade elevation changes not to exceed _____ ft.
  - Encroachment is a minimum of _____ ft horizontally from any transmission structure.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - Trees, shrubs and plants not to exceed _____ ft (e.g., 10') in height at maturity.
  - Temporary or permanent structures larger than __(size and height)__ are not allowed on ROW.

Relevant transmission maintenance and construction standards covering topics such as:

- Working clearances from energized conductors.
- Minimum operating line to ground clearances.
- Grounding of fences, buildings and objects near transmission lines.

National, state and local relevant industry standards and codes covering topics such as:

- National Electric Safety Code.
- Fire and electrical codes.
- Work regulations or electrical safety code for working near energized conductors.

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Attachments

- Frequently asked questions.
- Definitions/glossary.
- Terms of reference.

E
ADMINISTRATIVE GUIDE - AGRICULTURAL ACTIVITIES

Scope

This guide outlines the activities required for evaluating requests for agricultural activities (including logging operations) on rights-of-way (ROW) or fee-owned land. It outlines the conditions under which the proposal may or may not be approved, and the administrative approval process.

Purpose

- Ensure public safety.
- Ensure safe working conditions for electric utility and third party personnel.
- Ensure a uniform review, evaluation and approval process.
- Ensure power system reliability and safe operation of the transmission circuits.
- Ensure access for transmission maintenance and future expansions and modifications.
- Ensure plant security.
- Ensure uncompromised power transmission capability.
- Ensure compliance with all applicable codes, standards and regulations, laws and ordinances.
- Protect the property rights of the power company.
- Protect the electric utility's ability to construct future works.
- Protect the natural environment, habitat and wildlife.
- Promote positive public image by allowing multiple use of the ROW for compatible public activities.

Policy

Requests for agricultural activities on ROW or fee owned land shall be processed through the procedure established in this document to ensure that all affected groups have the opportunity to review and approve or disapprove the proposal. Since well executed agricultural activities can minimize ROW management costs they can be of benefit to both the owner and the power company and there is value in encouraging them.

The department receiving the inquiry will determine, with appropriate consultation, whether the proposal has a minor or significant impact and follow the administrative procedure in this document.

For encroachment that needs approval on a site-specific basis, detailed construction drawings are to be submitted to the power company for approval, at least (lead time) in advance of construction. The power company will arrange for Engineering, Legal, Operational and others as appropriate to review the proposal. No work shall proceed until approval has been granted. This procedure ensures that all affected departments have the opportunity to review and approve or disapprove the proposal.

Responsibilities

Here is an example showing the responsible functions which may be assigned in the review and approval process:

- Civil Design - foundations, structural or geotechnical concerns.
- Station Design - impacts to substation.
- Cable Design - impacts to underground works.
- Electrical Design - studies related to induction, grounding, clearance, conductor thermal rating.
- System Planning - anything that affects future plant.
- Environmental Services - environmental compatibility concerns.
- Survey and Photogrammetry - detailed field measurements and mapping.
- Property/Real Estate/Legal Services - land rights, liabilities and legal information, maintaining records and correspondence with applicants.
- Field resources - site-specific information.

Requirements

- Maintain property rights of the power company.
- Compliance with local and national codes (e.g., fire and electrical codes).
- Personal safety.
- Applicant assumes all responsibility and repairs for damage to transmission property resulting from use of the ROW.
- Precautions to be taken when working near the transmission line
  - Maximum height of vehicles, including load and reach, not to exceed ___ ft (e.g., 13.5’).
  - Safe working distance from transmission line conductors.

- No refueling of vehicles or equipment on ROW.
- Irrigation spray must not reach the conductor.

- ROW and access roads to be restored to their original condition following any construction, at applicant's expense.
- The applicant is responsible for repair or replacement of its own equipment in the event of damage from an electrical fault and/or structural failure.
- Plant security and maintenance
  - Access to transmission structures must be unobstructed at all times.
  - No grade changes to facilitate the disposal of overburden will be allowed.
  - Ensure the ROW use/encroachment is a minimum of _____ ft (e.g., 30') horizontally from any transmission structure.
  - No burning within or near the ROW, unless approved by the power company.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - Landscaping, trees, shrubs and plants must not exceed _____ ft (e.g., 10') in height at maturity on ROW.
  - No storage of flammable materials will be allowed on ROW.
  - No storage of other materials on ROW unless approved by the power company.
  - No temporary or permanent structures larger than _(size and height)_ are allowed on the ROW unless approved by the power company.
  - Adequate guards or management practices are required to avoid damage to structures, guys and anchors by equipment and livestock.
- There should be a clear understanding among the power company, the landowner and the farm operator regarding compensation should crop damage occur as a result of power company maintenance activities.
- Since many agricultural activities are common to many farms, it would be a good practice to have a list of acceptable activities and perhaps public documents outlining items like good grounding practice, good irrigation practice, height limitation for vehicles, and annoyance due to electric and magnetic field induction, radio and television interference. Some of the information to be included in the public documents for these items can be summarized from various ROW guides.

Related Guidelines, Standards and Documents

Internal guidelines should be established and used for all installation on power company ROWs. The following is a list of relevant internal guidelines covering topics such as:

- General conditions

  - Contact the power company at least ______ days prior to working on ROW.
  - Power company not responsible for damage to works caused by normal activities.
  - Power company reserves the right to terminate consent.
  - Applicant responsible for all costs for plant alterations/protection.
  - Below ground works must be designed to withstand heavy loads (e.g., large maintenance equipment).
  - "As constructed" drawings required within ____ days.
  - Survey plan of works is required showing relation to ROW boundaries and transmission structures.
  - Remove or relocate works upon issue of ____ days' written notice from the power company.
  - Works must not be enlarged, moved or added to without the consent of the power company.
  - Metal fences must be grounded according to the power company guidelines.
- Personal safety
  - Safe working distance from transmission line conductors (e.g., 20' for 500 kV lines).
  - Maximum height of vehicles, including load and reach, not to exceed _____ ft.
  - No refueling of vehicles within the ROW.
  - Levels of induction in objects near transmission lines.
- Plant security and maintenance
  - Access to be maintained.
  - Grade elevation changes not to exceed _____ ft.
  - Encroachment is a minimum of _____ ft horizontally from any transmission structure.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - Trees, shrubs and plants not to exceed _____ ft (e.g., 10') in height at maturity.
  - Temporary or permanent structures larger than __(size and height)__ are not allowed on ROW.

Relevant transmission maintenance and construction standards covering topics such as:

- Working clearances from energized conductors.
- Minimum operating line to ground clearances.
- Grounding of fences, buildings and objects on or near transmission facilities.
- Safe operation of irrigation equipment near transmission lines.

National, state and local relevant industry standards and codes covering topics such as:

- National Electric Safety Code.
- Fire and electric safety codes.
- Work regulations or electrical safety code for working near energized conductors.

Other references:

- See Technical Guide for other references.

Administrative Procedure

Approval without review can be granted when there are no violations in the requirements. Otherwise, the request must be referred to various departments for review and approval. See Flowchart for evaluation and approval process.

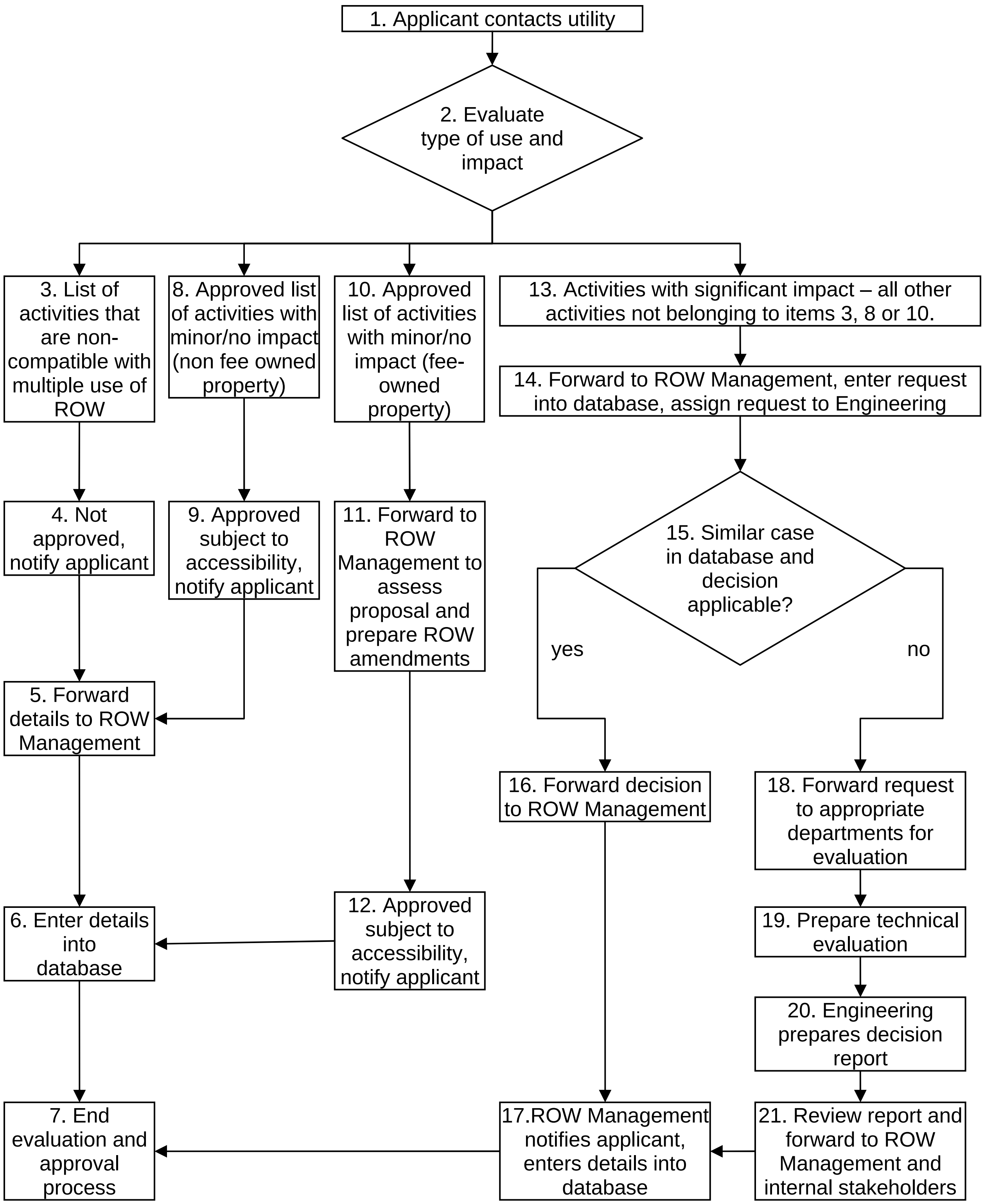
- Receive application, enter into log book and data base recording the following minimum information:
  - Property contact.
  - Engineering contact.
  - Type of use.
  - Applicant.
  - Landowner.
  - Location.
  - Transmission circuits.
- Assign request
  - Determine level of complexity.
  - Determine other stakeholders.
  - Determine need for other information from Applicant.
- Determine type of use
  - Access previous similar requests in database.
  - Confirm development on ROW.
  - Confirm civil engineering impact (e.g., foundation, roadwork, soil effects); transmit request to Civil Design.
  - Confirm property impact (e.g., future expansion); transmit request to System Planning.
  - Confirm development on station property, transmit request to Station Design.
  - Confirm significant environmental impact; transmit request to Environmental Services.

- Prepare engineering (technical) evaluation (See Technical Guide for details)
- Assemble responses and engineering evaluation (See Technical Guide for details)
- Prepare engineering report (See Technical Guide for details)
- Review report (See Technical Guide for details)
- File report
  - File hard copies of report, original request, departmental responses, marked location maps, profiles and other related documents.
  - Log completed report into ROW database with a case number.
  - Enter email correspondence, requests and all electronic documents into ROW database.
  - The approved cases can be kept for future reference.

Attachments

- Frequently asked questions.
- Definitions/glossary.
- Terms of reference.

Flowchart for Evaluation and Approval Process for Agricultural Activities



Notes for Flowchart:

1. Applicant contacts utility and seeks approval for using the ROW.

2. The office receiving the request evaluates the type of use and classifies the request into one of the four categories: a) Not Approved (non-compatible usage), b) Approved (minor or no impact) on non fee-owned property, c) Approved (minor or no impact) on fee-owned property, and d) Further Review (significant impact, require technical evaluation).

3. **Activities that are non-compatible** with multiple use of the ROW are not approved. A utility sets its own criteria and its own list of activities under this category, for example:

   - Permanent buildings and structures.
   - Anything that is too close to structures or conductors.
   - Storage of flammable, explosive or environmentally unfriendly materials or conditions.
   - Installation of most low voltage electrical wiring.
   - Any land use that extinguishes the utility rights.
   - Anything that impacts the utility's flexibility to install future plant.
   - Some utilities may consider the installation of wireless communication systems on transmission line structures as non-compatible use.

4. Requests for non-compatible use of the ROW are not approved. Notify applicant.

5. Forward case details to the ROW Management Department.

6. ROW Management enters details into the database for record keeping, future reference and information retrieval (e.g., property contact, type of use, applicant, landowner, location, transmission circuits, and final decision).

7. End of the evaluation and approval process.

8. **Approved list of minor/no impact on non fee-owned property** refers to those activities that meet the utility's standards, guidelines and terms of the ROW agreement and do not require further review. A utility sets its own criteria and its own list of activities under this category, paying attention to concerns such as:

   - Maintain property rights of the power company.
   - Compliance with local and national codes (e.g., fire and electrical codes).
   - Personal safety.
   - Plant security and maintenance

   Some examples in this category are:

   - Residential gardens where no metal irrigation pipes are placed within the ROW.
   - Grazing of animals.
   - Short term uses (e.g., less than one year) if no safety hazard.
   - Light landscaping or agricultural uses with no change in grade and vegetation with a maximum height of 10' at maturity.

- Storage of non-hazardous, non-toxic materials well beyond the working clearance to transmission conductors.

9. Activities falling under the approved list of activities with minor/no impact on non fee-owned property are approved without technical review provided access to utility facilities is maintained.

10. **Minor/no impact on fee-owned property** refers to those activities that meet the utility's standards, guidelines and terms of the ROW agreement and require only assessment by the ROW Management Department so that the appropriate ROW amendments and documentation are prepared. A utility sets its own criteria and its own list of activities under this category. The approved list of activities or criteria for this category may or may not be the same as those listed for minor/no impact on non fee-owned property. In addition, the administrative procedure requires the involvement of the ROW Management Department in the approval process for requests on fee-owned property.

11. The ROW Management Department assesses the proposal and prepares the appropriate ROW amendments and documentation.

12. Activities falling under the approved list of activities with minor/no impact on fee-owned property are approved by the ROW Management Department without technical review provided access to utility facilities is maintained. Notify applicant.

13. **Significant impact** refers to those activities that may affect items like the environment, future use, safety, plant security and accessibility. All other activities that do not fall under the non-compatible use or minor/no impact categories belong to this category. Activities belonging to this category require a technical evaluation process. Some examples in this category are:

    - Major change in land use.
    - Variations from ROW agreements.
    - Tree farms.
    - Plant modifications and cost estimates.

14. ROW Management enters details of the request details into the database (e.g., property contact, type of use, applicant, landowner, location, transmission circuits), evaluates the request, obtains additional information from the applicant (if necessary), determines who are the stakeholders, evaluates the level of complexity, and assigns the request to a technical individual in the Engineering department accordingly.

15. Engineering determines if similar cases exist in the database and if the decision made in a former case applicable today. Please note that a decision made previously may not be valid today due to possible changes in the evaluation criteria and/or company policies.

16. If the decision made in a former case is applicable today, no further technical evaluation is required. Forward the decision from a former case to ROW Management.

17. ROW Management notifies the applicant of its decision and enters details into the database for record keeping, future reference and information retrieval.

18. If no similar cases exist in the database or if the decision made in a former case is not applicable today, Engineering confirms the needs for technical evaluation and prepares a referral package containing details of the application and background information (e.g., reference to the former cases, correspondence with the applicant). Forward the referral package to the appropriate departments for technical evaluation. See

"Responsibilities" Section in the Administrative Guide for an example showing the responsibilities of the departments assigned in the evaluation and approval process.

19. Engineering and other departments prepare technical evaluations (e.g., check operating clearances, check electrical parameters, check industry work standards, check future line criteria, check plant protection and internal policies and standards). If underground, refer to Cables Design. If estimate required, refer to Transmission Project/Construction.

20. Engineering assembles and compiles responses from all departments. Prepare engineering decision report and recommendation using analysis criteria that include standards of acceptance as a minimum. See "Technical Evaluation" Section in the Technical Guide for more details.

21. Engineering reviews report for accuracy, consistency and coverage. Forward report to internal stakeholders and ROW Management. File all relevant materials. See "Administrative Procedure" in the Administrative Guide for more details.

F
TECHNICAL GUIDE - AGRICULTURAL ACTIVITIES

Scope

This guide outlines the activities required for evaluating the technical compatibility of requests for agricultural activities (including logging operations) on rights-of-way (ROW) or fee-owned land. It outlines the conditions under which the proposal may or may not be approved, and the technical evaluation process.

Purpose

- Ensure public safety.
- Ensure safe working conditions for electric utility and third party personnel.
- Ensure a uniform review, evaluation and approval process.
- Ensure power system reliability and safe operation of the transmission circuits.
- Ensure access for transmission maintenance and future expansions and modifications.
- Ensure plant security.
- Ensure uncompromised power transmission capability.
- Ensure compliance with all applicable codes, standards and regulations, laws and ordinances.
- Protect the property rights of the power company.
- Protect the electric utility's ability to construct future works.
- Protect the natural environment, habitat and wildlife.
- Promote positive public image by allowing multiple use of the ROW for compatible public activities.

Policy

Requests for agricultural activities on ROW or fee-owned land shall be processed through the procedure established in this document to ensure that all affected groups have the opportunity to review and approve or disapprove the proposal. Since well executed agricultural activities can minimize ROW management costs they can be of benefit to both the owner and the power company and there is value in encouraging them.

Requirements

- Maintain property rights of the power company.
- Compliance with local and national codes (e.g., fire and electrical codes).
- Personal safety.
  - Avoid agricultural equipment contact with the powerline. Flashovers from the powerline to the agricultural equipment will occur when any conductive part of the equipment (e.g., a long boom) is brought close to the powerline. A contact is not necessary to initiate the flow of dangerous discharge currents. Be cautious when moving agricultural equipment near the powerline.
  - Induced voltages and currents on large objects (e.g., long irrigation pipes).
  - Transfer of fault voltages on irrigation and related equipment as a result of irrigation pipes that are buried close to the transmission structures.
  - Follow safety procedures when working near powerlines.
- Applicant assumes all responsibility and repairs for damage to transmission property resulting from use of the ROW.
- Precautions to be taken when working near the transmission line
  - Safe working distance from transmission line conductors (e.g., 20' for 500 kV lines).
  - Maximum height of vehicles, including load and reach, not to exceed ___ ft (e.g., 13.5').
  - No refueling of vehicles or equipment on ROW.
  - Irrigation spray must not reach the conductor.
- ROW and access roads to be restored to their original condition following any construction, at applicant's expense.
- The applicant is responsible for repair or replacement of its own equipment in the event of damage from an electrical fault and/or structural failure.
- Plant security and maintenance
  - Access to transmission structures must be unobstructed at all times.
  - Grade elevation changes not to exceed _____ ft.
  - Ensure ROW use/encroachment is a minimum of _____ ft (e.g., 30') horizontally from any transmission structure.
  - No burning within or near the ROW, unless approved by the power company.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - Maximum height of trees, shrubs and plants shall not exceed _____ ft (e.g., 10') at harvest or maturity on ROW.
  - No storage of flammable materials will be allowed on ROW.

- No storage of other materials on ROW unless approved by the power company.
- No temporary or permanent structures larger than (size and height) are allowed on the ROW unless approved by the power company.
- Adequate guards or management practices are required to avoid damage to structures, guys and anchors by equipment and livestock.

- There should be a clear understanding among the power company, the landowner and the farm operator regarding compensation should crop damage occur as a result of power company maintenance activities.
- Since many agricultural activities are common to many farms, it would be a good practice to have a list of acceptable activities and perhaps public documents outlining items like good grounding practice, good irrigation practice, height limitation for vehicles, and annoyance due to electric and magnetic field induction, radio and television interference. Some of the information to be included in the public documents for these items can be summarized from various ROW guides.

Common Utility Practices

- Landscape, vegetation and tree farms <10' in height on ROW
- No obstructions, including plants and trees within 30 to 50 ft (a range of values from different utilities) of transmission structure foundations.
- Equipment <14 to 15 ft (a range of values from different utilities) can be operated under all transmission lines.
- No decking, stacking or piling of material on ROW.
- No ground elevation changes or excavation within 20' of tower footings to avoid changes in drainage pattern.
- No ground elevation increases on the ROW without specific approval and limits provided by the power company.
- No deterioration in soil stability or drainage pattern within and adjacent the ROW.
- No storage of materials on the ROW.
- Trenching and excavation must be >20' from any structure foundation.
- All corrugated steel pipe used for culverts must have a minimum of 12" of cover.
- The depth of any spoil material shall not exceed a point 6" below the top elevation of the concrete cap of the tower foundation.
- Applicable federal, state and local rules and regulations governing work, construction and electrical clearance requirements near electric power lines must be followed.
- Conductive objects that are permanently located within or adjacent to the ROW must be grounded if the resulting induced short-circuit currents are >2 mA.

- Allow free and unrestricted access to the transmission facilities for maintenance.
- Any drainage ditch that allows water to pond or to cause erosion around a structure is prohibited.

Agricultural Uses/Trees

- Trees are not allowed on ROW.
- Christmas trees and nursery stock must be <10’ in height on ROW.
- Liquid fertilizer and overhead sprinkler systems are not allowed on ROW.
- For one utility, the vertical clearance between conductor and vegetation must be •30’ for transmission lines of voltages from 138 to 500 kV, at the maximum operating temperature of the conductors, not at cold conductor temperature. The distance required for cold conductors may be •50’. For separation distances less than those indicated, approval from the power company for the vegetation must be obtained.
- Plants at maturity with heights <10 to 15 ft (a range of values from different utilities) are permitted under all transmission lines.
- Plants must be >20’ from any transmission structures.
- A path of 20’ wide must be maintained to allow access to transmission facilities.
- No berms or mounds are allowed.
- The natural drainage pattern must not be altered.
- No self-propelled equipment is allowed directly beneath the tower.
- All structures must be properly grounded.
- Crops and landscaping must not limit access for the maintenance crews and equipment.
- Trees and shrubs must not be planted directly over underground cable installations. Invasive roots may damage underground ducts and equipment.
- Spray irrigation equipment must be operated at safe clearances from the utility facilities.
- Trees planted beside or directly under the power lines must be of a species that will not reach to such height or width that it will grow into or fall onto the power lines.
- Trees in orchards with a maintained height between 13’ and 18’ must have the minimum conductor to ground clearance shown in Table AGA-1. Crops >18’ require special authorization.

Table AGA-1
Conductor to Ground Clearance for Orchards with Trees between 13' and 18' – Utility 1

Type of Construction	Line Voltage (kV)	Minimum Conductor to Ground Clearance (ft)
Wood pole construction	115	39.5
	230	42
Steel construction	115	38
	230	41
	345	43.5
	500	50

- Trees at maturity on the ROW must have the minimum conductor to tree top clearance shown in Table AGA-2.

Table AGA-2
Conductor to Tree Top Clearance – Utility 2

Line Voltage (kV)	Minimum Conductor to Tree Top Clearance
115	15' 8"
138	16' 4"
161	16' 8"
230	18'
345	20' 4"
500	24'

- Trees planted beside or directly under the power lines must be of a species that will not reach to such height or width that it will grow into or fall onto the power lines.
- Trees in orchards with a maintained height between 13' and 18' must have the minimum conductor to ground clearance shown in Table AGA-1. Crops >18' require special authorization.
- Trees are not allowed on ROW.
- Christmas trees and nursery stock must be <10' in height on ROW
- Plants at maturity with heights <10 to 15 ft (a range of values from different utilities) are permitted under all transmission lines.

- No trees with heights at maturity exceeding 10 to 15 ft (a range of values from different utilities) are to be planted on the ROW.
- Trees (including Christmas tree farms) and other vegetation with a height at maturity less than 10 to 15 ft (a range of values from different utilities) may be planted on the ROW.
- Trees in orchards with a maintained height between 13’ and 18’ must have the minimum conductor to ground clearance shown in Table AGA-1. Crops >18’ require special authorization.
- Where a tree growing operation, which exceeds the 10 to 15 ft. limit, is evaluated and authorized the trees at maturity on the ROW must have the minimum conductor to tree top clearance shown in (Table AGA-1 or AGA-2 are examples).

Irrigation Systems

- Safe irrigation spray clearances from power lines vary with the voltage and height of the overhead electrical conductors.
- Metal irrigation systems paralleling a transmission line for •1000’ and is •50’ of the outside conductor should be grounded while at rest.
- Irrigation pipes stacked on rubber-tired vehicles under powerlines should be grounded.
- Shocks and incidents of contact between irrigation pipes and conductors can be avoided by unloading pipes a distance of •50’ from the outside conductor.
- Metal irrigation pipes should be >50’ from transmission structure grounding system.
- Irrigation pipes should be moved in a horizontal position in the vicinity of powerlines. Never up-end irrigation pipes under a powerline.
- Do not install long lengths of pipes parallel and adjacent the powerlines. They should be laid at an angle > 45° to reduce induced charges.
- Solid part of a water stream should never be allowed to contact the conductor. The minimum conductor to water stream clearances must be maintained as shown in Table AGA-3.

Table AGA-3
Conductor to Water Clearance – Utility 1

Line Voltage (kV)	Minimum Conductor to Water Stream clearance (m / ft)
•69	2' (0.6 m)
138	3' (0.9 m)
230	5' (1.5 m)
287	6' 4" (1.9 m)
345	7' 8" (2.3 m)
500	10' 8" (3.2 m)

- Fixed-Type Systems
  - Locate the sprinkler heads such that they never spray water on the transmission lines.
  - Bury pipes a minimum of 24". Pipes must be marked where they enter and leave the ROW, and at all angle points within the ROW. Pipes must cross at an angle >60° to the centerline of the transmission lines.
  - Keep all metal pipelines, above or below ground, 50' from any part of a structure and 15' from any grounding system.
- Mobile Systems
  - A person carrying a length of pipe must always carry the pipe in the horizontal position, especially while under the power line. Do not stand pipe on end to remove dirt or small animals unless the electrical clearance in Table AGA-4 is maintained.

Table AGA-4
Clearances between Conductors and Objects – Utility 1

Type of Construction	Line Voltage (kV)	Vertical Clearance (ft)	Horizontal Clearance* (ft)
Wood pole construction	115	16.5	11.0
	230	19.0	13.5
Steel construction	115	15.3	11.0
	230	17.8	13.5
	345	20.3	14.0
	500	25.8	15.5

*The horizontal electrical clearance is only a portion of the total horizontal clearance requirement. Higher horizontal clearances are required in wind conditions.

- Wheel-Type Systems
  - Install wheel type systems with its length perpendicular to the transmission line whenever possible. When the system must be operated parallel to the transmission line, connecting the header valve first to the irrigation pipe may help reduce the chance of induced voltage shocks.
- Circular Irrigation Systems
  - Locate the sprinkler heads so that they never spray water on the transmission lines. When this is not practical the distances given in Table AGA-5 must be used between nozzle and centerline of the transmission line.
  - To insure that a solid stream of water will not be projected into the transmission line, all nozzle risers that pass under a transmission line must be equipped with spoilers or automatic shut-offs in case a nozzle breaks or drops off.
  - The pivot of a circular irrigation system must be >20’ from the outside conductor to prevent water from a damaged pivot spraying into the conductors.

  Perform maintenance work preferably with the sprinkler pipe perpendicular and away from the transmission line. If this is not possible, use metal ground rods to electrically ground each length before decoupling the system.
- High Volume, High Velocity Systems
  - Follows standards of previous systems.
  - Exercise extreme caution when moving these systems under transmission lines. Small wheelbases make the system unstable on rough terrain and could cause the system to swing off balance lifting a piece of the system into the transmission lines.

Table AGA-5
Conductor to Nozzle Minimum Clearance – Utility 1

Sprinkler Nozzle Diameter (inches)	Horizontal Distance Between Nozzle and Centerline of Power Line (ft)			
	115 kV	230 kV	345 kV	500 kV
1/4	29	43	51	61
3/8	37	51	63	73
1/2	44	60	68	82
5/8	51	69	80	92
3/4	53	73	87	106
7/8	68	84	97	106
1	68	89	97	111
1 1/8	84	104	118	132
1 3/8	89	109	123	137
1 5/8	99	125	138	157
1 15/16	124	150	164	182

Logging

- Trees falling near and onto transmission lines pose extreme safety hazards. Extreme cautions must be used to prevent electrical shocks and power outages.
- Helicopter logging around transmission lines is extremely hazardous. Logs can slip through the chokes and land on power lines. Prior to any helicopter logging in proximity to power lines, contact the utility.
- Any power company and third party losses (such as lost revenues) due to service interruptions as a result of logging operations will be the responsibility of the applicant.
- Logging utilizing steel spars or cables is subject to significant electrical induction hazards in the vicinity of transmission lines.
- Trees must be felled away from the transmission facilities. In cases where this is not possible and a falling tree may encroach within the minimum electrical clearance to overhead electrical conductors, controlled directional falling methods must be used.
- Access to the ROW must not be restricted by logging activities.
- No storage of logs and debris within the ROW.

- Operators must ensure that there is no risk to the transmission facilities due to runaway equipment and/or logs.

Fences and Buildings

- See ROW Guide on Structures, Buildings and Fences (to be prepared).

Technical Background

Use of Vehicles and Large Equipment near Transmission Lines

Induction (Section 12.13.1, EPRI 2005, "Red Book")

Use of vehicles and large equipment on transmission-line rights-of-way gives rise to two safety concerns: inadvertent electrical contact with energized conductors, and capacitive coupling of currents and voltages to these large objects. Electrical contact with transmission-line conductors can produce fatal shocks for persons on or near a vehicle. Induced currents and voltages on large vehicles represent a potential source of nuisance or hazardous shocks when contacting the vehicles (Section 7.8, Red Book). Under extremely rare circumstances, spark discharges associated with induced voltages can also cause fuel ignition (Section 7.14.1, Red Book).

Electrical safety codes are intended to minimize the occurrence of situations that give rise to electrical contact and induction hazards. In addition, strict adherence to safe working practices near transmission lines is also required to ensure hazardous situations do not arise. Safe practices include limiting the height of vehicles, equipment and accessories, and booms, to maintain safe electrical clearances when passing under conductors. Reduced ground clearances must be anticipated in areas with heavy snow accumulation.

In the United States, the National Electrical Safety Code (NESC) specifies the minimum clearance required for conductors over various areas such as roads and highways, railroads, bodies of water, and areas accessible to pedestrians only (IEEE 2002). These clearances are intended to provide safe electrical clearances for typical equipment, vehicles, and sailboats passing under the lines. Agricultural equipment can be quite high so that electrical contact is the primary safety concern for the equipment, although electrical induction is also a concern for irrigation equipment, fencing and buildings (Section 12.13.2, Red Book).

Although personal safety is the primary concern, when the agricultural activities include livestock, the comfort and safety of the livestock are also of concern to the agricultural operator. The limits of induced voltages and currents may require lower limits with some livestock to avoid unsettling them. Induction related shocks can disturb some animals and it may be necessary to improve grounding or use localized insulating materials such as gravels.

Induced Currents from Vehicles and equipment (Section 12.13.2)

For lines with voltage greater than 98 kV ac to ground, the NESC limits the induced short-circuit current to the largest vehicle anticipated under the transmission line. The maximum allowed short-circuit current is 5 milliamperes (mA). This 5 mA criterion needs to be evaluated for the anticipated types of agricultural equipment since access to the ROW by the farm operator is usually uncontrolled.

For a person to actually experience the maximum short-circuit current requires a very-well-insulated large vehicle and a well-grounded person. Occurrence of these two conditions is highly unlikely. In addition to the induced current, very perceivable and probably annoying spark discharges generally serve as a warning of the presence of annoying contact currents (Section 7.10.5, Red Book).

The 5 mA criterion approximates the let-go current threshold for 99.5% of children; in other words, only 0.5% of children would be unable to release a gripped contact at this current level (Reilly 1992, p. 435). The Underwriters Laboratories uses a limit of 0.5 mA for continuous currents from hand-held appliances. This is the level at which most people can perceive a continuous current through their hands. Although a startle reaction with unintended movement is possible at the 0.5 mA level, it is not likely (Reilly 1992, p. 434).

An estimate of the short-circuit current from a vehicle requires both the electric field in the area of the vehicle and the size of the vehicle (Section 7.8, Red Book). The specified condition for computing the maximum induced current to a vehicle is with the line operating at maximum voltage and conductors at final unloaded sag at 50°C.

Estimates of the short-circuit current from a vehicle assume that the entire induced current to the vehicle passes through a person to ground. This is equivalent to no leakage current through the vehicle tires and zero impedance for the current path through the person. This is a worst-case estimate of the current that could pass through a person touching an ungrounded vehicle. In realistic situations, there is finite resistance to earth through the vehicle tires that offers an alternative current path.

Many agricultural vehicles operating on soil are likely to have low resistance to ground. Dragging a chain from a vehicle, which is insulated from ground, is a commonly recommended method of reducing nuisance shocks for such vehicles under transmission lines. However, the effectiveness of such a method has not been substantiated.

The impedance of the person to ground may be substantial due to contact resistance between the shoes and ground or the resistance of the shoes themselves (Section 7.8.5, Red Book). The impedance of a thin, highly resistive layer on the surface of the earth can also limit current flow during contact (Section 12.2, Red Book). Both of these practical conditions (vehicles not well insulated and person not well grounded) will tend to reduce the current through a person touching a vehicle in an electric field to values well below the worst-case short-circuit current (Section 7.8.5, Red Book). Reported short-circuit current measurements on various realistic surfaces indicate that, for realistic conditions, the actual currents from vehicles to persons would generally not be perceptible even when the worst-case short-circuit current approaches the 5 mA criterion (Section 7.8.5, Red Book).

The most common agricultural sources of induced currents and voltages are buildings, irrigation equipment and fences. These hazards can be managed by designing adequate grounding systems.

Spark Discharges (Induced Voltages) from Vehicles (Section 12.12.3, Red Book)

As an insulated person contacts a grounded vehicle or as a grounded person touches an insulated vehicle in a 60-Hz electric field, a series of spark discharges may occur across the air gap between finger or hand and the vehicle. After contact is established, a steady-state current flows. The intensity of the spark discharge depends on the field level, the voltage difference between person and vehicle, the level of insulation of person and vehicle, and the size of the electrically ungrounded vehicle. Perceivable spark discharges occur for contacts with other objects under transmission lines, such as fences or blades of grass. However, contacts with passenger, commercial, and farm vehicles probably represent the most common source of concern and complaints about nuisance shocks.

Reaction to spark discharges can range from imperceptible, to perceptible, to annoying, and to a startle with inadvertent movements (Section 7.10.5, Red Book). Individuals vary widely in their response to spark discharges. The level of response is dependent on the voltage between the person and object, the capacitance of the charged object, and the leakage resistance of the charged object (Reilly 1992, p. 347). For example, the voltage threshold for perception of repetitive 60-Hz discharges (from a constant capacitance) decreases as the leakage resistance decreases.

An example of the evaluation of the response to spark discharges from a charged gutter is provided in Section 7.10.5 of the Red Book. The approach used for the gutter can easily be applied to vehicles. As with induced currents, the actual value for the induced voltage on an object is usually much reduced from the worst-case situation with the object perfectly insulated from ground. This leads to a reduction in the level of response to potential spark discharges from that under worst-case conditions. Figures 7.8-20 to 7.8-22 in the Red Book provide statistical distributions for person-to-vehicle voltages under practical conditions.

Fuel Ignition (Section 12.13.4)

It is extremely unlikely that conditions for fuel ignition by a spark discharge from an insulated vehicle to ground will occur in an electric field under a transmission line, and no such event has been reported. Nevertheless there are ideal conditions under which such an event could occur. In addition, the possibility of fires during refueling is not limited to those ignited by spark discharges. Therefore utilities often recommend against refueling under transmission lines for both public safety and line reliability reasons.

Agricultural Activities (Sections12.12.1 and 12.13.5, Red Book)

Concerns related to the use of ROW for agricultural activities are physical damage to transmission-line structures, exceedance of the 5 mA criterion for large vehicles, opportunities for person or livestock contact to equipment and facility in high electric fields that produce nuisance shocks, and vehicle fires arising from fuel ignition. By increasing human and animal activity under energized lines, agricultural activities can also increase the opportunities for unsafe activities that are hazardous whenever they occur near transmission lines. Some of these would include unauthorized tower climbing, use of heavy tilling or harvesting equipment immediately adjacent to towers and guys, or transport of excessively tall objects under lines. Physical access to towers can be limited by no-vehicle zones around towers and anti-climbing barriers. Warning signs can also be used to advise the public of unsafe activities.

Induction effects related to electric fields can be controlled by exclusion of vehicles above a certain size from areas of peak field intensity or by reducing the fields on the ROW where agricultural activities are planned. One approach is to apply the NESC clearance for road crossings that is based on the 5 mA short-circuit current criterion. However, because of the expense involved, it is most practical to limit the agricultural activities to those which do not involve large equipment, where this is a concern.

Other issues that relate to agricultural operations near power lines include: (1) possible biological effects on plants, wildlife, and domestic animals; (2) the use of motorized equipment; (3) the possibility of shocks from metallic objects such as vehicles, fences, and support structures for crops; (4) the safety of using spray irrigation systems; and (5) interference with the operation of magnetically guided cornering arms associated with center-pivot irrigation systems.

The first issue on biological effects is really outside the scope of this document. However, because the literature is not very well known, it is useful to refer to a relatively recent review of the literature (Lee et al. 1996). In this review, the authors concluded that plants growing near transmission lines generally experienced no adverse effects of power frequency electric and magnetic fields. One effect that was observed was damage due to corona on the sharp tips of leaves and branches (see Section 7.15.3, Red Book). Honeybee hives were adversely affected by electric-field-induced shocks and current, but these effects can easily be mitigated by shielding. Finally, relatively few effects on wildlife and domestic animals have been reported.

The use of motorized equipment under transmission lines raises two questions. The first is the clearance required between them and the power line. The second is the possibility that a person who touches the equipment will experience either a transient or steady-state shock due to electric field effects.

Utilities that have a considerable amount of irrigated land within their service areas have conducted research on, and developed policies for, the installation and operation of irrigation systems near their transmission lines (BPA 1978; Starr et al. 1969; Ewy et al. 1981). In addition, the IEEE Corona and Field Effects (CFE) Subcommittee held discussions on this topic. While the results of these discussions were not published, they represent the thinking of a group of

IEEE members on this subject. The following is a summary of the findings of the above-mentioned research and the IEEE discussions.

First, it was recommended that the minimum distances shown in Table AGA-6 be maintained between irrigation pipes or equipment and energized conductors. Since the height of conductors can change with the electrical load on the line, it is important to know the minimum height of the line before applying the distances in Table AGA-6. Further, according to the Bonneville Power Administration (BPA) policy, "all metal pipe lines, electrical power cables and communication cables should be kept 16 meters (53 feet) from any part of a BPA structure including any grounding system and perpendicular to the transmission line centerline" (BPA 1978). Finally, any underground water supply piping, electric power cables, and communication cables crossing the right-of-way should do so at an angle of not less than 60º to the centerline of the transmission line and buried, if possible, a minimum of 2 ft underground.

Table AGA-6
Minimum Separation Distances between Irrigation Equipment and Energized Conductors
(Table 12.12-1, Red Book)

Voltage (kV)	Minimum Distance
765	7.30 m (24 ft)
500	5.79 m (19 ft)
345	4.88 m (16 ft)
230	4.26 m (14 ft)
138	3.66 m (12 ft)

(Note that these distances should never be measured with devices such as tape measures, poles, etc.)

It was also recommended that, to avoid nuisance shocks, the unloading of irrigation pipe sections from a vehicle should be done at least 15.24 m (50 ft) horizontally from the nearest conductor. The pipe and other large objects should always be carried in a horizontal position. Caution should also be used when touching irrigation equipment used near power lines. To avoid nuisance shocks, it is essential that the equipment be grounded. However, when long pipes (such as with center-pivot systems) are used, magnetic fields from power lines can induce voltages at the ungrounded end (if the irrigation system is parallel to the power line). Thus these ends should not be touched, and for maintenance, the long pipe should be oriented perpendicular to the transmission line to minimize magnetic-field induction.

Operation of Irrigation Equipment (Section 12.12.2, Red Book)

Whenever possible, it is recommended that irrigation systems be operated so that there is no direct contact between the stream of water and the power line. A continuous stream of water should never be directed at energized conductors. However, when irrigation nozzles cause the water to break up into a spray, the probability of line-to-nozzle flashover is greatly reduced (Starr et al. 1969; Ewy et al. 1981). Thus, it is important that the irrigation system be designed to produce a spray rather than a continuous stream. Generally, any obstruction or discontinuity in the pipes, hoses, and nozzle (such as a ring insert) will cause breakup of the water stream.

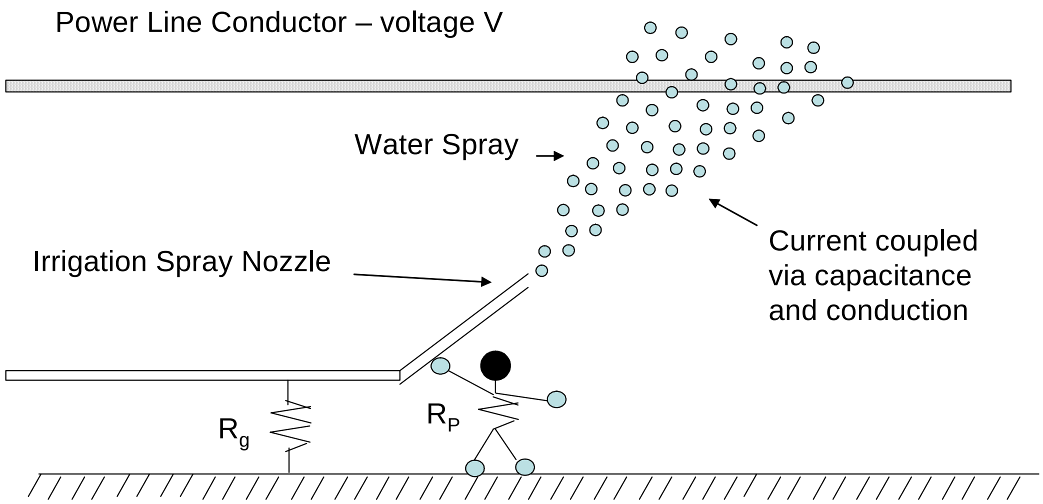


Figure AGA-1
Illustration of current flow through spray, irrigation ground and person to ground
(Figure 12.12-1, Red Book)

The work of Starr et al. (1969) and Ewy et al. (1981) on determining minimum conductor-to-nozzle distances for safe operation of the irrigation system when the stream is in contact with an energized conductor can be summarized in the following way. Since it is nearly impossible to model the impedance of the spray, these results are based on measurements of leakage current flowing from the transmission line through the water spray (via conductance through droplets and capacitance between them) and to ground via the irrigation system. When a person touches the irrigation hardware, a portion of this current flows through him/her to ground. The process by which this occurs is illustrated in Figure AGA-1. The fundamental criterion on which the recommendations are based is that this current through the person should not exceed 5 mA. Some example results are given in Table AGA-7. For these calculations, it has been assumed that the person's body resistance is 1500 , the irrigation system ground resistance is 10 , the water conductivity is 1200 µS/cm, and the water pressure is 80 psi.

Table AGA-7
Conductor-to-Nozzle Distance for Water Spray
(Table 12.12-2, Red Book)

Nozzle Diameter mm (in.)	Conductor-to-Nozzle Distance,[1] m (ft)					
	115 kV	**138 kV**	**230 kV**	**345 kV**	**500 kV**	**765 kV**
19.5 (0.75)	3.66 (12.0)[3]	3.66 (12.0)[3]	3.66 (12.0)[3]	4.7 (15.4)	6.4 (21.0)	7.8 (25.6)
22.9 (0.9)	3.66 (12.0)[3]	3.66 (12.0)[3]	5.2 (17.1)	6.9 (22.6)	9.2 (30.2)	10.7 (35.1)
27.9 (1.1)	4.2 (13.8)	5.0 (16.4)	7.3 (23.9)	9.2 (30.2)	11.2 (36.8)	12.6 (41.3)
35.6 (1.4)	5.69 (18.7)	7.0 (23.0)	10.7 (35.1)	13.8 (45.3)	17.3 (56.8)	19.7 (64.6)
40.6 (1.6)	6.19 (20.3)	8.8 (28.9)	13.4 (44.0)	17.3 (56.8)	21.0 (56.8)	22.9 (75.1)
49.0 (1.93)[2]	6.19 (20.3)	9.0 (29.5)	13.4 (44.0)	16.7 (54.8)	19.9 (65.4)	22.1 (72.5)

1. For water spray, the water stream is broken up so there is no solid and continuous stream.
2. Ring insert.
3. Limited by regulations (OSHA).

Interference with Cornering Guidance Systems (Section 12.12.3, Red Book)

For many years, center-pivot irrigation systems have been used to provide automated uniform irrigation of agricultural fields. These systems consist of a long pipe mounted on motor-driven wheels (Figure AGA-2). The system is driven in a circle around a field as shown in Figure AGA-3. Water is connected to the pivot point at the center and sprayed on the field as the system rotates around the field. Since some of these systems are located near high-voltage transmission lines, questions have been raised about the potential for flashover initiation, the potential for shock hazards for personnel touching the system, and proper techniques for handling irrigation pipe. Responses to these questions have been summarized above.

One drawback of center-pivot irrigation systems is that most plots of land are square or rectangular in shape, while the footprint of the land irrigated by the system described above is circular. Thus, land in the corners of the field is not well irrigated. To resolve this problem, manufacturers developed “cornering” systems that consist of an additional length of pipe at the end of the system that can be swiveled with respect to the main pipe. This type of system is pictured in Figure AGA-2 and diagrammed in Figure AGA-3. The swiveling pipe tends to align with the main section of pipe when in a corner of the field and thus extends the length of the system into the corner (condition “a” in Figure AGA-3). The swiveling pipe is perpendicular to the main section of the pipe when the system passes to the short edge of the field (condition “b” in Figure AGA-3).

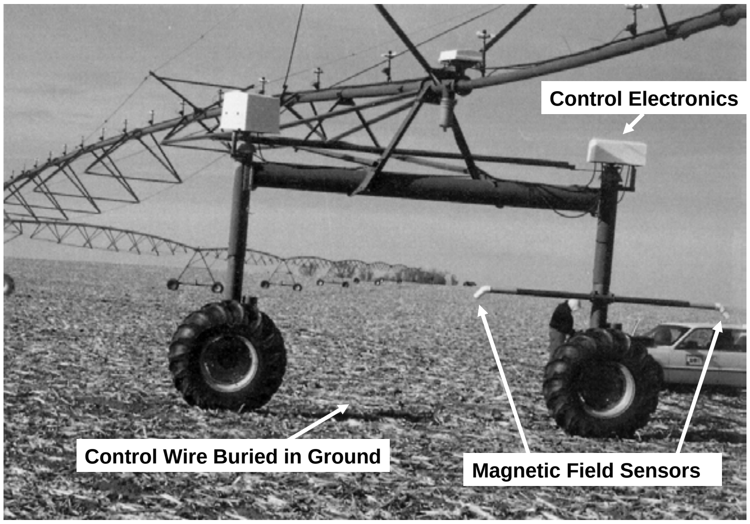


Figure AGA-2
A center-pivot irrigation system
This particular one is a cornering unit with a section of pipe near the end that can rotate separately to fill in the corners of the field as shown in Figure AGA-3. (Figure 12.12-2, Red Book).

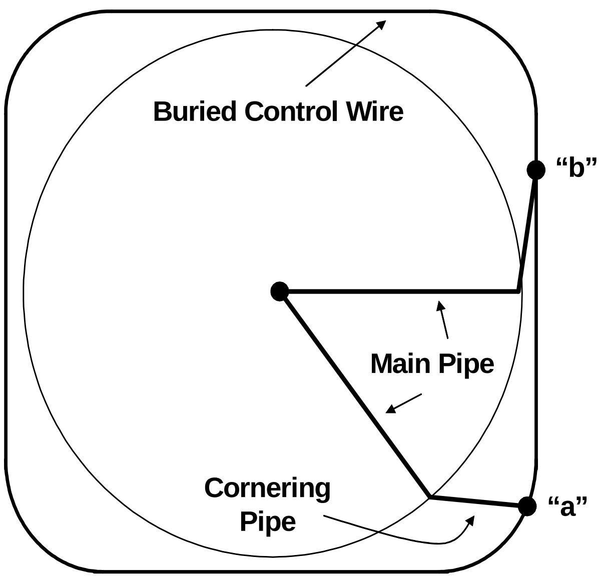


Figure AGA-3
Diagram of a corner irrigation system from above
(Figure 12.12-3, Red Book)

The orientation of the swiveled corner pipe is controlled by a magnetic-field guidance system. The guidance system employs a buried wire that carries a 1000-Hz current. More details of such systems can be found in (Olsen and Heins 1998). Although the system is designed to follow the 1000-Hz magnetic field, a strong 60-Hz field can interfere with the system. Thus, the operation of these systems near power lines can, in principle, be compromised.

Tests with one system indicated that a 50 µT magnetic field at 60 Hz was required to interfere with the operation of the guidance system (Olsen and Heins 1998). Of course, other manufacturers' systems may be designed with different filtering systems and hence may have different thresholds.

Buildings (Section 12.14, Red Book)

Whether structures are allowed on the right-of-way or not is determined by the operator for lands owned in fee and otherwise by language in the easement agreement. Generally, buildings are not allowed under transmission lines in the United States. In other countries, buildings may be permitted on rights-of-way. The presence of buildings raises issues related to the reliability of the transmission line and the safety and annoyance of occupants.

Combustible materials, including structures, are generally prohibited from transmission-line rights-of-way to minimize the chance of fire. Flames or smoke can cause a flashover to ground. The presence of buildings also increases the level of human activity under and near transmission line, with opportunities for hazardous or unsafe activities. Of special concern is the possibility of a person upending a long object and reaching unintentionally near the conductors (to within the flashover distance of the conductors). Construction of buildings on a right-of-way can also encroach on required safe electrical clearances and increase the required height of the conductors above ground.

Many of the safety and annoyance issues for occupants of structures near transmission lines are discussed in various chapters of the Red Book: electric and magnetic field induction effects in Chapter 7; interference with computer monitors in Appendix 7.4; electromagnetic interference, including radio and television interference, in Chapter 9; and audible noise in Chapter 10.

Induced current and voltage shocks from building components are possible even in the reduced electric field beyond the edge of the right-of-way. Such shocks can lead to inadvertent startle responses that could be hazardous. For example, a startle response while on a ladder cleaning gutters or installing an antenna could increase the risk of falling. Grounding of conducting building components, such as gutters, metal roofs, and metal siding, may be necessary to eliminate these objects as potential sources of shocks. However, this grounding does not remove the startle response initiated by the induced voltage shocks received by an insulated person touching a grounded building component. Electrically bonding the person to the grounded building component is the only way to eliminate such a hazard. Depending on the size of the component, grounding may be required off the right-of-way. Metal window frames or other conducting objects that penetrate the walls of a structure can be a source of shocks inside a structure as well as outside. Formulae for the charge collecting areas and spark-discharge capacitance of various structural components and shapes are described in Table 7.8-1 of the Red Book.

The electric field on the roofs of buildings adjacent to transmission-line rights-of-way will be increased from the field at ground level. Consequently, construction and maintenance activities on the roof may require special precautions to avoid nuisance shocks. For example, grounding sheet metal ducting and other large metal objects may be required during installation.

Conducting metal objects are generally well separated from transmission-line structures. However, as houses and other buildings are placed along the edges of rights-of-way, separation requirements may be violated. When a fault to ground occurs at a tower with a nearby, long conducting object, a hazardous voltage may be transferred to distant points, as described for pipelines in Section 12.3 of the Red Book. Similarly, hazardous conditions may arise when a grounded fence passes near a faulted tower and is also near or attached to a building. In such cases, the increased voltage at the transmission tower (or a portion of this voltage) may be transferred to the distribution line and internal building wiring designed for lower voltages. The result can be damaged equipment or fire as the insulation level of the lower voltage wires is exceeded, or possibly a severe shock if someone is in contact with the affected wiring.

Technical Evaluation

See Flowchart for Evaluation and Approval Process in the Administrative Guide.

Solicit inputs on issues and concerns from all impacted departments.

Prepare Engineering Evaluation

- Check operating clearances
  - Determine type of agricultural activity - there are many activities which are minimal or no risk and can be approved without further evaluation. A list of these with criteria attached can be prepared in advance to avoid costly and time consuming evaluation.
  - Determine line voltage.
  - Determine location, span, structure numbers.
  - Get design profile / mapping.
  - Plot encroachment on profile.
  - Measure conductor to ground clearance.
  - Add tolerance.
  - Compare to minimum operating clearance.
  - If clearance is marginal, do conductor thermal study.
  - If clearance is insufficient, suggest alternative location, lower ground elevation, raise conductors.
- Check industry work standards
  - Determine line voltage.
  - Refer to industry/electrical safety regulations for minimum working clearance to transmission conductors.
- Check future line criteria
  - Review electric system plan for future lines on ROW.

  - Contact System Planning for updated information.
- Check plant protection and internal policies and standards
  - Ensure ROW use/encroachment is a minimum of _____ ft horizontally from any transmission structure.
  - Specify structure protection if necessary (e.g., secure fencing of the equipment box).
  - Review power company policies (e.g., refer EMF concerns to EMF Project Manager).
  - Check if good engineering practice.
  - Environmental/social acceptability.
  - Compliance with local and national codes (e.g., fire and electrical codes).
  - Review induction and grounding concern.
- Check hard criteria
  - Clearance to vehicle and equipment (including load and reach) must exceed the minimum operating clearance.
  - Maximum induced current from the largest anticipated vehicle and equipment must be below 5 mA.
- Check soft criteria
  - If clearance is insufficient, suggest alternative location, lower ground elevation, raise conductors.
  - Increase tolerance to nuisance shocks by increasing electric field limit criteria (if acceptable).
- If estimate required – refer to Transmission Project/Construction.

Assemble Responses and Engineering Evaluation

- Assemble responses from all departments and assure all pertinent technical issues are addressed.
- Select applicable general conditions.
- Compile all findings.

Prepare Engineering Report and Recommendations

Analysis criteria shall include standards of acceptance and the following as a minimum:

- Conductor to ground clearance.
- Horizontal clearances from conductors, structures and related plant.
- Local, national and internal standards.
- Work safety regulations.

- Access for maintenance.
- Provision for future plant.
- Environmental protection.
- Public image.
- Assessment of technical risk issues.
- All relevant information received from others.

Review Report

- Review report for accuracy, consistency and coverage.
- Transmit report to Property Services with copies to appropriate internal stakeholders.

Related Guidelines, Standards and Documents

Internal guidelines should be established and used for all installation on power company ROWs. The following is a list of relevant internal guidelines covering topics such as:

- General conditions
  - Contact the power company at least ______ days prior to working on ROW.
  - Power company not responsible for damage to works caused by normal activities.
  - Power company reserves the right to terminate consent.
  - Applicant responsible for all costs for plant alterations/protection.
  - Below ground works must be designed to withstand heavy loads (e.g., large maintenance equipment).
  - "As constructed" drawings required within ____ days.
  - Works must not approach within ______ ft of power company plant.
  - Survey plan of works is required showing relation to ROW boundaries and transmission structures.
  - Remove or relocate works upon issue of ____ days' written notice from the power company.
  - Works must not be enlarged, moved or added to without the consent of the power company.
  - Metal fences must be grounded according to the power company guidelines.
- Personal safety
  - Safe working distance from transmission line conductors (e.g., 20’ for 500 kV lines).
  - Maximum height of vehicles, including load and reach, not to exceed _____ ft.

  - No refueling of vehicles within the ROW.
  - Levels of induction in objects near transmission lines.
  - Long non-electric metallic fences paralleling transmission lines must be sectionalized and isolated with insulators and then grounded to avoid induction hazards. Maximum length of fence sections shall be _______ ft.
  - Electric fences exceeding _____ ft must be grounded through electric fence (power frequency) filters to avoid induction hazards.
  - Work practices to avoid contact to conductors must be established (e.g., do not up-end irrigation pipes when working near powerlines).
  - Safety procedures for unplanned mishap such as when a water stream accidentally hits the conductor.
  - Produce a public document on work practices near powerlines (e.g., do not disrupt the irrigation system ground; move irrigation pipes in a horizontal position; load, unload and store irrigation pipes at least ____ ft from the powerlines; do not use the irrigation system in stormy weather; be aware of changing spray angle when using irrigation system on uneven ground).
  - Induction in metallic irrigation pipes and current flow through water spray discussed in the Technical Background Section must be managed.
  - Grounding of metallic sheathed buildings or linear metallic elements of buildings (such as eave troughs) is necessary to avoid induction hazards.
- Plant security and maintenance
  - Access to be maintained.
  - Grade elevation changes not to exceed _____ ft.
  - Encroachment is a minimum of _____ ft horizontally from any transmission structure.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - Trees, shrubs and plants not to exceed _____ ft (e.g., 10') in height at maturity.
  - Temporary or permanent structures larger than __(size and height)__ are not allowed on ROW.
  - Barriers or markers to limit approach distances of farm equipment to structures and guys.
  - There have been cases of livestock using guys for scratching/rubbing and it may be necessary to install livestock guards around guys.

Relevant transmission maintenance and construction standards covering topics such as:

- Working clearances from energized conductors.
- Minimum operating line to ground clearances.
- Grounding of fences, buildings and objects on or near transmission facilities.

- Safe operation of irrigation equipment near transmission lines.

National, state and local relevant industry standards and codes covering topics such as:

- National Electric Safety Code.
- Fire and electrical codes.
- Work regulations or electrical safety code for working near energized conductors.

Other references:

BPA 1978. “Guidelines for the Installation and Operation of Irrigation Systems near High Voltage Transmission Lines,” *Bonneville Power Administration*, Portland, OR.

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Lee, J. M., K. S. Pierce, C. A. Spiering, R. D. Stearns and G. VanGinhoven. 1996. “Electrical and Biological Effects of Transmission Lines: A Review.” *Bonneville Power Administration,* Portland, OR, December.

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Starr, E. C., J.J. Managan, W. L. Boling, A.L. Kinyon and F. Chambers. 1969. “Electrical Conducting and Flashover Characteristics of Large Irrigation Sprinkler Water Streams near High Voltage Transmission Lines.” *IEEE Transactions on Power Apparatus and Systems*, Vol. PAS-88. pp. 141-146. February.

Attachments

- Frequently asked questions.
- Definitions/glossary.
- Terms of reference.

G
ADMINISTRATIVE GUIDE - PARKING FACILITIES

Scope

This guide outlines the activities required for evaluating requests for parking facilities (including road crossings) on rights-of-way ((ROW) or fee-owned land. It outlines the conditions under which the proposal may or may not be approved, and the administrative approval process.

Purpose

- Ensure public safety.
- Ensure safe working conditions for electric utility and third party personnel.
- Ensure a uniform review, evaluation and approval process.
- Ensure power system reliability and safe operation of the transmission lines.
- Ensure access for transmission maintenance, future expansions and modifications.
- Ensure plant security.
- Ensure uncompromised power transmission capability.
- Ensure compliance with all applicable codes, standards, regulations, laws and ordinances.
- Protect the property rights of the power company.
- Protect the electric utility's ability to construct future works.
- Protect the natural environment, habitat and wildlife.
- Promote positive public image by allowing multiple use of the ROW for compatible public activities.

Policy

Requests for parking facilities on rights-of-way or fee owned land shall be processed through the administrative procedure established in this document to ensure that all affected groups have the opportunity to review and approve or disapprove the proposal.

The department receiving the inquiry will determine, with appropriate consultation, whether the proposal has a minor or significant impact and follow the administrative procedure in this document.

For encroachment that needs approval on a site-specific basis, detailed construction drawings are to be submitted to the power company for approval, at least _(lead time)_ in advance of construction. The power company will arrange for Engineering, Legal, Operational and others as appropriate to review the proposal. No work shall proceed until approval has been granted. This procedure ensures that all affected departments have the opportunity to review and approve or disapprove the proposal.

Responsibilities

Here is an example showing the responsible functions which may be assigned in the review and approval process:

- Civil Design - foundations, structural or geotechnical concerns.
- Station Design - impacts to substation.
- Cable Design - impacts to underground works.
- Electrical Design - studies related to induction, grounding, clearance, conductor thermal rating.
- System Planning - anything that affects future plant.
- Environmental Services - environmental compatibility concerns.
- Survey and Photogrammetry - detailed field measurements and mapping.
- Property/Real Estate/Legal Services - land rights, liabilities and legal information, maintaining records and correspondence with applicants.
- Field resources - site-specific information.

Requirements

- Maintain property rights of the power company.
- Compliance with fire and electrical codes.
- Personal safety
  - All parked vehicles must meet the minimum safe working distance from transmission line conductors (e.g., 20’ for 500 kV lines).
  - Maximum height of vehicles, including load and reach, not to exceed _____ ft (e.g., 13.5’ for the maximum height of the vehicle plus a soft criterion of ______ ft, e.g., 6.5’, as a buffer distance for reducing the probability of flashover as a result of tall objects such as a tall antenna protruding above the height of the vehicle.)
  - No refueling of vehicles within the ROW.
- Plant security and maintenance

- Access to transmission structures must be unobstructed at all times.
- Grade elevation changes not to exceed _____ ft (e.g., 1.5’).
- A ____ ft zone for access and security must be maintained around all transmission structures (towers, poles, anchor wires and rods).
- Protective barriers must be installed for transmission structures, if required by the power company.
- No deterioration of drainage patterns or soil stability.
- ROW to be restored to transmission specifications at applicant's expense.
- No landscaping, trees, shrubs and plants must exceed _____ ft (e.g., 10’) in height at maturity on the ROW.
- No storage of materials on ROW unless approved by the power company.
- No temporary or permanent structures larger than _(size and height)_ are allowed on the ROW unless approved by the power company.

Related Guidelines, Standards and Documents

Internal guidelines should be established and used for all installation on power company ROWs. The following is a list of relevant internal guidelines covering topics such as:

- General conditions
  - Contact the power company at least ______ days prior to working on ROW.
  - Power company not responsible for damage to works caused by normal activities.
  - Power company reserves the right to terminate consent.
  - Applicant responsible for all costs for plant alterations/protection.
  - Works must not approach within ______ ft of power company plant.
  - “As constructed” drawings required within ____ days.
  - Survey plan of works is required showing relation to ROW boundaries.
  - Remove or relocate works upon issue of ____ days' written notice from the power company.
  - Works must not be enlarged, moved or added to without the consent of the power company.
  - Metal fences must be grounded according to the power company guidelines.
- Personal safety
  - Safe working distance from transmission line conductors (e.g., 20’ for 500 kV lines).
  - Maximum height of vehicles, including load and reach, not to exceed _____ ft.
  - No refueling of vehicles within the ROW.

- Levels of induced voltage and current in objects near transmission lines.

- Plant security and maintenance
  - Access to be maintained.
  - Grade elevation changes not to exceed _____ ft.
  - Encroachment is a minimum of _____ ft horizontally from any transmission structure.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - Trees, shrubs and plants not to exceed _____ ft (e.g., 10') in height at maturity.
  - Temporary or permanent structures larger than __(size and height)__ are not allowed on ROW.

Relevant transmission maintenance and construction standards covering topics such as:

- Working clearances from energized conductors.
- Minimum operating line to ground clearances.
- Grounding of fences, buildings and objects near transmission lines.
- Safe operation of Irrigation equipment near transmission lines.

National, local and industry standards and codes covering topics such as:

- National Electric Safety Code.
- Fire and electric safety codes.
- Work regulations or electrical safety code for working near energized conductors.

Administrative Procedure

Approval without review can be granted when there are no violations in the requirements. Otherwise, the request must be referred to various departments for review and approval. See Flowchart for evaluation and approval process.

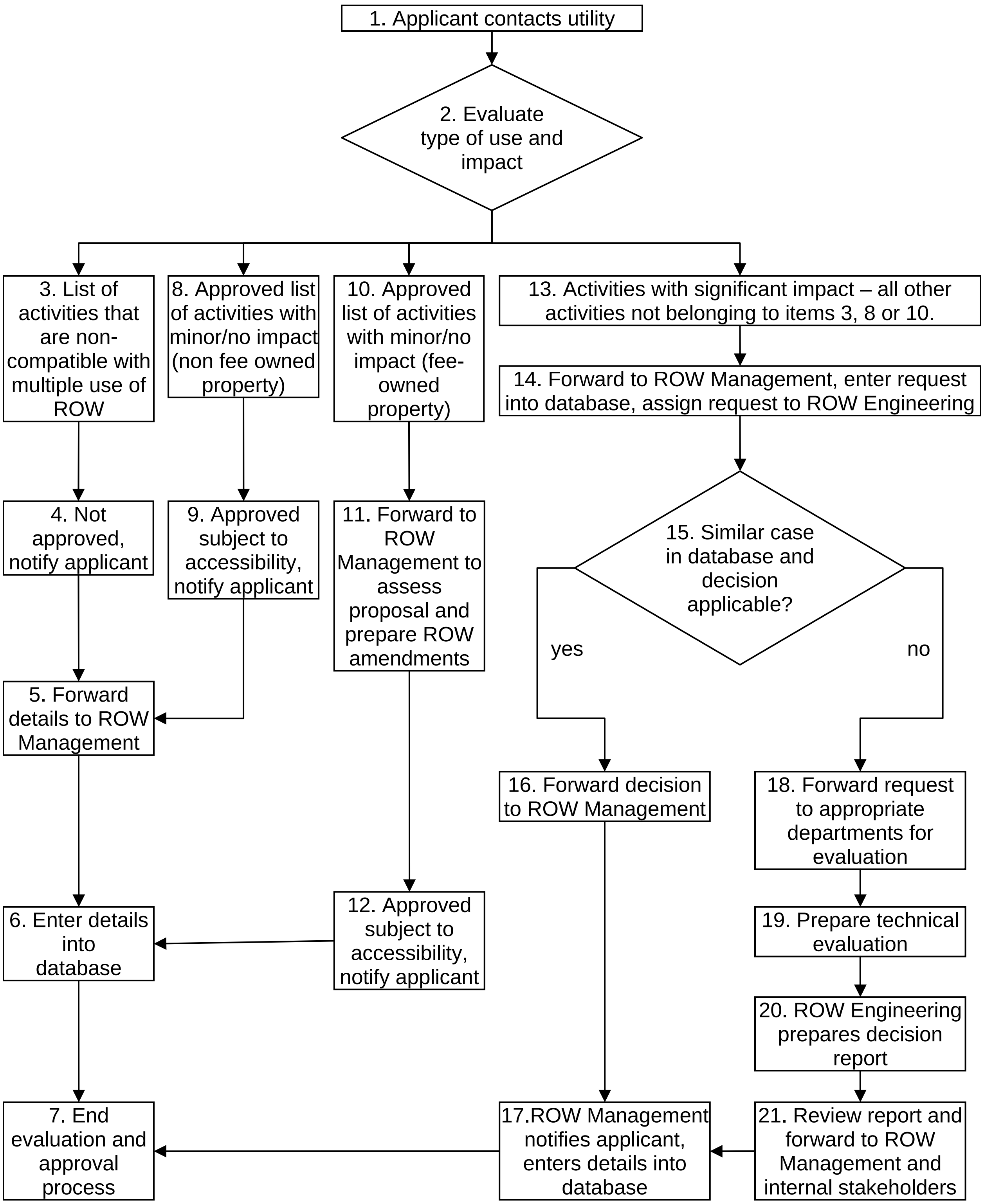
- Receive application, enter into log book and data base recording the following minimum information:
  - Property contact.
  - Engineering contact.
  - Type of use.
  - Applicant.
  - Landowner.
  - Location.

  - Transmission circuits.
- Assign request
  - Determine level of complexity.
  - Determine other stakeholders.
  - Determine need for other information from Applicant.
- Determine type of use
  - Access previous similar requests in database.
  - Confirm development on ROW.
  - Confirm civil engineering impact (e.g., foundation, roadwork, soil effects); transmit request to Civil Design.
  - Confirm property impact (e.g., future expansion); transmit request to System Planning.
  - Confirm development on station property, transmit request to Station Design.
  - Confirm significant environmental impact; transmit request to Environmental Services.
- Prepare engineering (technical) evaluation (See Technical Guide for details)
- Assemble responses and engineering evaluation (See Technical Guide for details)
- Prepare engineering report (See Technical Guide for details)
- Review report (See Technical Guide for details)
- File report
  - File hard copies of report, original request, departmental responses, marked location maps, profiles and other related documents to ROW Engineering files.
  - Log completed report into ROW database with a case number.
  - Enter email correspondence, requests and all electronic documents into ROW database.
  - The approved cases can be kept for future reference.

Attachments

- Frequently asked questions.
- Definitions/glossary.
- Terms of reference.

Flowchart for Evaluation and Approval Process for Parking Facilities



Notes for Flowchart:

1. Applicant contacts utility and seeks approval for using the ROW.

2. The office receiving the request evaluates the type of use and classifies the request into one of the four categories: a) Not Approved (non-compatible usage), b) Approved (minor or no impact) on non fee-owned property, c) Approved (minor or no impact) on fee-owned property, and d) Further Review (significant impact, require technical evaluation).

3. **Activities that are non-compatible** with multiple use of the ROW are not approved. A utility sets its own criteria and its own list of activities under this category, for example:
   - Permanent buildings and structures.
   - Anything that is too close to structures or conductors.
   - Storage of flammable, explosive or environmentally unfriendly materials or conditions.
   - Installation of most low voltage electrical wiring.
   - Any land use that extinguishes the utility rights.
   - Anything that impacts the utility's flexibility to install future plant.

4. Requests for non-compatible use of the ROW are not approved. Notify applicant.

5. Forward case details to the ROW Management Department.

6. ROW Management enters details into the database for record keeping, future reference and information retrieval (e.g., property contact, type of use, applicant, landowner, location, transmission circuits, and final decision.).

7. End of the evaluation and approval process.

8. **Minor/no impact on non fee-owned property** refers to those activities that meet the utility's standards, guidelines and terms of the ROW agreement and do not require further review. A utility sets its own criteria and its own list of activities under this category, paying attention to concerns such as:
   - Maintain property rights of the power company.
   - Compliance with local/national fire and electrical codes.
   - Personal safety:
   - Plant security and maintenance

9. Activities falling under the approved list of activities with minor/no impact on non fee-owned property are approved without technical review provided access to utility facilities is maintained.

10. **Minor/no impact on fee-owned property** refers to those activities that meet the utility's standards, guidelines and terms of the ROW agreement and require only assessment by the ROW Management Department so that the appropriate ROW amendments and documentation are prepared. A utility sets its own criteria and its own list of activities under this category. The approved list of activities or criteria for this category may or may not be the same as those listed for minor/no impact on non fee-owned property. In addition, the administrative procedure requires the involvement of the ROW Management Department in the approval process for requests on fee-owned property.

11. The ROW Management Department assesses the proposal and prepares the appropriate ROW amendments and documentation.

12. Activities falling under the approved list of activities with minor/no impact on fee-owned property are approved by the ROW Management Department without technical review provided access to utility facilities is maintained. Notify applicant.

13. **Significant impact** refers to those activities that may affect items like the environment, future use, safety, plant security and accessibility. All other activities that do not fall under the non-compatible use or minor/no impact categories belong to this category. Activities belonging to this category require a technical evaluation process.

14. ROW Management enters details of the request details into the database (e.g., property contact, type of use, applicant, landowner, location, transmission circuits), evaluates the request, obtains additional information from the applicant (if necessary), determines who are the stakeholders, evaluates the level of complexity, and assigns the request to a technical individual in the ROW Engineering department accordingly.

15. ROW Engineering determines if similar cases exist in the database and if the decision made in a former case applicable today. Please note that a decision made previously may not be valid today due to possible changes in the evaluation criteria and/or company policies.

16. If the decision made in a former case is applicable today, no further technical evaluation is required. Forward the decision from a former case to ROW Management.

17. ROW Management notifies the applicant of its decision and enters details into the database for record keeping, future reference and information retrieval.

18. If no similar cases exist in the database or if the decision made in a former case is not applicable today, ROW Engineering confirms the needs for technical evaluation and prepares a referral package containing details of the application and background information (e.g., reference to the former cases, correspondence with the applicant). Forward the referral package to the appropriate departments for technical evaluation. See "Responsibilities" Section in the Administrative Guide for an example showing the responsibilities of the departments assigned in the evaluation and approval process.

19. Engineering and other departments prepare technical evaluations (e.g., check operating clearances, electrical parameters, industry work standards, future line criteria, plant protection and internal policies and standards). If underground, refer to Cables Design. If estimate required, refer to Transmission Project/Construction.

20. Assemble and compile responses from all departments. Prepare engineering decision report and recommendation using analysis criteria that include standards of acceptance as a minimum. See "Technical Evaluation" Section in the Technical Guide for more details.

21. Engineering reviews report for accuracy, consistency and coverage. Forward report to internal stakeholders and ROW Management. File all relevant materials. See "Administrative Procedure" in the Administrative Guide for more details.

H
TECHNICAL GUIDE - PARKING FACILITIES

Scope

This guide outlines the activities required for evaluating the technical compatibility of requests for parking facilities on rights-of-way (ROW) or fee-owned land. It outlines the conditions under which the proposal may or may not be approved, and the technical evaluation process.

Purpose

- Ensure public safety.
- Ensure safe working conditions for electric utility and third party personnel.
- Ensure a uniform review, evaluation and approval process.
- Ensure power system reliability and safe operation of the transmission lines.
- Ensure access for transmission maintenance, future expansions and modifications.
- Ensure plant security.
- Ensure uncompromised power transmission capability.
- Ensure compliance with all applicable codes, standards, regulations, laws and ordinances.
- Protect the property rights of the power company.
- Protect the electric utility's ability to construct future works.
- Promote positive public image by allowing multiple use of the ROW for compatible public activities.

Policy

Requests for parking facilities on rights-of-way or fee owned land shall be processed through a procedure established to ensure that all affected groups have the opportunity to review and approve or disapprove the proposal.

Requirements

- Maintain property rights of the power company.

- Compliance with fire and electrical codes.
- Personal safety.
- Safe working distance from transmission line conductors (e.g., 20’ for 500 kV lines).
- Maximum height of vehicles, including load and reach, not to exceed _____ ft.
- Plant security and maintenance
  - Access to transmission structures must be unobstructed at all times.
  - Grade elevation changes not to exceed _____ ft.
  - No parking within a zone of _____ ft horizontally from any transmission structure.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - No landscaping, trees, shrubs and plants must exceed _____ ft (e.g., 10’) in height at maturity on the ROW.
  - No refueling of vehicles or equipment on ROW.
  - No storage of materials on ROW unless approved by the power company.
  - No temporary or permanent structures larger than (size and height) are allowed on the ROW unless approved by the power company.

Common Utility Practices

- A radius of 50’from where each tower leg enters the earth, or 25’ from where each wood pole, or guy anchor enters the earth must be kept free from all parking and vehicular activities. If these clearances cannot be met, guard devices must be installed to protect transmission facilities.
- Protective barriers must be installed if parking area activities are <10’ to 50’ (a range of values from different utilities) from the transmission facilities.
- Protective barriers must be installed where necessary.
- A barrier, sufficient to withstand a 15 mph vehicular impact, must be erected to protect the pole or tower, and must be so placed to restrict parking to >5’ from the structure.
- Access to ROW must be maintained.
- Semi tractor-trailer trucks are restricted from parking where the electric field is >2.5 kV/m. The maximum electric field level for commercial/industrial parking lots is 2.5 kV/m.
- Vehicles equal or smaller in size than a pick-up truck with camper shell are restricted from parking where the electric field is >3.5 kV/m. The maximum electric field level for shopping center parking lots is 3.5 kV/m.
- The electric field must be <5 kV/m for all roads associated with the parking area.

- No through roads are allowed along the ROW; therefore, if the parking lot has multiple entrances, the lot must be so constructed that through traffic is not possible.
- Access is not permitted from a street directly onto the ROW. Lot access must be from the applicant’s property, and not from public streets which cross the utility’s property.
- If fences or traffic restrictors are placed across the ROW, an access gate >20’ must be installed.
- No storage of fuels or refueling of vehicles within the ROW.
- All parked vehicles must meet the minimum vertical and horizontal electrical clearance as specified by the utility’s electrical clearance requirements to its facilities.
- A 20’ zone for access is maintained around the structures, including anchor wires.
- Changes in elevation caused by paving must be approved by the utility.
- No change in soil stability and drainage pattern.
- Any access areas, entrances, or exits to the parking area must cross the ROW at or near right angles to the centerline, and must not pass within 20’ of any structure.
- Lighting structures >15’ are not allowed within the ROW.

Technical Background Information

Introduction (Section 12.13.1, EPRI 2005, “Red Book”)

Use of vehicles and large equipment on transmission-line rights-of-way gives rise to two safety concerns: inadvertent electrical contact with energized conductors, and capacitive coupling of currents and voltages to these large objects. Electrical contact with transmission-line conductors can produce fatal shocks for persons on or near a vehicle. Induced currents and voltages on large vehicles represent a potential source of nuisance or hazardous shocks when contacting the vehicles (Section 7.8, Red Book). Under extremely rare circumstances, spark discharges associated with induced voltages can also cause fuel ignition (Section 7.14.1, Red Book).

Electrical safety codes are intended to minimize the occurrence of situations that give rise to electrical contact and induction hazards. In addition, strict adherence to safe working practices near transmission lines is also required to ensure hazardous situations do not arise. Safe practices include limiting the height of vehicles, equipment, and accessories, such as antennas, masts, or booms, to maintain safe electrical clearances when passing under conductors. Reduced ground clearances must be anticipated in areas with heavy snow accumulation.

In the United States, the National Electrical Safety Code (NESC) specifies the minimum clearance required for conductors over various areas such as roads and highways, railroads, bodies of water, and areas accessible to pedestrians only (IEEE 2002). These clearances are intended to provide safe electrical clearances for typical equipment, vehicles, and sailboats passing under the lines.

Induced Currents from Vehicles

For lines with voltage greater than 98 kV ac to ground, the NESC limits the induced short-circuit current to the largest vehicle anticipated under the transmission line. The maximum allowed short-circuit current is 5 milliamperes or mA (Section 12.13.2, Red Book). This is one of the hard criteria for parking facilities.

For a person to actually experience the maximum short-circuit current requires a very-well-insulated large vehicle and a well-grounded person. Occurrence of these two conditions is highly unlikely. In addition to the induced current, very perceivable and probably annoying spark discharges generally serve as a warning of the presence of annoying contact currents (Section 7.10.5, Red Book).

The 5 mA criterion approximates the let-go current threshold for 99.5% of children; in other words, only 0.5% of children would be unable to release a gripped contact at this current level (Reilly 1992, p. 435). The Underwriters Laboratories uses a limit of 0.5 mA for continuous currents from hand-held appliances. This is the level at which most people can perceive a continuous current through their hands. Although a startle reaction with unintended movement is possible at the 0.5 mA level, it is not likely (Reilly 1992, p. 434).

An estimate of the short-circuit current from a vehicle requires both the electric field in the area of the vehicle and the size of the vehicle (Section 7.8, Red Book). The specified condition for computing the maximum induced current to a vehicle is with the line operating at maximum voltage and conductors at final unloaded sag at 50°C.

Estimates of the short-circuit current from a vehicle assume that the entire induced current to the vehicle passes through a person to ground. This is equivalent to no leakage current through the vehicle tires and zero impedance for the current path through the person. This is a worst-case estimate of the current that could pass through a person touching an ungrounded vehicle. In realistic situations, there is finite resistance to earth through the vehicle tires that offers an alternative current path.

Vehicles operating on soil are likely to have low resistance to ground. Dragging a chain from the vehicle is a commonly recommended method of reducing nuisance shocks for such vehicles under transmission lines. However, the effectiveness of such a method has not been substantiated.

The impedance of the person to ground may be substantial due to contact resistance between the shoes and ground or the resistance of the shoes themselves (Section 7.8.5, Red Book). The impedance of a thin, highly resistive layer on the surface of the earth can also limit current flow during contact (Section 12.2, Red Book). Both of these practical conditions (vehicles not well insulated and person not well grounded) will tend to reduce the current through a person touching a vehicle in an electric field to values well below the worst-case short-circuit current (Section 7.8.5 of the Red Book). Reported short-circuit current measurements on various realistic surfaces indicate that, for realistic conditions, the actual currents from vehicles to persons would generally not be perceptible even when the worst-case short-circuit current approaches the 5 mA criterion (Section 7.8.5, Red Book).

Spark Discharges (Induced Voltages) from Vehicles (Section 12.13.3, Red Book)

As an insulated person contacts a grounded vehicle or as a grounded person touches an insulated vehicle in a 60-Hz electric field, a series of spark discharges may occur across the air gap between finger or hand and the vehicle. After contact is established, a steady-state current flows. The intensity of the spark discharge depends on the field level, the voltage difference between person and vehicle, the level of insulation of person and vehicle, and the size of the electrically ungrounded vehicle. Perceivable spark discharges occur for contacts with other objects under transmission lines, such as fences or blades of grass. However, contacts with passenger, commercial, and farm vehicles probably represent the most common source of concern and complaints about nuisance shocks.

Reaction to spark discharges can range from imperceptible, to perceptible, to annoying, and to a startle with inadvertent movements (Section 7.10.5, Red Book). Individuals vary widely in their response to spark discharges. The level of response is dependent on the voltage between the person and object, the capacitance of the charged object, and the leakage resistance of the charged object (Reilly 1992, p. 347). For example, the voltage threshold for perception of repetitive 60-Hz discharges (from a constant capacitance) decreases as the leakage resistance decreases.

An example of the evaluation of the response to spark discharges from a charged gutter is provided in Section 7.10.5 of the Red Book. The approach used for the gutter can easily be applied to vehicles. As with induced currents, the actual value for the induced voltage on an object is usually much reduced from the worst-case situation with the object perfectly insulated from ground. This leads to a reduction in the level of response to potential spark discharges from that under worst-case conditions. Figures 7.8-20 to 7.8-22 in the Red Book provide statistical distributions for person-to-vehicle voltages under practical conditions.

Fuel Ignition (Section 12.13.4, Red Book)

It is extremely unlikely that conditions for fuel ignition by a spark discharge from an insulated vehicle to ground will occur in an electric field under a transmission line, and no such event has been reported. Nevertheless there are ideal conditions under which such an event could occur. In addition, the possibility of fires during refueling is not limited to those ignited by spark discharges. Therefore utilities often recommend against refueling under transmission lines for both public safety and line reliability reasons.

Parking Lots

Concerns related to the use of rights-of-way for vehicle and equipment parking lots are physical damage to transmission-line structures, exceedance of the 5 mA criterion for large vehicles, frequent opportunities for person-vehicle contact in high electric fields that produce nuisance shocks, and vehicle fires arising from fuel ignition or mechanical problems, such as broken fuel lines, faulty catalytic converters, electrical failures, and overheating (Section 12.13.5, Red Book). By creating a public space and increasing human activity under energized lines, parking lots can also increase the opportunities for unsafe activities that are hazardous whenever they occur near transmission lines. Some of these would include unauthorized tower climbing, transport of excessively tall objects under lines, or kite flying. Corona-generated audible noise during foul weather from lines directly overhead can also be a source of public complaints and/or unease when using parking lots (Section 12.13.5, Red Book).

Physical access to towers can be limited by no-vehicle zones around towers and anti-climbing barriers. Warning signs can also be used to advise the public of unsafe activities.

Induction effects related to electric fields can be controlled by exclusion of vehicles above a certain size from areas of peak field intensity or by reducing the fields in the parking lot area. One approach is to apply the NESC clearance for road crossings that is based on the 5 mA short-circuit current criterion to parking lots. However, the increased public use of a parking area beyond that at road crossings may result in an increased number of nuisance-shock complaints. To reduce the number of complaints requires measures that reduce the electric field in parking lots below levels required by the NESC 5 mA criterion. This is one of the soft criteria for parking lots.

Electric fields can be reduced by increasing the conductor clearance or by employing the shielding methods described in Section 7.16 of the Red Book. For example, a horizontal grid of grounded wires can be employed in the area of minimum clearance to reduce ground level fields (Section 7.16.2, Red Book). In instances where field reduction is required in a limited area, it may be possible to use grounded light poles or other conducting architectural objects to achieve the required field reduction (Section 7.16.5, Red Book). Lower voltage lines suspended under transmission lines can also provide shielding of the electric field (Section 7.16.6, Red Book). All shielding options must meet code requirements for electrical clearance and, if grounded, employ redundant grounds to minimize the possibility of a shock hazard caused by a damaged ground.

Trees and other vegetation also provide shielding. However, their susceptibility to damage and the need to maintain electrical clearances may preclude their use as permanent shields.

The surfaces of parking lots will help reduce the impact of induced currents and voltages. With the vehicle and person standing on the same surface, it is difficult to achieve the worst-case condition with the entire short-circuit current from a vehicle passing through a person (Section 12.16.2, Red Book).

The Bonneville Power Administration (BPA) policy on parking lots provides an example of criteria that are more stringent than the 5 mA criterion for short-circuit current (Lee et al. 1996, p. 5-5). Instead of let-go current, the BPA criteria for electric fields are based on limiting the probability of perception or annoyance from field effects. This results in a 3.5 kV/m limit for shopping center parking lots, with the stipulation that parking for large trucks is not allowed. This field produces a short-circuit current in sedans and pickup trucks of less than 1 mA in the worst-case situation. Under realistic conditions, the current level is well below 1 mA and is generally not perceptible. In commercial and industrial parking lots, the field limit is reduced to 2.5 kV/m with the intent of limiting the short-circuit current to 2 mA for large trucks. Shopping center and commercial parking lots are not permitted where fields exceed 3.5 and 2.5 kV/m, respectively. In this case, the soft criterion results in a buffer of 4 mA (5 mA – 1 mA) for sedan and pickup trucks in shopping center parking lots, and a buffer of 3 mA (5 mA – 2 mA) for large trucks in commercial and industrial parking lots.

Limiting the electric field and/or vehicle size in parking lots reduces the already low probability for fuel ignition by spark discharges during refueling. Nevertheless the potential public health and transmission-line reliability impacts of a fire under a line lead to the recommendation of no refueling in parking lots. Posting signs advising of the restriction on refueling vehicles can serve as a warning to the public.

Technical Evaluation

See Flowchart for Evaluation and Approval Process in the Administrative Guide.

Solicit inputs on issues and concerns from all impacted departments.

Prepare Engineering Evaluation

- Check operating clearances
  - Determine type of parking lot.
  - Determine line voltage.
  - Determine location, span, structure numbers.
  - Get design profile / mapping.
  - Plot parking lot on profile.
  - Measure conductor to ground clearance.
  - Add tolerance.
  - Compare to minimum operating clearance.
  - If clearance is marginal, do conductor thermal study.
  - If clearance is insufficient, suggest alternative location, lower ground elevation, raise conductors.
- Check industry work standards
  - Determine line voltage.
  - Refer to industry/electrical safety regulations for minimum working clearance to transmission conductors.
- Check future line criteria

  - Review electric system plan for future lines on ROW.
  - Contact System Planning for updated information.
- Check plant protection and internal policies and standards
  - No parking within a zone of _____ ft horizontally from any transmission structure.
  - Specify structure protection if necessary.
  - Review power company policies.
  - Check roads parallel and within ROW against future use requirements.
  - Good engineering practice.
  - Environmental/social acceptability.
  - Compliance with fire and electrical codes.
  - Review induction and grounding concern.
- Check hard criteria
  - Clearance to vehicle (including load and reach) must exceed the minimum operating clearance.
  - Maximum induced current from the largest anticipated vehicle must be below 5 mA.
- Check soft criteria
  - No parking within a zone of _____ ft horizontally from any transmission structure.
  - If clearance is insufficient, suggest alternative location, lower ground elevation, raise conductors.
  - Limit vehicle size by installing height barriers.
  - Increase tolerance to nuisance shocks by increasing electric field limit criteria (if acceptable).
  - Install shielding device to lower electric field levels.

Assemble Responses and Engineering Evaluation

- Assemble responses from all departments and assure all pertinent technical issues are addressed.
- Select applicable general conditions.
- Compile all findings.

Prepare Engineering Report and Recommendations

Analysis criteria shall include standards of acceptance and the following as a minimum:

- Conductor to ground clearances.
- Horizontal clearance from conductors, structures and related plant.

- Local, national and internal standards.
- Work safety regulations.
- Access for maintenance.
- Provision for future plant.
- Environmental protection.
- Public image.
- Assessment of technical risk issues.
- All relevant information received from others.

Review Report

- Review report for accuracy, consistency and coverage.
- Transmit report to Property Services with copies to appropriate internal stakeholders.

Related Guidelines, Standards and Documents

Internal guidelines should be established and used for all installation on power company ROWs. The following is a list of relevant internal guidelines covering topics such as:

- General conditions
  - Contact the power company at least ______ days prior to working on ROW.
  - Power company not responsible for damage to works caused by normal activities.
  - Power company reserves the right to terminate consent.
  - Applicant responsible for all costs for plant alterations/protection.
  - Below ground works designed to withstand heavy loads.
  - Works must not approach within ______ ft of power company plant.
  - "As constructed" drawings required within ____ days.
  - Survey plan of works is required showing relation to ROW boundaries.
  - Proposed road/park shall not be dedicated.
  - Remove or relocate works upon issue of ____ days' written notice from the power company.
  - Works must not be enlarged, moved or added to without the consent of the power company.
  - Metal fences must be grounded according to the power company guidelines.
- Personal safety

  - Safe working distance from transmission line conductors (e.g., 20' for 500 kV lines).
  - Maximum height of vehicles, including load and reach, not to exceed _____ ft.
  - Levels of induction in objects near transmission lines.
- Plant security and maintenance
  - Access to be maintained.
  - Grade elevation changes not to exceed _____ ft.
  - No parking within a zone of _____ ft horizontally from any transmission structure.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - Other uses of ROW require written consent from the power company.
  - Trees, shrubs and plants not to exceed _____ ft (e.g., 10') in height at maturity.
  - Temporary or permanent structures larger than __(size and height)__ are not allowed on ROW.

Relevant transmission maintenance and construction standards covering topics such as:

- Working clearances from energized conductors.
- Minimum operating line to ground clearances.
- Grounding of fences, buildings and objects near transmission lines.

National, state and local relevant industry standards and codes covering topics such as:

- National Electric Safety Code
- Fire and electrical codes.
- Work regulations or electrical safety code for working near energized conductors.

Other references:

EPRI. 1995. "Transmission Line Reference Book: 345 kV and Above." Red Book.

IEEE Standard C2. 2002. "National Electric Safety Code."

Lee, J. M., K. S. Pierce, C. A. Spiering, R. D. Stearns and G. VanGinhoven. 1996. "Electrical and Biological Effects of Transmission Lines: A Review." Bonneville Power Administration, Portland, OR, December.

Reilly, J.P. ed. 1992. "Electrical Stimulation and Electropathology." Cambridge University Press, New York, NY.

Attachments

- Frequently asked questions.
- Definitions/glossary.
- Terms of reference.

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ADMINISTRATIVE GUIDE - RAILROADS

Scope

This guide outlines the activities required for evaluating requests for railroad facilities on rights-of-way or fee-owned land. It outlines the conditions under which the proposal may or may not be approved, and the administrative approval process.

Note: It is more common for the utility to request a joint corridor with a railroad than for the railroad to make the request. While the technical issues are the same independent of who makes the request, the administrative procedures vary. This guide will address both situations.

Purpose

- Ensure public safety.
- Ensure safe working conditions for electric utility and third party personnel.
- Ensure a uniform review, evaluation and approval process.
- Ensure power system reliability and safe operation of the transmission circuits.
- Ensure access for transmission maintenance and future expansions and modifications.
- Ensure plant security.
- Ensure uncompromised power transmission capability.
- Ensure compliance with all applicable codes, standards and regulations, laws and ordinances.
- Protect the property rights of the power company.
- Protect the electric utility's ability to construct future works.
- Protect the natural environment, habitat and wildlife.
- Promote positive public image by allowing multiple use of the ROW for compatible public activities.

Policy

Request for railroad facilities on rights-of-way or fee owned land has a significant impact. It shall be processed through the administrative procedure established in this document to ensure that all affected groups have the opportunity to review and approve or disapprove the proposal.

This type of encroachment needs approval on a site-specific basis. Detailed construction drawings are to be submitted to the power company for approval, at least _(lead time)_ in advance of construction. The power company will arrange for Engineering, Legal, Operational and others as appropriate to review the proposal. No work shall proceed until approval has been granted. This procedure ensures that all affected departments have the opportunity to review and approve or disapprove the proposal.

If the utility initiates the request, initial contact with the railroad should occur one year in advance of construction to the railroad's Real Estate Department. Preliminary design drawings of the joint corridor should be submitted incorporating best engineering practices for joint railroad rights-of-way[1]. Several months will be required for the railroad's Signal Department to evaluate the impact to the signal system. The railroad will probably require an independent analysis of electromagnetic interference.

Responsibilities

Here is an example showing the responsible functions which may be assigned in the review and approval process:

- Civil Design - foundations, structural or geotechnical concerns.
- Station Design - impacts to substation.
- Cable Design - impacts to underground works.
- Electrical Design - studies related to induction, grounding, clearance, conductor thermal rating.
- System Planning - anything affecting future plant.
- Environmental Services - environmental compatibility concerns.
- Survey and Photogrammetry - detailed field measurements and mapping.
- Property/Real Estate/Legal Services - land rights, liabilities and legal information, maintaining records and correspondence with applicants.
- Field resources - site-specific information.

Requirements

- Maintain property rights of the power company.
- Compliance with fire and electrical codes.

[1] The most comprehensive discussion of this subject can be found in the EPRI publication entitled *Power System and Railroad Electromagnetic Compatibility Handbook* (EPRI 2004).

- Maintain horizontal distance from installed railroad to transmission structures a minimum of _____ ft.
- Personal safety
  - Safe working distance from transmission line conductors.
  - Maximum height of vehicles, including load and reach, not to exceed _____ ft.
  - Supervision during construction.
  - Grounding of rail during storage and construction.
  - Safe step and touch potentials on accessible equipment.
- Electrical damage to railroad and associated equipment
  - There should be no damage to the railroad and associated equipment (with the exception of sacrificial devices such as surge arrestors and fuses) from electrical effects.
- Plant security and maintenance
  - Access to transmission structures must be unobstructed at all times.
  - Grade elevation changes not to exceed _____ ft.
  - No parking within a zone of _____ ft horizontally from any transmission structure.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - No landscaping, trees, shrubs and plants must exceed _____ ft (e.g., 10') in height at maturity on the ROW.
  - No storage of materials on ROW unless approved by the power company.
  - No temporary or permanent structures larger than _(size and height)_ are allowed on the ROW unless approved by the power company.

Related Guidelines, Standards and Documents

Request for railroad facilities on rights-of-way or fee owned land has a significant impact and must be referred to relevant departments for review. It is not necessary for the ROW Administrator to review the relevant guidelines, standards and documents.

Administrative Procedure

Request for railroad facilities must be referred to various departments for review and approval.

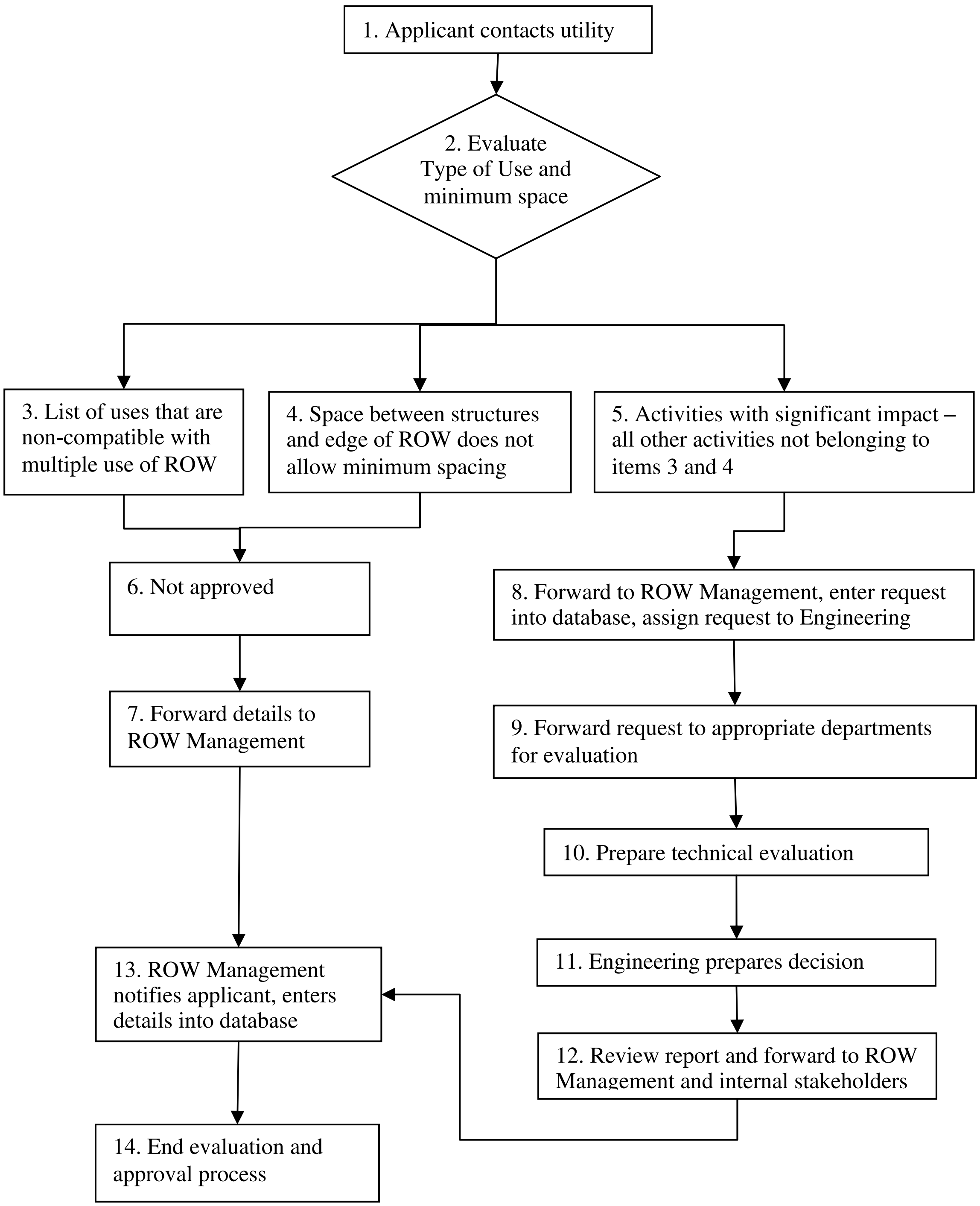
- Receive application, enter into log book and data base recording the following minimum information:
  - Property contact.

  - Engineering contact.
  - Type of use.
  - Applicant.
  - Landowner.
  - Location.
  - Transmission circuits.
- Assign request
  - Determine level of complexity.
  - Determine other stakeholders.
  - Determine need for other information from Applicant.
- Determine type of use
  - Access previous similar requests in database.
  - Confirm development on ROW.
  - Confirm civil engineering impact (e.g., foundation, roadwork, soil effects); transmit request to Civil Design.
  - Confirm property impact (e.g., future expansion); transmit request to System Planning.
  - Confirm development on station property, transmit request to Station Design.
  - Confirm significant environmental impact; transmit request to Environmental Services.
- Prepare engineering (technical) evaluation (See Technical Guide for details)
- Assemble responses and engineering evaluation (See Technical Guide for details)
- Prepare engineering report (See Technical Guide for details)
- Review report (See Technical Guide for details)
- File report
  - File hard copies of report, original request, departmental responses, marked location maps, profiles and other related documents to ROW Engineering files.
  - Log completed report into ROW database with a case number.
  - Enter email correspondence, requests and all electronic documents into ROW database.
  - The approved cases can be kept for future reference.

Attachments

- Frequently asked questions.
- Definitions/glossary.
- Terms of reference.

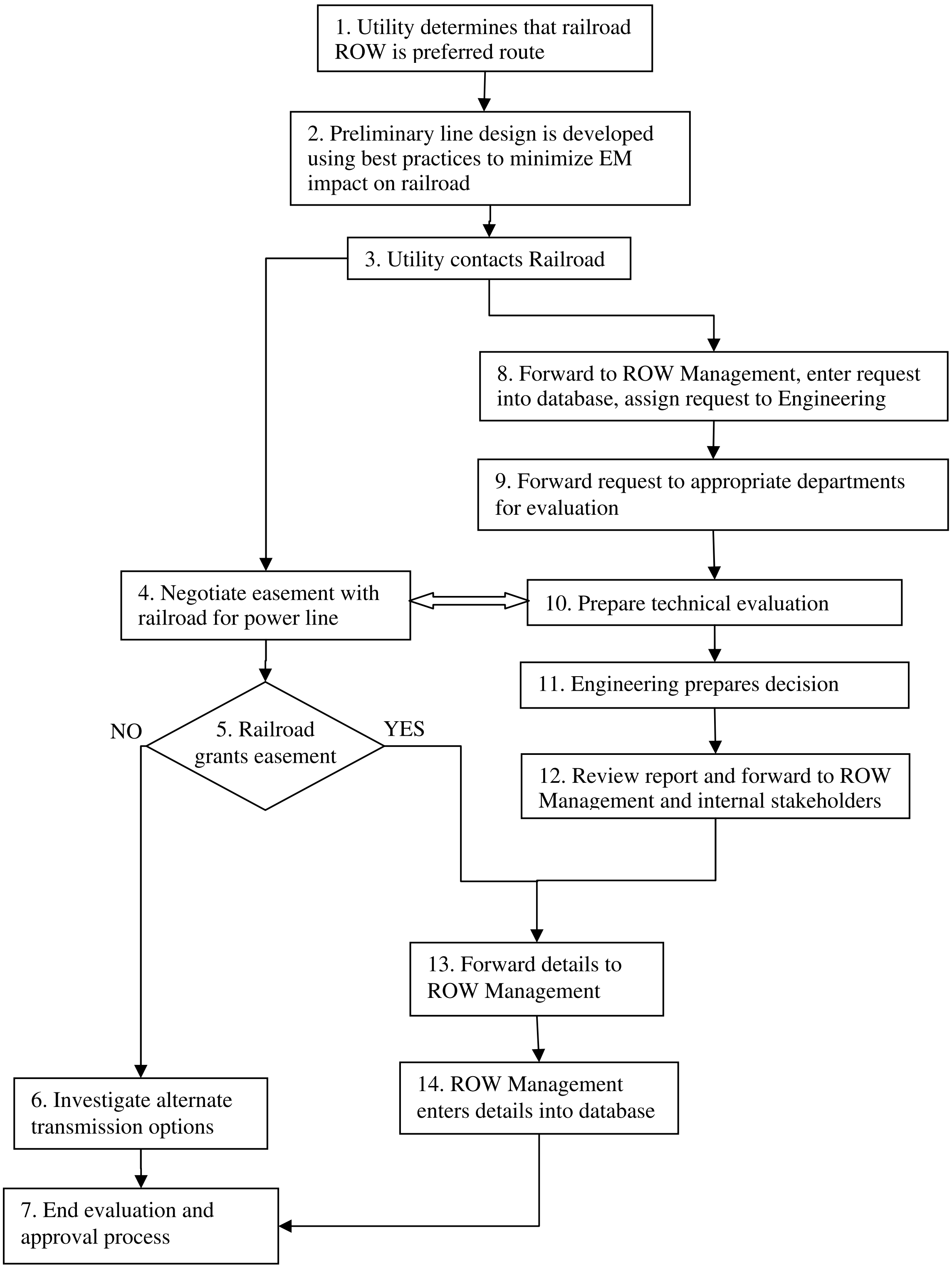
Flowchart for Evaluation and Approval Process for Railroad on Transmission Line Right-of-Way – Railroad Initiated



Notes for Railroad Initiated Flowchart:

1. Applicant contacts utility and seeks approval for using the ROW.
2. The office receiving the request evaluates the type of use and classifies the request into one of the four categories: a) Not Approved (non-compatible usage), b) Approved (minor or no impact) on non fee-owned property, c) Approved (minor or no impact) on fee-owned property, and d) Further Review (significant impact, require technical evaluation). Requests for installing railroads on transmission line structures can be classified into two categories: "a" or "d".
3. **Activities that are non-compatible** with multiple use of the ROW are not approved. A utility sets its own criteria and its own list of activities under this category, for example:
   Anything that is too close to structures or conductors.
   Storage of flammable, explosive or environmentally unfriendly materials or conditions.
   Any land use that extinguishes the utility rights.
   Anything that impacts the utility's flexibility to install future plant.
   Some utilities may consider the installation of wireless communication systems on transmission line structures as non-compatible use.
4. The space between the existing structures and the edge of the ROW is insufficient to accommodate the minimum spacing between railroads and structures.
5. **Significant impact** refers to those activities that may affect items like the environment, future use, safety, plant security and accessibility. All other activities that do not fall under the non-compatible use or minor/no impact categories belong to this category. Activities belonging to this category require a technical evaluation process.
6. Requests for non-compatible use of the ROW are not approved.
7. Forward case details to the ROW Management Department.
8. ROW Management enters details of the request details into the database (e.g., property contact, type of use, applicant, landowner, location, transmission circuits), evaluates the request, obtains additional information from the applicant (if necessary), determines who are the stakeholders, evaluates the level of complexity, and assigns the request to a technical individual in the Engineering department accordingly.
9. Engineering prepares a referral package containing details of the application and background information (e.g., reference to the former cases, correspondence with the applicant). Forward the referral package to the appropriate departments for technical evaluation. See "Responsibilities" Section in the Administrative Guide for an example showing the responsibilities of the departments assigned in the evaluation and approval process.
10. Engineering and other departments prepare technical evaluations (e.g., check operating clearances, check electrical parameters, check industry work standards, check future line criteria, check plant protection and internal policies and standards). If estimate is required, refer to Transmission Project/Construction.
11. Engineering assembles and compiles responses from all departments. Prepare engineering decision report and recommendation using analysis criteria that include standards of acceptance as a minimum. See "Technical Evaluation" Section in the Technical Guide for more details.
12. Engineering reviews report for accuracy, consistency and coverage. Forward report to internal stakeholders and ROW Management. File all relevant materials. See "Administrative Procedure" in the Administrative Guide for more details.
13. ROW Management notifies the applicant of its decision and enters details into the database for record keeping, future reference and information retrieval.
14. End of the evaluation and approval process.

Flowchart for Evaluation and Approval Process for Railroad on Transmission Line Right-of-Way – Utility Initialized



Notes for Utility Initiated Flowchart:

1. When a utility determines that an existing railroad ROW is a preferred route for transmission, the process of working with the railroad to obtain both the easement and approval of the design should begin immediately.
2. To begin its evaluation of the proposed joint corridor, the railroad will usually need the preliminary line design.
3. The initial contact with the railroad should be as early as possible. While the processes of obtaining railroad easements and state regulatory approval for line siting can proceed in parallel, there is a risk that difficulties with either could impact the in-service date of the line.
4. The process of negotiating an easement will involve technical issues as well as Property/Real Estate/Legal Services issues. See note 10.
5. Ultimately the railroad will approve or deny the easement.
6. If an acceptable easement cannot be obtained from the railroad, alternate transmission options will have to be investigated. The best way to avoid this undesirable outcome is to maintain a good working relationship with railroads in your service territory.
7. End of the evaluation and approval process.
8. ROW Management enters details of the request details into the database (e.g., property contact, type of use, applicant, landowner, location, transmission circuits), evaluates the request, obtains additional information from the applicant (if necessary), determines who are the stakeholders, evaluates the level of complexity, and assigns the request to a technical individual in the Engineering department accordingly.
9. Engineering prepares a referral package containing details of the application and background information (e.g., reference to the former cases, correspondence with the applicant). Forward the referral package to the appropriate departments for technical evaluation. See “Responsibilities” Section in the Administrative Guide for an example showing the responsibilities of the departments assigned in the evaluation and approval process.
10. Engineering and other departments prepare technical evaluations (e.g., check operating clearances, check electrical parameters, check industry work standards, check future line criteria, check plant protection and internal policies and standards). If estimate is required, refer to Transmission Project/Construction. Approval of a railroad easement is usually contingent on the railroad’s engineering department approval of the line design. As a result, this engineering evaluation often involves ongoing interface with the railroad’s engineering departments, and can be part of the easement negotiation process (see note 4).
11. Engineering assembles and compiles responses from all departments. Prepare engineering decision report and recommendation using analysis criteria that include standards of acceptance as a minimum. See “Technical Evaluation” Section in the Technical Guide for more details.
12. Engineering reviews report for accuracy, consistency and coverage. Forward report to internal stakeholders and ROW Management. File all relevant materials. See “Administrative Procedure” in the Administrative Guide for more details.
13. Forward case details to the ROW Management Department.
14. ROW Management notifies the applicant of its decision and enters details into the database for record keeping, future reference and information retrieval.

J
TECHNICAL GUIDE - RAILROADS

Scope

This guide outlines the activities required for evaluating the technical compatibility of requests for railroad facilities on rights-of-way or fee-owned land. It outlines the conditions under which the proposal may or may not be approved, and the technical evaluation process[2].

Purpose

- Ensure public safety.
- Ensure safe working conditions for electric utility and third party personnel.
- Ensure a uniform review, evaluation and approval process.
- Ensure power system reliability and safe operation of the transmission circuits.
- Ensure access for transmission maintenance and future expansions and modifications.
- Ensure plant security.
- Ensure uncompromised power transmission capability.
- Ensure compliance with all applicable codes, standards and regulations, laws and ordinances.
- Protect the property rights of the power company.
- Protect the electric utility's ability to construct future works.
- Promote positive public image by allowing multiple use of the ROW for compatible public activities.

Policy

Requests for railroad facilities on rights-of-way or fee owned land shall be processed through a procedure established to ensure that all affected groups have the opportunity to review and approve or disapprove the proposal.

[2] The most comprehensive discussion of this subject can be found in the EPRI publication entitled *Power System and Railroad Electromagnetic Compatibility Handbook* (EPRI 2004).

Requirements

- Maintain property rights of the power company.
- Compliance with fire and electrical codes.
- Horizontal distance from installed railroad to transmission structures a minimum of _____ ft.
- Personal safety
  - Safe working distance from transmission line conductors.
  - Maximum height of vehicles, including load and reach, not to exceed _____ ft.
  - Supervision during construction.
  - Grounding of rail during storage and construction.
  - Safe step and touch potentials on accessible equipment.
  - Safety exposure limits (to be completed)
- Electrical damage to railroad and associated equipment
  - There should be no damage to the railroad and associated equipment (with the exception of sacrificial devices such as surge arrestors and fuses) from electrical effects.
  - Low pressure tanks (to be completed)
  - Communication or signal cables (to be completed)
- Plant security and maintenance
  - Access to transmission structures must be unobstructed at all times.
  - Grade elevation changes not to exceed _____ ft.
  - No parking within a zone of _____ ft horizontally from any transmission structure.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - No landscaping, trees, shrubs and plants must exceed _____ ft (e.g., 10’) in height at maturity on the ROW.
  - No storage of materials on ROW unless approved by the power company.
  - No temporary or permanent structures larger than __(size and height)__ are allowed on the ROW unless approved by the power company.

Common Utility Practices

Here are some common utility practices:

- Railroads should not connect to the transmission structure grounding systems.
- Railroads must establish and maintain grade crossings if necessary for vehicular access to transmission structures.

- Although it is highly unlikely that a spark could cause ignition, if fuel is to be transferred under high-voltage power lines, the fuel container should be electrically bonded to the equipment being fueled prior to and during fueling. Any fumes should be allowed to dissipate before removing the bond.
- Anode beds, grounding cells, test points or any catholic protection equipment must be approved.
- Maintain a minimum of 2' vertical separation between fiber optic cable conduits and proposed railroad crossings, and a minimum of 5' horizontal separation between the fiber optic conduits/pull holes and the railroad.

Technical Background Information

Introduction (Section 12.2.1, EPRI 2005, "Red Book")

Shared corridors for railroads and power lines such as the one shown in Figure RAIL-1 are often an economic necessity. However, over the years, these joint-use corridors have led to a small but consistent number of EMC issues. In this context, EMC relates to the ability of one system (e.g., railroad signals) to operate in the presence of effects caused by a nearby system (e.g., electric power lines).

Any conductor carrying an alternating current creates time-varying electric and magnetic fields in its vicinity and distributions of current within conducting regions such as the nearby earth. These "induced" fields and currents cause separate alternating currents and voltages on any system of conductors (e.g., railroad tracks and associated electrical equipment) that are placed near the power line. In turn, these voltages and currents may interfere with the proper and safe operation of the nearby system. These effects become greatest with ac power lines and railroads that are parallel and in close proximity to each other over a long distance. Unfortunately, this is exactly the situation when ac power lines are located along a railroad right-of-way, as illustrated in Figure RAIL-1.

Effects considered here include compromised equipment operation, equipment damage, and personnel safety (i.e., direct electrical effects on a person touching the equipment). Of particular interest here is the fact that modern electrical communications technologies are not necessarily as robust as the simple electromechanical systems of the past.

It will be assumed here that the primary interference is between the electric power system and railroad equipment. This is certainly true for "diesel" locomotives (in reality "diesel electric" since the diesel turns an electric generator that provides power to motors that drive the wheels) that do not cause large currents in the rails. In some parts of North America and in most of Europe, however, electric traction is used. In these cases, electricity from another source, usually delivered through an overhead catenary wire or an electrified third rail, is used to drive the electric motors to turn the wheels. Because electric traction requires the railroads to have their own electric power distribution systems, railroads using electric traction can be sources of ac power interference. Problems specific to railroads using electric traction are covered in many IEC and European standards, but will not be discussed further here (CENELEC 1999; IEC 2003a to f).

Figure RAIL-1
Joint railroad transmission-line corridor
(Figure 12.2-1, Red Book)

Programs to address ac interference challenges have been undertaken in the past. Most of these programs concentrated on the issues of ac induction (JCIIRC 1918; Leisenring 1926; AAR/EEI 1936; AAR/EEI 1977). The last of these references is known as *Principles and Practices for Inductive Coordination of Electric Supply and Railroad Communication/Signal Systems*. While it is not a standard, this document, commonly called the "Bluebook," is the closest thing in North America to an industry accepted guide.

EPRI and the American Association of Railroads (AAR) conducted several research projects on railroad/electric power inductive coordination in the 1980s (EPRI 1983b; EPRI 1985). These projects included development of CORRIDOR software to predict magnetic and electric coupling into railroads and pipelines. Included in this work was the creation of the Track Circuit Simulator to permit testing of any interference condition on actual equipment installed on simulated track. The EPRI work, as with most of the prior work, was concentrated on electric and magnetic field coupling. However, many of the problems that railroads have with newer signaling equipment technologies are caused by distributions of current injected into the earth. The most comprehensive discussion of this subject can be found in a recent EPRI publication entitled *Power System and Railroad Electromagnetic Compatibility Handbook* (EPRI 2004).

Introduction to Coupling Mechanisms between Power Lines and ***Railroads*** *(Section 12.2.2, Red Book)*

It is well known that one electromagnetic system (e.g., a power line) can couple energy into another electromagnetic system such as a railroad signaling circuit. While, in general, this interaction is complex, it is possible to understand the most important mechanisms by considering electric-field, magnetic-field, and conductive induction separately, if all relevant dimensions of the systems are small compared to a wavelength in the air and the earth. This is, in part, because electric- and magnetic-field coupling can be superimposed under these conditions and, in part, because one of the three mechanisms usually dominates the others. For simplicity here, only coupling to the electrical circuits that involve the railroad tracks will be considered. Descriptions of coupling to other circuits, such as parallel communications networks, can be found in the publications mentioned above.

Electric-Field (Capacitive) Induction (Section 12.2.3, Red Book)

Required Conditions

Electric-field induction is of concern whenever there are long and/or large objects near the power line that are not well grounded. Two cases for which electric-field coupling can be the dominant coupling mechanism are between power lines and insulated pole-top communication wires, and between power lines and long trains parked in parallel to power lines. In the former case, the impedance between the pole-top circuits and ground is large, which results in higher voltage on the wires. In the latter case, the induced voltage may be higher because the large surface area of the train results in a large power line/train capacitance. This type of induction occurs during both normal operating and fault conditions. The voltages, however, may be different under the two conditions.

Predictive Methods

Capacitive induction can be understood by referring to the circuit diagram in Figure RAIL-2. Note here that (for simplicity) the power line is a simple two-conductor line. In the absence of the railroad, no current will be injected into the earth by the power line in this simple system since it is “balanced.” However, unequal coupling from the two conductors to the tracks causes a slight unbalance. The result is a current driven by the power line voltage through the capacitance between the power line and the railroad tracks and then to the earth through the impedances that connect the tracks to the earth. Because the capacitance between power line and tracks is so small, this current is usually limited to milliampere levels. Usually this level is either too small to interfere with the operation of railroad systems or is dominated by currents induced by other mechanisms and can be neglected. Further, the voltages induced on the tracks are usually small because the impedance between the tracks and ground is generally much smaller than the capacitive impedance between the power line and the tracks. More detailed discussions of electric field coupling can be found in Sections 7.8 and 12.3.2 of the Red Book.

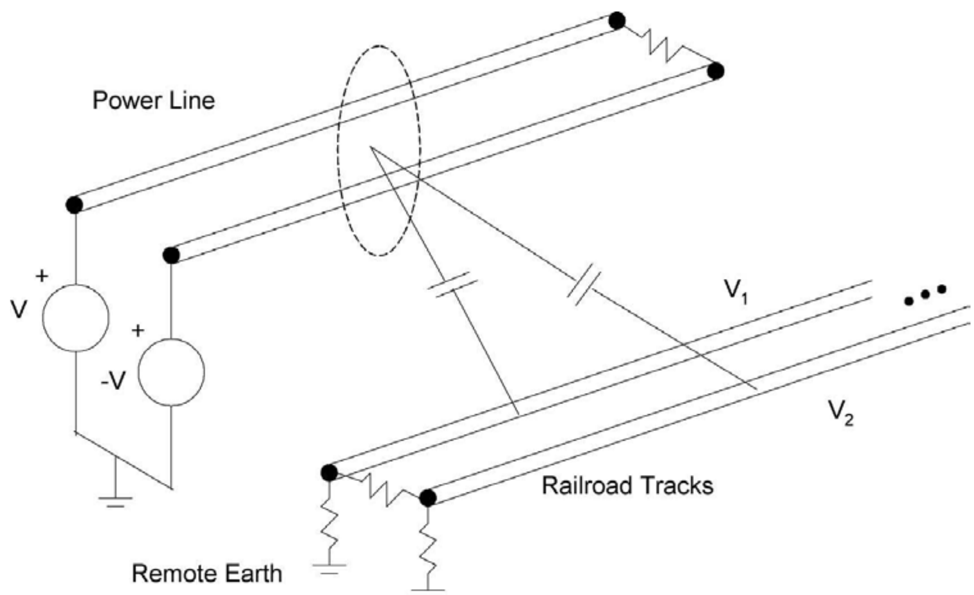


Figure RAIL-2
Electric-field (capacitive) coupling mechanism. Voltages V_1 and V_2 are the capacitively coupled voltages (with respect to remote earth) on each of the two tracks
(Figure 12.2-2, Red Book)

Mitigation

Mitigation of capacitively induced voltages is usually achieved by either increasing the distance between the transmission line and the system on which the voltages are induced or (when possible) by installing additional grounds. The method used to evaluate potential hazards to personnel is essentially equivalent to the one described in Section 12.3.2 of the Red Book for capacitively induced voltages on pipelines. The reader is referred to that section for more detail on this subject.

Magnetic-Field (Inductive) Induction (Section 12.2.4, Red Book)

Required Conditions

Magnetic-field induction is of concern whenever railroad tracks are parallel to transmission lines for long distances. It is often the dominant induction mechanism when the impedance between the tracks and ground is relatively small (i.e., the tracks are reasonably well grounded), so that effect of electric-field induction is reduced. Again, inductive coupling may be of concern during normal power system operation. During faults, however, the current may increase dramatically and hence dramatically increase the coupled currents and voltages.

Predictive Methods

Inductive coupling can be understood by referring to the circuit diagram in Figure RAIL-3. The mechanism by which coupling occurs is indicated by the magnetic field lines that pass through both the power line and the track circuit. Note that the "track circuit" here refers to loops that consist of current paths from: (1) one rail to the other and back again (i.e., the "differential" or "rail-to-rail" mode), and (2) the set of rails to ground and through the earth to the other end of the rails (the "common" or "rail-to-ground" mode). Because the magnetic fields are generated by current, it is the power lines' current that drives this coupling mechanism. The equivalent sources (i.e., voltage sources in series with impedances connected to the railroad tracks that replace the power line) that drive the railroad circuit can be shown to have both a low open-circuit voltage and low impedance. For typical values of these parameters, the current induced into the railroad circuit may be on the order of amperes. Hence magnetic induction is usually the dominant coupling mechanism during normal power line operation, and can be responsible for malfunction of signals, equipment damage, and personnel safety. It should be noted that EMC problems related to inductive coupling may be driven by harmonic currents on the power system as well as the 50/60-Hz currents. Part of the reason for this is that inductive coupling increases in proportion to frequency. A more detailed discussion of magnetic field coupling can be found in Section 7.9 of the Red Book.

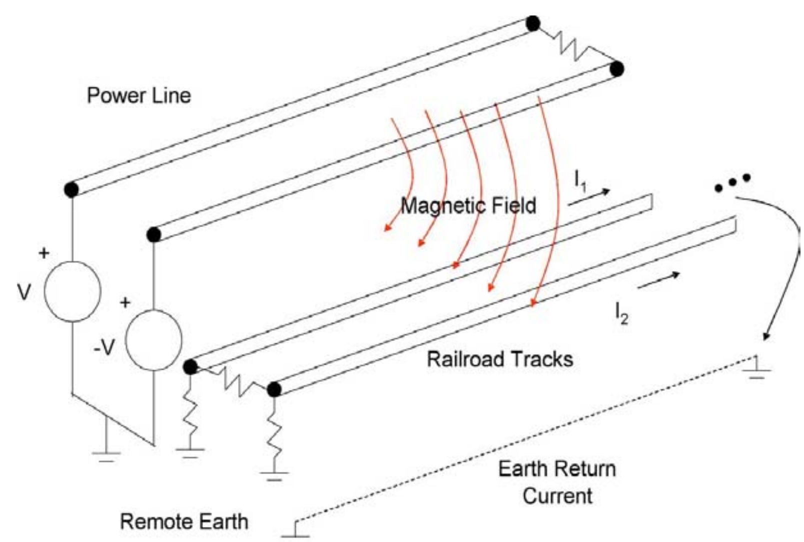


Figure RAIL-3
Magnetic field (inductive) coupling mechanism. Currents I_1 and I_2 are the inductively coupled currents on each of the two tracks
(Figure 12.2-3, Red Book)

Mitigation

As with electric-field induction, increasing the distance between the track and power lines will reduce magneticfield induction. Other techniques used to reduce magneticfield induction include minimizing the magnetic field at the rails by either reducing the spacing between phase conductors or phasing multiple circuit lines for minimum magnetic field levels. In some cases it may be possible to reduce the length of parallel exposure between the transmission line and the track. If the problem is related to fault currents, installing fault-current-limiting devices may help. Many other techniques for mitigating problems due to magnetic induction can be found in EPRI (2004).

Conductive (Resistive) Induction (Section 12.2.5, Red Book)

Required Conditions

Whenever magnetic induction is suspected to be a problem, conductive induction should be considered as well. This is especially true under fault conditions since the currents will generally be unbalanced, and hence the probability of large earth currents is increased.

Predictive Methods

Conductive coupling can be understood by referring to the circuit diagram in Figure RAIL-4. In this figure, the power line is represented by a single conductor because the emphasis is on the current injected into the earth by the power line. Under ground-fault (i.e., the power line is shorted to ground) conditions, the power line is effectively grounded at various points along its length, and a significant amount of current flows into the earth. In the figure, the resistors between the power line, remote earth (the "ground" symbol in the circuit), and the railroad tracks represent the resistances through earth for each of these. Coupling from the power line to the railroad system occurs through the currents injected into the earth. The currents are then distributed throughout the railroad system because of its relatively low impedance back to the power-line source. The currents, in turn, cause voltages across the impedances through which they flow. If these voltages are comparable to, or greater than, the railroad equipment immunity level, improper equipment operation is possible.

It should be noted that conductive coupling is dependent on soil resistivity, which in turn, is dependent on the moisture content of the soil. Consequently, one indication of the presence of conductive coupling is a dependence of any problem on the moisture content of the soil.

Finally, while distribution systems are not the subject of this book, it should be noted that their multiple-grounded neutral system is often responsible for injection of significant current under normal (often unbalanced) operation.

Mitigation

For conducted induction, methods used to reduce electric or magnetic fields are generally not useful. Most mitigation methods that are effective require some modification of the railroad plant. For more specific information on recommended methods for reducing susceptibility due to conducted induction, the reader is referred to EPRI (2004).

Common and Differential Modes (Section 12.2.6, Red Book)

Often it is helpful to identify the voltage between the rails and the average voltage of the rails with respect to remote earth. Similarly it is helpful to identify the portion of the current on each rail that returns to the source via the other rail and the portion that returns to the source via the earth. This can easily be done by defining two modes: the "common mode" and the "differential mode."

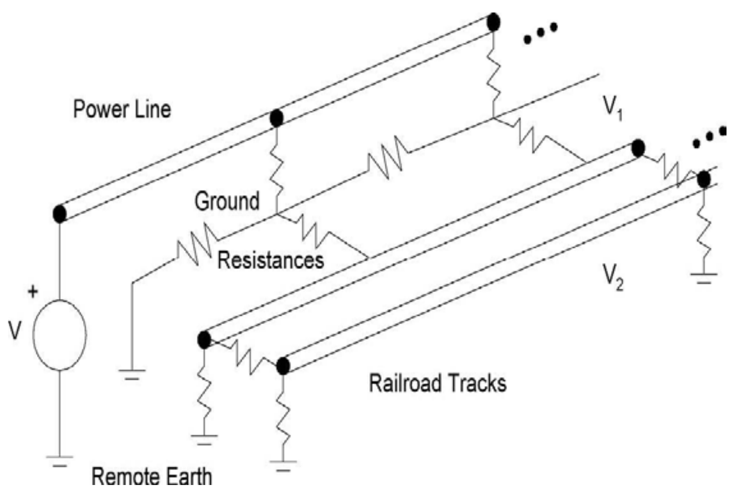


Figure RAIL-4
Conductive (resistive) coupling mechanism. Voltages *V_1* and *V_2* are the conductively coupled voltages on each of the two tracks
(Figure 12.2-4, Red Book)

The common-mode voltage (V_c) and current (I_c) are defined respectively as

$$V_c = \frac{V_1 + V_2}{2} \quad , \quad I_c = \frac{I_1 + I_2}{2}. \qquad \text{RAIL-1}$$

These represent the average voltage (with respect to remote earth) and current on the two rails. The former is relevant to issues relating to worker safety and equipment damage since voltages with respect to earth are the ones to which workers standing on the ground and equipment are exposed. The general rule is that these should not exceed 50 V rms rail to ground.

The differential-mode voltage (V_d) and current (I_d) are defined respectively as

$$V_d = \frac{V_1 - V_2}{2} \quad , \quad I_d = \frac{I_1 - I_2}{2}. \qquad \text{RAIL-2}$$

These voltages are generally the more significant sources of interference to railroad signals. They are of concern for abnormal operation of railroad systems if greater than equipment immunity. The American Railway Engineering and Maintenance of Way Association (AREMA) manual recommends 5 V or 10 V of ac rms immunity, depending on type of equipment. Grade-crossing equipment is particularly susceptible.

Coupling between Common and Differential Modes (Section 12.2.7, Red Book)

Whenever there is an unbalance in the system (e.g., different resistances between each rail and the earth) common-mode currents can be converted into differential-mode currents. This is important because often the dominant currents induced magnetically are the common-mode currents that are induced in the rails and that return through the earth. While these currents (and associated voltages) do not interfere with most signaling systems, the differential-mode currents caused by system unbalances do.

Overview of Railroad Signaling (Section 12.2.8, Red Book)

The most common types of railroad-signaling equipment usually fall into one (or more) of the following categories of systems designed to:

- Detect the presence of a train within an area defined by a track circuit “transmitter” and a track circuit “receiver.”
- Communicate information (such as a train’s location) along a railroad line (e.g., coded track circuits, wire-line circuits, radio communications).
- Measure a train’s position or motion with respect to a fixed point (e.g., motion sensors, crossing predictors).
- Detect specific hazards to railroad operations (e.g., slide fences, dragging equipment detectors, etc.).
- Provide safety-critical information to trains or motorists (e.g., wayside signals, cab signals, crossing flashers, crossing gates, bells).
- Physically reconfigure the railroad tracks to construct a particular route of travel for a train (e.g., switch machines, switch heaters, switch locks, etc.).

Although most types of equipment listed above can suffer from interference due to nearby ac power transmission and distribution systems, the first indication of an ac interference problem will usually come from the motion sensors and crossing predictors used to control the warning devices at grade crossings. Since they are often the most sensitive detectors of unwanted ac electrical energy on railroad tracks, particular attention should be paid to these systems.

Abnormal Operation of Railroad Equipment (Section 12.2.9, Red Book)

Railroad equipment is designed to fail in such a way that safety is maintained. So, if the track signals detect a problem, they slow or stop the trains. If the highway-crossing gate system detects an inappropriate input, it lowers the gates. The idea is that it is better to stop people and freight than to risk a collision. These “safe” failures are sometimes called “right-side” failures. The opposite would be “wrong-side” failures. These are simply unacceptable.

As mentioned earlier, the most common abnormal operations resulting from ac interference are false activation of highway-grade-crossing train detection equipment (the gates are down with no train). Another common problem is dropout of the locomotive cab signaling system that displays wayside signals inside the cab. Because these cab systems utilize inductive coupling from the track, operate at audio frequencies near power frequencies, and use very low power levels, they are more susceptible to ac interference than other systems.

Damage to Railroad Equipment (Section 12.2.10, Red Book)

When damage is caused by transmission-line operation, it is usually due to surges from faults or switching operations. Steady-state ac interference does not often cause damage because railroad signal equipment is designed to withstand ac voltage levels well above those considered hazardous to personnel (50 V rms steady-state). Since steady-state interference levels are usually maintained below this level for safety, steady-state interference rarely causes damage.

Track surge protective devices (SPDs or arresters) used on railroad equipment are designed to withstand lightning. SPDs used on track circuits are designed to fail open (not shorted). They fail when the energy flowing through them exceeds their i^2t capacity (i = current in amperes, t = time in seconds). While the current through an arrester will be an order of magnitude higher for lightning than for a power line fault, the duration of the current can be three to five orders of magnitude greater for the power line fault. Thus, the energy coupled by a power line fault can be much greater than from a lightning strike. The result is that the arrester is often destroyed, leaving the rest of the undamaged equipment vulnerable to lightning.

Personnel Safety Considerations (Steady-State Operation) (Section 12.2.11, Red Book)

Ac interference sometimes can be large enough to have an effect on a person on the ground touching the railroad system. If the voltage levels are high enough, a shock hazard might exist. Where voltage is induced in railroad facilities by electric-field induction, the steady-state short-circuit current to ground should not exceed 5 mA ac rms. More specific information on this topic can be found in Section 12.3.6 of the Red Book. A minimum criterion for steady-state voltage induced on railroad facilities by magnetic field induction would be to limit the voltage to a maximum of 50 V ac rms point-to-point (within reach) under worst case conditions.

Although it is highly unlikely that a spark could cause ignition (Deno and Silva 1985), care should also be taken when fueling machinery with gasoline under high-voltage lines. As a general rule, if fuel is to be transferred under high-voltage power lines, the fuel container should be electrically bonded to the equipment being fueled prior to and during fueling. Any fumes should be allowed to dissipate before removing the bond. Additional information on this subject can be found in Section 7.14 of the Red Book.

Another aspect of personnel safety is exposure to electric and magnetic fields. More information on this subject can be found in Chapter 7 of the Red Book.

Personnel Safety Considerations (Fault Conditions) (Section 12.2.12, Red Book)

Computer modeling can be used to predict fault-current induction into railroad systems. For these calculations, the worst-case fault should be modeled. To this end, various fault locations should be used to identify the maximum exposure voltage, and more specifically, the closest phase conductor to the track under elevated temperature final sag conditions should be faulted if this conductor also carries the largest possible fault current.

Experience shows that the voltage induced in communication/signal circuits from power line faults may be tolerated if the rms value of the induced voltage does not exceed: 430 V rms for typical power line equipment and maintenance or 650 V rms for high reliability power lines with high-speed relaying and fault clearing (AAR/EEI 1977). In any case, it is reasonable to evaluate the situations using either the IEC (1987) or IEEE (2000) method (or both) to ensure adequate safety and to ensure mitigation is not unnecessarily expensive. More detail on how this should be done can be found in Section 12.3.6 of the Red Book.

"Rules of Thumb" of Railroad Signals and AC Interference (Section 12.2.13, Red Book)

In summary, evaluation of ac interference with railroad systems can be summarized by several basic tenets: (EPRI 2004)

- 90% of problems are related to induction on the track.
- Motion sensors and crossing predictors are the most sensitive devices connected to the track, and will usually be the first indicators or victims of ac interference.
- Railroad signal circuits respond to the voltage between the two rails (differential mode).
- Anything that unbalances the electrical characteristics of one rail with respect to the other can act as a catalyst in turning induced common-mode voltage into differential or "rail-to-rail" voltage.
- Many cases thought to be related to "induction" turn out to be related to "conduction."

- Just because there is some ac interference on the track, does not mean that this is the cause of the problem.
- Many railroad signal circuits are frequency-selective, but enough of even a non-adjacent frequency can cause operational problems.
- Transmission lines may look big, but ordinary distribution lines are often the source of ac interference.

Changes to power line alignment that tend to decrease ac interference levels include:

- Increasing the horizontal or vertical distance between the track and power lines.
- Phasing multiple circuits for minimum magnetic field levels at rails.
- Decreasing the length of the parallel exposure.
- Decreasing the spacing between phase wires.
- Adding a second circuit to a single-circuit corridor, and optimizing the phase arrangement for minimum magnetic field levels from both circuits.

Changes to equipment that tend to decrease ac interference levels include:

- Decreasing the current-carrying capacity of the lines
- Installing fault-current-limiting devices.

More detail about mitigation options can be found in the *Power System and Railroad Electromagnetic Compatibility Handbook* (EPRI 2004).

Technical Evaluation

See Flowchart for Evaluation and Approval Process in the Administrative Guide.

Solicit inputs on issues and concerns from all impacted departments.

Prepare Engineering Evaluation

- Check railroad plan
  - Determine type of railroad (all possible materials to be transported).
  - Determine diameter of pipe.
  - Determine material of pipe.
  - Determine thickness of pipe.
  - Determine coating of pipe.
  - Determine depth of pipe.

- Determine plan of railroad including all insulated joints, discontinuities, exposures (above ground equipment), cathodic protection, and grounding.

- Determine design parameters
  - Maximum steady-state induced voltage.
  - Maximum fault induced voltage.
  - Available mitigation options.
- Check operating clearances
  - Determine line voltage.
  - Determine location, span, structure numbers.
  - Get design profile / mapping.
  - Verify that line clearances meet standard clearance.
  - Establish work rules for railroad installation to ensure electrical safety.
- Check physical configuration of transmission line
  - Structure profile.
  - Conductor positions.
  - Conductor types.
  - Alignment.
- Check transmission line electrical properties
  - Determine voltages and impedances for all phase wires.
  - Overhead ground wires.
  - Steady state currents.
  - Fault currents.
  - Fault clearing times.
  - Reclosing schemes
- Check industry work standards
  - Determine line voltage.
  - Refer to industry/electrical safety regulations for minimum working clearance to transmission conductors.
- Check future line criteria
  - Review electric system plan for future lines on ROW and capacity upgrades.
  - Contact System Planning for updated information.
- Check plant protection and internal policies and standards
  - No parking within a zone of _____ ft horizontally from any transmission structure.

  - Specify structure protection if necessary.
  - Review power company policies.
  - Check roads parallel and within ROW against future use requirements.
  - Good engineering practice.
  - Environmental/social acceptability.
  - Compliance with fire and electrical codes.
- Evaluate induction and grounding concerns
  - Perform graphic evaluation
    - Using the graphic evaluation produced by EPRI in 1983a (EL-3106-V2), updated for recent developments, and restructured to permit much easier application (to be completed).
  - Model ROW if necessary.
  - Model mitigation options.
- Check hard criteria
  - Clearance to vehicle (including load and reach) must exceed the minimum operating clearance.
  - Maximum induced current from the largest anticipated vehicle must be below 5 mA.
- Check soft criteria
  - If clearance is insufficient, suggest alternative location, lower ground elevation, raise conductors.
  - Limit vehicle size by installing height barriers.
  - Increase tolerance to nuisance shocks by increasing electric field limit criteria (if acceptable).
  - Install shielding device to lower electric field levels.

Assemble Responses and Engineering Evaluation

- Assemble responses from all departments and assure all pertinent technical issues are addressed.
- Select applicable general conditions.
- Compile all findings.

Prepare Engineering Report and Recommendations

Analysis criteria shall include standards of acceptance and the following as a minimum:

- Conductor to ground clearances.

- Horizontal clearance from conductors, structures and related plant.
- Local, national and internal standards.
- Work safety regulations.
- Access for maintenance.
- Provision for future plant.
- Environmental protection.
- Public image.
- Assessment of technical risk issues.
- All relevant information received from others.

Review Report

- Review report for accuracy, consistency and coverage.
- Transmit report to Property Services with copies to appropriate internal stakeholders.

Related Guidelines, Standards and Documents

Internal guidelines should be established and used for all installation on power company ROWs. The following is a list of relevant internal guidelines covering topics such as:

- General conditions
  - Contact the power company at least ______ days prior to working on ROW.
  - Power company not responsible for damage to works caused by normal activities.
  - Power company reserves the right to terminate consent.
  - Applicant responsible for all costs for plant alterations/protection.
  - Below ground works designed to withstand heavy loads.
  - Works must not approach within ______ ft of power company plant.
  - "As constructed" drawings required within ____ days.
  - Survey plan of works is required showing relation to ROW boundaries.
  - Proposed road/park shall not be dedicated.
  - Remove or relocate works upon issue of ____ days' written notice from the power company.
  - Works must not be enlarged, moved or added to without the consent of the power company.
  - Metal fences must be grounded according to the power company guidelines.
- Personal safety

- Safe working distance from transmission line conductors (e.g., 20' for 500 kV lines).
- Maximum height of vehicles, including load and reach, not to exceed _____ ft.
- Levels of induction in objects near transmission lines.

- Plant security and maintenance
  - Access to be maintained.
  - Grade elevation changes not to exceed _____ ft.
  - No parking within a zone of _____ ft horizontally from any transmission structure.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - Other uses of ROW require written consent from the power company.
  - Trees, shrubs and plants not to exceed _____ ft (e.g., 10') in height at maturity.
  - Temporary or permanent structures larger than __(size and height)__ are not allowed on ROW.

Relevant transmission maintenance and construction standards covering topics such as:

- Working clearances from energized conductors.
- Minimum operating line to ground clearances.
- Grounding of fences, buildings and objects near transmission lines.

National, state and local relevant industry standards and codes covering topics such as:

- National Electric Safety Code.
- Fire and electrical codes.
- Work regulations or electrical safety code for working near energized conductors.

Other references:

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Deno DW, Silva M. 1985. "Probability and Consequence of Gasoline Ignition Under HVAC Transmission Lines." *IEEE Transactions on Power Apparatus and Systems*, .PAS 104, no. 11, pp. 3181-3188, November.

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IEEE Standard 80. 2000. "IEEE Guide for Safety in AC Substation Grounding."

JCIIRC, 1918. "Final Report of the Joint Committee on Inductive Interference to the Railroad Commission of the State of California," *California State Printing Office*, Sacramento.

Attachments

- Frequently asked questions.
- Definitions/glossary.
- Terms of reference.

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ADMINISTRATIVE GUIDE - PIPELINES

Scope

This guide outlines the activities required for evaluating requests for pipeline facilities on rights-of-way (ROW) or fee-owned land. It outlines the conditions under which the proposal may or may not be approved, and the administrative approval process.

Purpose

- Ensure public safety.
- Ensure safe working conditions for electric utility and third party personnel.
- Ensure a uniform review, evaluation and approval process.
- Ensure power system reliability and safe operation of the transmission circuits.
- Ensure access for transmission maintenance and future expansions and modifications.
- Ensure plant security.
- Ensure uncompromised power transmission capability.
- Ensure compliance with all applicable codes, standards and regulations, laws and ordinances.
- Protect the property rights of the power company.
- Protect the electric utility's ability to construct future works.
- Protect the natural environment, habitat and wildlife.
- Promote positive public image by allowing multiple use of the ROW for compatible public activities.

Policy

Request for pipeline facilities on rights-of-way or fee owned land has a significant impact. It shall be processed through the administrative procedure established in this document to ensure that all affected groups have the opportunity to review and approve or disapprove the proposal.

This type of encroachment needs approval on a site-specific basis. Detailed construction drawings are to be submitted to the power company for approval, at least __(lead time)__ in advance of construction. The power company will arrange for Engineering, Legal, Operational and others as appropriate to review the proposal. No work shall proceed until approval has been granted. This procedure ensures that all affected departments have the opportunity to review and approve or disapprove the proposal.

Responsibilities

Here is an example showing the responsible functions which may be assigned in the review and approval process:

- Civil Design - foundations, structural or geotechnical concerns.
- Station Design - impacts to substation.
- Cable Design - impacts to underground works.
- Electrical Design - studies related to induction, grounding, clearance, conductor thermal rating.
- System Planning - anything affecting future plant.
- Environmental Services - environmental compatibility concerns.
- Survey and Photogrammetry - detailed field measurements and mapping.
- Property/Real Estate/Legal Services - land rights, liabilities and legal information, maintaining records and correspondence with applicants.
- Field resources - site-specific information.

Requirements

- Maintain property rights of the power company.
- Compliance with fire and electrical codes.
- Maintain horizontal distance from installed pipeline to transmission structures a minimum of _____ ft.
- Personal safety
  - Safe working distance from transmission line conductors.
  - Maximum height of vehicles, including load and reach, not to exceed _____ ft.
  - Supervision during construction.
  - Grounding of pipe during storage and construction.
  - Safe step and touch potentials on accessible equipment.
- Electrical damage to pipeline and associated equipment
  - There should be no damage to pipeline and associated equipment from electrical effects.

- Plant security and maintenance
  - Access to transmission structures must be unobstructed at all times.
  - Grade elevation changes not to exceed _____ ft.
  - No parking within a zone of _____ ft horizontally from any transmission structure.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - No landscaping, trees, shrubs and plants must exceed _____ ft (e.g., 10') in height at maturity on the ROW.
  - No storage of materials on ROW unless approved by the power company.
  - No temporary or permanent structures larger than _(size and height)_ are allowed on the ROW unless approved by the power company.

Related Guidelines, Standards and Documents

Request for pipeline facilities on rights-of-way or fee owned land has a significant impact and must be referred to relevant departments for review. It is not necessary for the ROW Administrator to review the relevant guidelines, standards and documents.

Administrative Procedure

Request for pipeline facilities must be referred to various departments for review and approval. See Flowchart for evaluation and approval process.

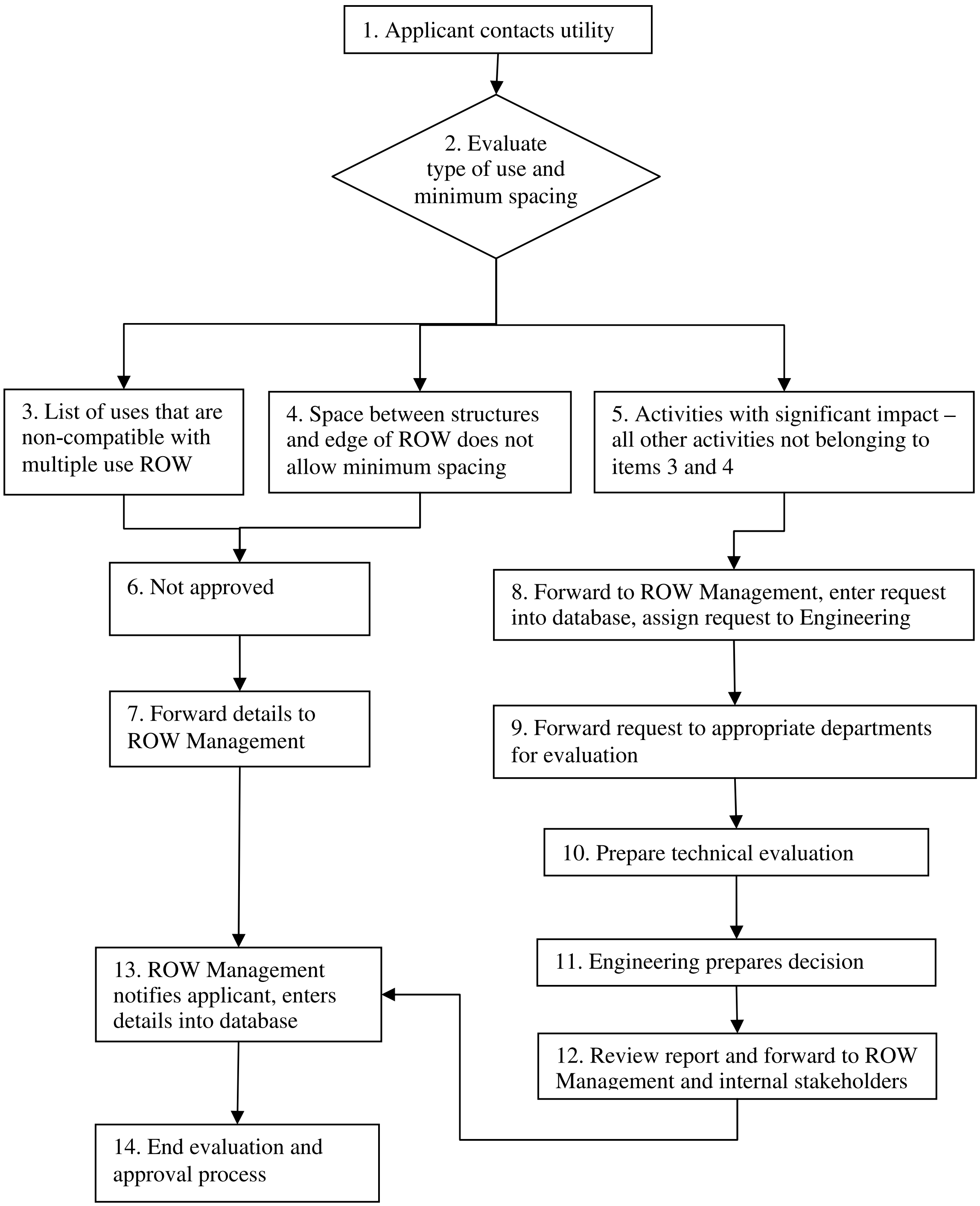
- Receive application, enter into log book and data base recording the following minimum information:
  - Property contact.
  - Engineering contact.
  - Type of use (e.g., materials to be transported in the pipeline).
  - Applicant.
  - Landowner.
  - Location.
  - Transmission circuits.
- Assign request
  - Determine level of complexity.
  - Determine other stakeholders.
  - Determine need for other information from Applicant.

- Determine type of use
  - Access previous similar requests in database.
  - Confirm development on ROW.
  - Confirm civil engineering impact (e.g., foundation, roadwork, soil effects); transmit request to Civil Design.
  - Confirm property impact (e.g., future expansion); transmit request to System Planning.
  - Confirm development on station property, transmit request to Station Design.
  - Confirm significant environmental impact; transmit request to Environmental Services.
- Prepare engineering (technical) evaluation (See Technical Guide for details)
- Assemble responses and engineering evaluation (See Technical Guide for details)
- Prepare engineering report (See Technical Guide for details)
- Review report (See Technical Guide for details)
- File report
  - File hard copies of report, original request, departmental responses, marked location maps, profiles and other related documents to ROW Engineering files.
  - Log completed report into ROW database with a case number.
  - Enter email correspondence, requests and all electronic documents into ROW database.
  - The approved cases can be kept for future reference.

Attachments

- Frequently asked questions.
- Definitions/glossary.
- Terms of reference.

Flowchart for Evaluation and Approval Process for Pipelines on Transmission Line Right-of-Way



Notes for Flowchart:

1. Applicant contacts utility and seeks approval for using the ROW.
2. The office receiving the request evaluates the type of use and classifies the request into one of the three categories: a) Not Approved (non-compatible usage), b) Not Approved (not meeting minimum spacing requirement), and c) Further Review (significant impact, require technical evaluation).
3. **Activities that are non-compatible** with multiple use of the ROW are not approved. A utility sets its own criteria and its own list of activities under this category, for example:
   Anything that is too close to structures or conductors.
   Storage of flammable, explosive or environmentally unfriendly materials or conditions.
   Any land use that extinguishes the utility rights.
   Anything that impacts the utility's flexibility to install future plant.
4. The space between the existing structures and the edge of the ROW is insufficient to accommodate the minimum spacing between pipelines and structures required by the utility.
5. **Significant impact** refers to those activities that may affect items like the environment, future use, safety, plant security and accessibility. All other activities that do not fall under the non-compatible use belong to this category. Activities belonging to this category require a technical evaluation process.
6. Requests for non-compatible use of the ROW are not approved.
7. Forward case details to the ROW Management Department.
8. ROW Management enters details of the request details into the database (e.g., property contact, type of use, applicant, landowner, location, transmission circuits), evaluates the request, obtains additional information from the applicant (if necessary), determines who are the stakeholders, evaluates the level of complexity, and assigns the request to a technical individual in Engineering accordingly.
9. Engineering prepares a referral package containing details of the application and background information (e.g., reference to the former cases, correspondence with the applicant). Forward the referral package to the appropriate departments for technical evaluation. See "Responsibilities" Section in the Administrative Guide for an example showing the responsibilities of the departments assigned in the evaluation and approval process.
10. Engineering and other departments prepare technical evaluations (e.g., check operating clearances, check electrical parameters, check industry work standards, check future line criteria, check plant protection and internal policies and standards). If estimate is required, refer to Transmission Project/Construction.
11. Engineering assembles and compiles responses from all departments. Prepare engineering decision report and recommendation using analysis criteria that include minimum standards of acceptance. See "Technical Evaluation" Section in the Technical Guide for more details.
12. Engineering reviews report for accuracy, consistency and coverage. Forward report to internal stakeholders and ROW Management. File all relevant materials. See "Administrative Procedure" in the Administrative Guide for more details.
13. ROW Management notifies the applicant of its decision and enters details into the database for record keeping, future reference and information retrieval.
14. End of the evaluation and approval process.

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TECHNICAL GUIDE - PIPELINES

Scope

This guide outlines the activities required for evaluating the technical compatibility of requests for pipeline facilities on rights-of-way (ROW) or fee-owned land. It outlines the conditions under which the proposal may or may not be approved, and the technical evaluation process.

Purpose

- Ensure public safety.
- Ensure safe working conditions for electric utility and third party personnel.
- Ensure a uniform review, evaluation and approval process.
- Ensure power system reliability and safe operation of the transmission circuits.
- Ensure access for transmission maintenance and future expansions and modifications.
- Ensure plant security.
- Ensure uncompromised power transmission capability.
- Ensure compliance with all applicable codes, standards and regulations, laws and ordinances.
- Protect the property rights of the power company.
- Protect the electric utility's ability to construct future works.
- Protect the natural environment, habitat and wildlife.
- Promote positive public image by allowing multiple use of the ROW for compatible public activities.

Policy

Requests for pipeline facilities on rights-of-way or fee owned land shall be processed through a procedure established to ensure that all affected groups have the opportunity to review and approve or disapprove the proposal.

Requirements

- Maintain property rights of the power company.
- Compliance with fire and electrical codes.
- Horizontal distance from installed pipeline to transmission structures a minimum of _____ ft.
- Personal safety
  - Safe working distance from transmission line conductors.
  - Maximum height of vehicles, including load and reach, not to exceed _____ ft.
  - Supervision during construction.
  - Grounding of pipe during storage and construction.
  - Safe step and touch potentials on accessible equipment.
- Electrical damage to pipeline and associated equipment
  - There should be no damage to pipeline and associated equipment from electrical effects.
- Plant security and maintenance
  - Access to transmission structures must be unobstructed at all times.
  - Grade elevation changes not to exceed _____ ft.
  - No parking within a zone of _____ ft horizontally from any transmission structure.
  - No deterioration of drainage patterns or soil stability.
  - ROW to be restored to transmission specifications at applicant's expense.
  - No landscaping, trees, shrubs and plants must exceed _____ ft (e.g., 10’) in height at maturity on the ROW.
  - No storage of materials on ROW unless approved by the power company.
  - No temporary or permanent structures larger than _(size and height)_ are allowed on the ROW unless approved by the power company.

Common Utility Practices

Here are some common utility practices:

- Must maintain a clearance of 50’ to where steel lattice tower legs or concrete foundations enter the earth for metal pipes and 30’ for non-metallic pipes; a clearance of 25’ to where wood poles, guy anchors, steel poles, or steel pole concrete foundations enter the earth.
- No requirements for the angle at which the non-metallic pipeline crosses the transmission lines.
- Pipeline locations must be marked with permanent signs where they enter and leave the ROW, and at any angle points within the ROW.

- Burial depth of the pipeline must meet national, state, and local standards. All pipelines must have a minimum cover of 36" except for gas and petroleum, where they need a minimum cover of 48" unless adequate protection for movement of heavy vehicles is provided for the pipeline.
- Pipelines must have a minimum cover of 48", measured from the top of the pipe to the natural ground level.
- Non-metallic pipelines may cross under the transmission line grounding systems with a minimum separation of 12". Metallic pipelines must not cross under the grounding systems and must maintain a minimum distance of 15' from the grounding system.
- If a crossing is required, the pipeline must be installed beneath the utility underground facilities. A minimum vertical clearance, outside pipe wall to outside concrete encasement or pipe wall, of 18" must be maintained between the utility underground facilities and any other facilities.
- If a pipeline is installed parallel to the utility underground facilities, a minimum horizontal clearance, outside pipe wall to outside concrete encasement or pipe wall, of 5'must be maintained between the utility underground distribution facilities and any other facilities.
- Pipelines installed within 20' of any structure foundation must be installed by either boring, tunneling, or other protective methods approved by the utility.
- No valve site is to be located closer than 50' to a transmission structure or appurtenance.
- Valve sites are to be located such that they do not limit access along the ROW.
- Valve sites, plus an additional 3' outside the site area, must be kept free of high grass and weeds at all times by the valve owners.
- Equipment for the purpose of flaring gas and blow-off vents are not permitted on the ROW.
- Anode beds, grounding cells, test points or any catholic protection equipment must be approved.
- Maintain a minimum of 2' vertical separation between fiber optic cable conduits and proposed pipeline crossings, and a minimum of 5' horizontal separation between the fiber optic conduits/pull holes and the pipeline.

Technical Background Information

Introduction (Section 12.3.1, EPRI 2005, "Red Book")

Like railroads, oil, gas, and other pipelines are long parallel transportation systems that commonly share a corridor with electric transmission lines. The long conductive pipelines are subject to electromagnetic interference (EMI) from power lines. EMI-induced currents and voltages on pipelines can degrade the pipeline coating and the pipe itself, disrupt the cathodic protection and other pipeline operating systems, and generate shock hazards for pipeline workers and the public. There is also a risk of gas ignition due to induced currents and voltages.

Concerns related to EMI impacts on pipelines have increased over the last decades. Competition for land and constraints on land use have encouraged the joint use of corridors by pipelines and electric transmission lines. In addition, improved pipeline coatings have reduced the number of defects (holidays) in the coatings where leakage to ground can occur (Bonds 1999; Shwehdi and Johar 2003). The lack of holidays increases the resistance of pipelines to ground and results in higher induced voltages.

Pipelines are subject to three types of coupling to the power line electric and magnetic fields: electric-field or capacitive coupling, magnetic-field or inductive coupling, and ohmic or conductive coupling through the earth (Sections 12.2.3, 12.2.4, and 12.2.5, Red Book). Capacitive coupling to pipelines is only of concern when the pipe is above ground and ungrounded. It can be analyzed with straightforward methods commonly used for coupling to objects under transmission lines (Section 7.8, Red Book). Burial of pipelines complicates the nature of inductive coupling relative to that for a conductor in air. A pipeline buried in soil must be considered as a conductor in a lossy medium, where leakage of the induced currents to earth occurs continuously along the length of the pipeline. This presents a more difficult analysis problem than induction between power lines and railroad tracks, since buried pipelines may be much lossier than railroad tracks. Burial of pipelines also introduces the possibility of conductive coupling through the earth during fault conditions.

Early prediction methods for induced currents on buried pipelines often relied on induction calculations for conductors in air. This approach overestimated induced voltages by up to a factor of 10 when compared with measured values (Taflove and Dabkowski, 1979). A more sophisticated and accurate prediction method for EMI from power lines to pipelines was developed during a comprehensive study of overhead ac transmission lines and pipelines sponsored jointly by the Electric Power Research Institute and the American Gas Association (EPRI/AGA) in the 1970s (EPRI 1978a; EPRI 1978b; Taflove and Dabkowski 1979; Dabkowski and Taflove 1979a; Taflove et al. 1979; Dabkowski and Taflove 1979b). The method developed in this study considers the pipeline as a lossy electrical transmission line in a conducting earth. An equivalent circuit for the pipeline is derived given the electrical characteristics and physical locations of the transmission line(s), pipeline(s), and the earth. The method predicts induced currents and voltages on pipelines in transmission corridors during steady-state conditions. This methodology produced results that compared favorably with measurements (Dabkowski and Taflove 1979a). This project also developed computational methods for predicting induced voltages and currents and mitigation strategies for reducing induced voltages on pipelines (Taflove et al. 1979; Dabkowski and Taflove 1979b; CEA 1979).

Two subsequent joint EPRI/AGA project in the 1980s also developed computation methods for interference from power lines to gas pipelines (EPRI 1983a; EPRI 1987; Dawalibi and Southey 1989; Dawalibi and Southey 1990). Besides addressing steady-state conditions, these subsequent projects emphasized inductive and conductive coupling during fault conditions.

Electric Field Induction (Section 12.3.2, Red Book)

Required Conditions

Electric-field induction is of concern whenever long sections of pipe are located above the ground without adequate grounding. This condition is of special concern for above-ground pipe storage that can occur during construction. In this case, electric fields from the overhead conductors can result in potentially hazardous voltages or currents on the pipe. Once a contiguous portion of the pipe is buried, an effective ground for mitigating electric-field coupling is established through the resistive pipe coating. However, such a ground may not reduce the potential for magnetic-field-induced voltages.

Predictive Methods

The nature of electric fields under transmission lines and the electric-field coupling to objects under transmission lines were discussed in Section 7.8 of the Red Book. The open-circuit voltage, V_{oc}, and induced short-circuit current, I_{sc}, to a pipe of length L, radius r, and height h above the ground in a uniform vertical electric field E is given by (EPRI 1982, p. 349; EPRI 1978a, p. 4-6):

$$V_{oc} \approx Eh \qquad (1)$$

and

$$I_{sc} = j\ EhL(2\ \ _{o}/(\ln(2h/r)) \qquad (2)$$

If the pipe is located parallel to the line, the electric field varies somewhat as the conductor height changes along the line. In this case, the average field along the pipe length represents the equivalent uniform vertical field. However, if the pipe is perpendicular to, or at an angle to, the transmission line, then the magnitude and phase of the field have to be taken into account to develop an equivalent vertical field for the purpose of estimating induced voltage and short-circuit current (Reilly 1979).

From Equation 2, it is apparent that the magnitude of the potential current shock from the ungrounded pipe is directly dependent on the length of the pipe and on the electric field, and also dependent on the height and radius of the pipe.

Mitigation

Mitigation to avoid transient discharges and steady-state currents to workers from electric-field-induced voltages on aboveground pipelines can be accomplished by moving the pipe away from the power line or by installing a separate grounding system for the pipe when it is near the transmission line. The use of independent grounds is also used to mitigate for nuisance shocks from conducting objects found on or near rights-of-way, such as fences, large metal buildings, and large vehicles.

Grounding systems should be placed away from towers to mitigate the possibility of a transferred potential (conductive coupling) to the pipe during a fault at the tower. To achieve this, the recommended location for grounds is midway between towers and as far from the transmission line as possible (EPRI 1978a, p. 8-2). Redundant grounds at each location minimize problems due to failed grounds.

The short-circuit current to earth from the pipe, I_{sc}, follows parallel current paths through the worker with impedance of Z_w and through the grounding system with impedance to remote earth of Z_g. The impedance of the grounding system to remote earth that is required to limit the current to the worker, I_w, to a given value can be determined from (Dabkowski and Taflove 1979a, p. 8-6).

$$Z_g = Z_w[I_w/(I_{sc} - I_w)] \qquad 3$$

If the limit on current through the worker is taken as the 3 mA limit for grasped contacts in IEEE Standard C95.6- 2002 (IEEE 2002a, p. 15), then the maximum ground system impedance is given by

$$Z_g \leq 4500/I_{sc} \qquad 4$$

where I_{sc} is in mA, I_{sc} is assumed to be much greater than I_w, and the worker impedance is taken as 1500 , the wet skin impedance (EPRI 1978a, p. 8-6). The maximum short-circuit current for a pipe, I_{sc}, can be calculated from Equation 2.

For long pipes, single-point grounds to eliminate hazards from electric-field-induced voltage may exacerbate problems associated with magnetic-field-induced voltages on the pipe. With a single-point ground, magnetic-field induction may generate a voltage on the pipe between the ground and the worker. The worker standing on remote earth may then experience a shock when touching the pipe. This can be alleviated somewhat by the introduction of multiple grounds along the above-ground pipe with low-impedance grounds at each end to reduce magnetic-field-induced voltages. All grounds should be far removed from towers where the possibility of conductive coupling during faults exists.

Hazards to personnel from all types of coupled voltages and currents can be mitigated by the use of ground mats in work areas. These are conducting wire grids that are bonded to the pipe and extending away from the work area. The ground mat provides an equipotential area that is essentially at the same voltage as the pipe. This precaution eliminates the possibility of the worker being at remote earth potential when he/she touches the pipe. Safety procedures with respect to the installation and use of ground mats are described in the NACE Standard Recommended Practice for Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems (NACE 2000).

Magnetic-Field Induction (Section 12.3.3, Red Book)

Required Conditions

Magnetic-field induction occurs on above-ground and buried pipeline segments that are adjacent to overhead transmission lines. The magnitude of the induced voltage will depend on the length of the segment and the grounding characteristics. The previously mentioned EPRI/AGA studies provided a comprehensive examination of prediction, mitigation, and design methodologies for induced voltages on gas transmission pipelines. The first study emphasized steady-state conditions (EPRI 1978a; EPRI 1978b). Subsequent studies investigated induction and conduction to pipelines during both steady-state and fault conditions (EPRI 1983a; Dawalibi and Southey 1989; Dawalibi and Southey 1990).

The principal concerns related to steady-state magnetic-field-coupled voltages on pipelines are physical damage to coating and hazards to personnel or the public who might contact the pipeline. Other concerns are interference with the operation of electronic equipment ancillary to pipeline operation such as cathodic protection, communications, and monitoring systems, and corrosion of the pipeline. The larger voltages and currents conducted to the pipeline during fault conditions raise the additional concern of damage to the pipeline itself.

Concern for induced voltages on pipelines is not limited to those parallel to transmission lines. Jaffa and Stewart (1981) report that objectionable voltage levels can be induced on long buried irrigation pipelines by parallel distribution lines.

For buried pipelines, the largest induced voltages occur where there is a physical change or discontinuity in the pipeline. The physical change results in a change in the impedance or the driving electric field along the pipeline. Such locations include a bend in the pipe, a cathodic protection system, an insulated joint, or where the transmission line veers away from the pipeline.

Predictive Methods

The original EPRI/AGA study of induction on buried pipelines developed computational methods for determining induced steady-state voltages on pipelines in shared corridors with ac transmission lines (Taflove and Dabkowski 1979; Dabkowski and Taflove 1979a). In this approach, the pipeline is treated as a lossy electrical transmission line with impedance per unit length of Z and admittance per unit length of Y. The line is described by a characteristic impedance $Z_o = (Z/Y)^{1/2}$ and propagation constant $= (ZY)^{1/2}$. The lossy transmission line is subject to a distributed voltage source along its length, corresponding to the longitudinal electric field of the transmission line that is parallel to the pipeline. The longitudinal field is a function of the currents and geometries of the parallel power lines and other conductors in the corridor.

The differential equations describing this electrical model of a pipeline are identical to the classical transmission-line equations, plus a term for the distributed source (Taflove and Dabkowski 1979). Solution of these equations leads to an expression for the voltage as a function of distance along the pipeline. Another important result is that the voltage at a termination of the pipeline can be modeled as a Thevinen equivalent circuit.

The Thevinen equivalent voltage for the pipeline is dependent on the longitudinal electric field, the pipeline length, characteristic impedance and propagation constant, and the impedance at the other termination. The Thevinen source impedance is dependent on the pipeline length, characteristic impedance and propagation constant, and the impedance at the other termination. Sections of the pipeline with constant or variable longitudinal electric field can be modeled as Thevinen equivalent circuits.

With the Thevinen equivalent approach, methodologies were developed for electrically short (L < 0.1/| |) and electrically long (L > 2 Real( )) pipelines, for parallel and nonparallel pipelines, and for long pipelines terminating outside the corridor. Nonparallel pipelines and those terminating outside the corridor are characterized by a non-constant driving electric field.

The common Thevinen equivalent circuit approach allows analysis of pipelines comprised of segments with different source terms. This capability is essential to analyze realistic scenarios where changes in the source term are introduced by, among others, pipe joints, grounds, cathodic protection systems, and transmission-line transpositions, as well as discontinuities in separation distance, pipeline coatings, and earth conductivity. The Thevinen voltages at the junctions between segments with dissimilar sources can be combined to estimate the induced voltages for the entire pipeline.

The prediction method for steady-state induced voltages requires computation of the longitudinal electric field, pipeline characteristics, and Thevinen circuits. These are determined by the physical and electrical characteristics of the transmission line, pipeline, other conductors, and earth. A series of calculations were developed to provide: the unknown currents in earth return circuits; the mutual impedances between adjacent, parallel earth return conductors; the pipeline propagation constant and characteristic impedance; and the Thevinen source voltage and source impedance.

These calculations were originally implemented in programs for a vintage handheld programmable calculator (TI-59) (EPRI 1978b; EPRI 1985). The programs are included in the reports and could be implemented on a modern PC or other platform.

Comparisons of the predicted induced voltages on pipelines in existing shared corridors agreed with measured values within about 10% (Dabkowski and Taflove 1979a). Both the predictions and the measurements exhibited local peaks in the induced voltage at electrical discontinuities in the pipelines.

As an example, the geometry and predicted and measured induced voltages for a pipeline parallel to a transmission line in the Mojave Desert are shown in Figures PIPE-1 and 2. The discontinuities are described in Table PIPE-1.

Table PIPE-1
Induced Voltage Peaks at Discontinuities along the Mojave Desert Pipeline
(Dabkowski and Taflove 1979a)

Milepost	Discontinuity	Predicted Voltage (V)	Measured Voltage (V)
101.7	Pipeline approaches power line	46.3	46
89	Change in separation from power line	54.0	53
78	Change in separation from power line	31.1	34
68	Power line phase transposition	54.8	51
54	Change in separation from power line	11.4	11
47	Pipeline departs power line	31.2	25

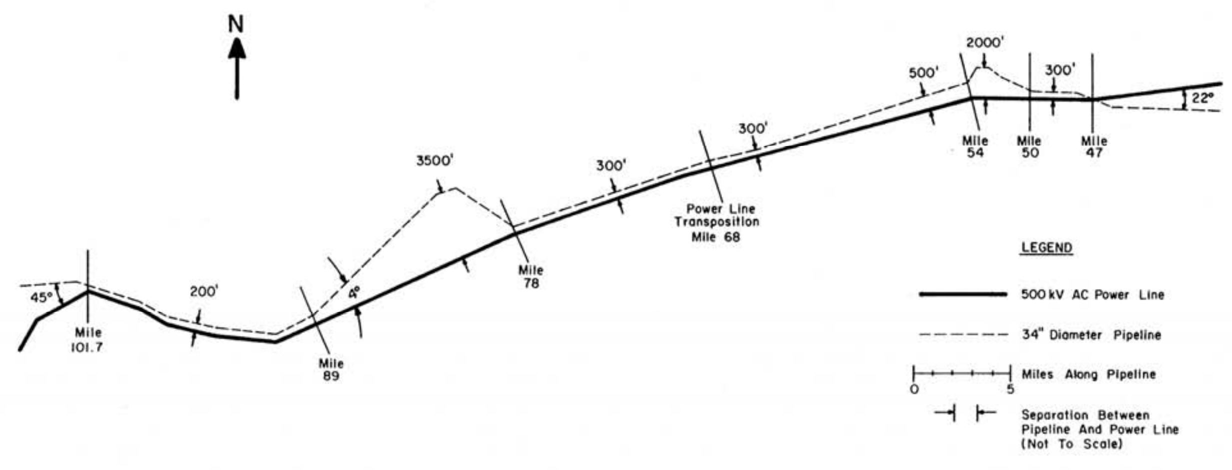

Figure PIPE-1
Mojave Desert pipeline-power line geometry
(Figure 12.3-1, Red Book)

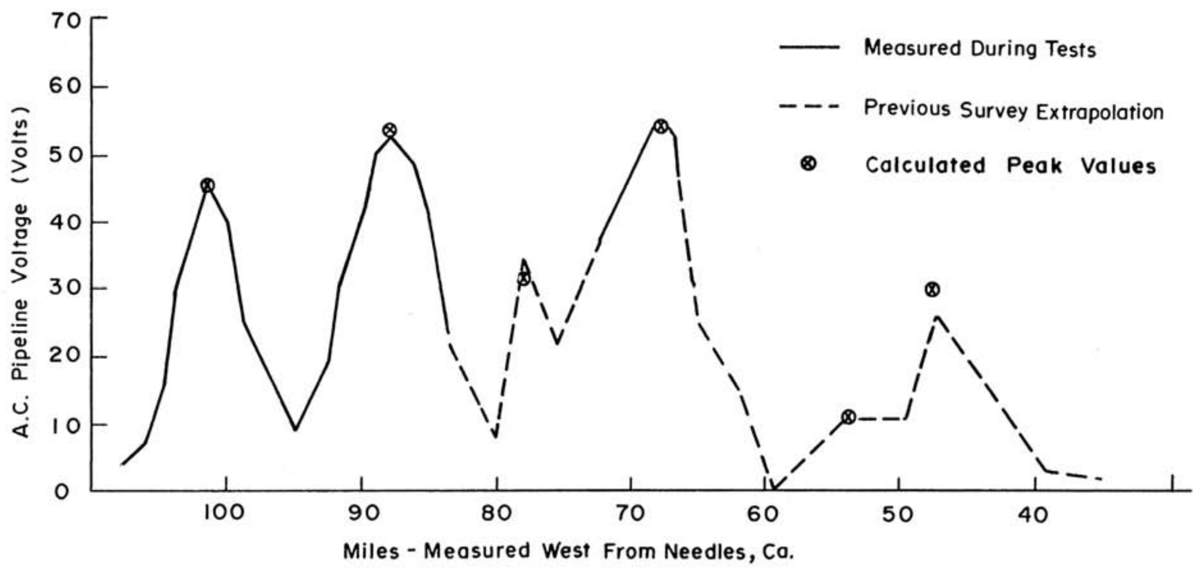

Figure PIPE-2
Mojave Desert pipeline voltage profile
(Figure 12.3-2, Red Book)

Additional computational methods to accurately simulate complex realistic right-of-way problems were developed in the second EPRI/AGA study (EPRI 1987; Dawalibi and Southey 1989; Dawalibi and Southey 1990). Electric- and magnetic–field induction and conductive coupling for steady-state and fault conditions are examined with an emphasis on the latter condition. The computer program that combines these methods predicts inductive and conductive coupling between power lines and arbitrarily positioned above-ground and buried pipelines. Both long and short conductor segments can be included, with the short segments often representing the grounding configuration of the towers or the pipeline. The grounding configuration is important for analyzing inductive and conductive coupling during fault conditions. The calculations also allow for inclusion of underground bare conductors, which can have different propagation characteristics than better insulated coated conductors.

For this approach to inductive coupling, short and long conductors are treated separately, at least initially. Ultimately, the different conductors are combined into a circuit model based on their voltage, ground impedance, and self and mutual impedances. Impedance to earth for grounding networks (short conductors) is determined with a field theory approach (Dawalibi and Southey 1989). The impedance-to–earth, per unit length of long buried conductors, is obtained from a similar approach. The self and mutual impedances for long conductors are obtained from expressions for conductors in air or equations for lossy underground conductors that have been developed over many years and are often used in analysis of transmission lines (Dawalibi and Southey, 1989, pp. 1842-1843).

The circuit model includes the voltages and impedances for all phase wires, overhead ground wires, pipelines, mitigation wires buried near pipelines, and tower grounds. The ground impedances for towers and other structures are also incorporated. Solution of the circuit model by the double-sided elimination method yields the magnetically induced voltages and currents in the pipeline and any mitigation wires (Dawalibi and Southey, 1989, p. 1845).

To incorporate conductive coupling into the model, computations are made of voltages and currents on the long conductors, due to known currents injected into the earth by the grounding systems. The results of computations for conductive effects are combined with those for inductive effects to produce the final prediction of pipeline voltages and currents due to steady-state or fault conditions on a nearby transmission line.

Predictions for coupled voltages and currents by the program were in agreement with measurements in previous tests under both steady-state and fault conditions. The program was also used to investigate the influence of various parameters on inductive and conductive coupling (Dawalibi and Southey 1990).

Mitigation

The parametric analysis of Dawalibi and Southey (1990) considered inductive and conductive coupling separately and suggested approaches to mitigation. For inductive coupling, separation between power line and pipeline is obviously an important factor: increased separation decreases coupling strength. The length of the pipeline is also important until the length exceeds the characteristic length of the pipeline (the inverse of the propagation constant), at which point, the induced voltage remains constant. This observation would suggest segmenting the pipeline into shorter sections with insulating junctions. However, the junctions can introduce higher cathodic protection costs and result in large voltage differences across the junctions during faults.

Grounding of the pipeline reduces the induced voltage and can be an effective mitigation tool at electrical discontinuities in the pipeline where peak-induced voltages occur. Mitigation wires that are parallel to, and near, the pipeline but are not bonded to the pipeline reduce the induced voltage on the pipeline. In this case, several smaller conductors are more effective than one large conductor.

NACE Standard RP0177-2000 describes design considerations for numerous protective devices to mitigate the effects of all types of ac coupling to metallic structures including pipelines (NACE 2000, pp. 4-10). Protection should be considered for locations that are restricted to workers and to those that are accessible to the general public. The protective devices include:

- *Electrical shields*. Mitigation wires or shields can be installed in the earth between the ac power systems and the pipeline. They can be a long, buried bare conductor or a group of electrodes surrounding a pipeline. Shields are intended to reduce the pipeline to earth potential and thus reduce the possibility of damage to the coating or to the pipe.
- *Grounding mats*. Grounding mats bonded to a structure may be placed at locations where persons may be in contact with hazardous step-and-touch potentials. For pipelines, these locations include areas near valves, metallic vents, cathodic protection test stations, and other components of a pipeline that protrude above ground, where contact can be made by a worker or the public. Ground mats should be large enough to ensure reduction of the step-and-touch potentials to acceptable levels for contact with the structure.

- *Isolating joints*. These joints divide the pipeline into shorter electrical segments or isolate a section in proximity to a power system from the remainder of the pipeline. Devices such as lightning arresters, polarization cells, or electrolytic grounding cells should be installed across the joints to protect them from breakdown under high-voltage conditions. These same devices can be installed between affected structures and grounds to reduce induced voltages during normal operation and surge conditions and to reduce the possibility of structure puncture.
- *Anodes and grounding cells*. Distributed anodes and/or electrolytic grounding cells used to prevent corrosion can be incorporated as part of a grounding system.

The NACE Standard recommends that during construction temporary electrical grounds be placed at intervals not to exceed 300 m (1000 ft) on long conducting structures such as pipelines (NACE 2000, p. 12). Bonding of temporary or permanent grounds to the existing structures of a power system is strongly discouraged because of the increased hazards during fault conditions.

Conductive Coupling (Section 12.3.4, Red Book)

Required Conditions

During faults to ground, the earth is a conductive path for fault current to remote earth. This current results in a localized potential rise relative to remote earth at the faulted structure. The current and potential rise can couple into an adjacent pipeline and cause physical damage to the pipeline and create voltages hazardous to personnel. Although pipes are generally coated, the fault-generated potential difference between the soil and the metal pipe can puncture the coating and even damage the pipe itself. The ground potential rise near a faulted tower can increase the step-and-touch potentials near the structure as well as near a pipeline. Any associated voltage rise on a pipeline can be transferred to locations remote from the fault, and represent a hazard on pipeline components that are accessible to persons in contact with the earth.

An unbalanced distribution system with a grounded neutral can also be a source of earth currents. However, the magnitude of these currents is generally orders of magnitude smaller and does not give rise to the large potential differences between pipe and soil or to hazardous step-and-touch potentials. However, ground faults or lightning strikes to a distribution system can result in the same hazards experienced under fault conditions near a transmission line.

Predictive Methods

Conductive coupling requires that current be injected into the earth near a pipeline or other buried structure. The current is injected through the tower footings and any counterpoise that is present. The grounding systems for towers and pipelines are generally comprised of short conductors for which the assumptions used in computing impedances of long conductors are not valid. As noted earlier in this section, Dawalibi and Southey (1989) describe a hybrid method for determining potentials and currents in the earth and on pipelines for a system with both short and long conductors present.

First, the circuit model is solved for the inductively coupled currents and voltages. Then the known fault currents injected into the earth through the grounding systems are incorporated. With field theory and the known injected currents, the user can then determine the potentials near the ground systems and the potentials and currents in the long conductors. The potentials and currents in the long conductors computed in this manner are the result of conductive coupling. The conductive and inductive coupling results are then added together (with care taken to correctly combine currents with different phases) to produce the total interference level.

Mitigation

For conductive coupling, separation between the tower ground and the pipeline is obviously an important factor in reducing coupled voltages during faults. The parametric analysis of Dawalibi and Southey (1990) examined other factors that can affect conductive coupling. The tower ground impedance affects coupled voltages: lower tower impedance results in lower potential rise near the tower during faults and thus lower soil potentials near the pipeline. The tower impedance depends directly on the soil resistivity and the size and extent of the structure ground. Long mitigation wires situated between the pipeline and the tower perturb the potential distribution during a fault and reduce conductive coupling effects.

Damage to Pipelines (Section 12.3.5, Red Book)

Induced voltages on pipelines are generally less than 50 V under steady-state conditions and less than 500 V during fault conditions (EPRI 1978a, p. 7-26). Consequently, most damage to pipelines from induction phenomena occurs during faults.

However, the relatively low voltages induced under steady-state conditions can damage the pipeline through various mechanisms (EPRI 1978a, p. 7-26). They can reduce the lifetime of cathodic protection rectifiers. They can cause current flow through unintended conducting bridges across insulating joints. This current flow can eventually heat up and damage the joint. Induced ac currents can interfere with data signals when the pipe is part of the communication system for the facility.

Under high-current conditions, due to either a power line fault to ground or a lightning strike to the power system, the fault current into the ground can cause a rise in soil-to-pipe potential. If this potential difference is of sufficient magnitude, it may break down the protective coating around the pipeline or, in extreme cases (5000 V), puncture a hole in the pipe itself. In this latter instance, there is a risk of ignition of leaking gas. A rise in the voltage on a pipeline can also damage isolating fittings between pipeline sections, bonding connections, lightning arresters, and cathodic protection systems. Large fault currents can also cause glow or arc discharges at coating punctures or in the earth. The discharges can have sufficient energy to damage coaxial cables or ignite gas vapors (EPRI 1978a, p. 7-28).

The communications networks associated with pipelines generally employ newer wireless and fiber optic technologies that are immune to EMI from transmission-line sources (Association of Oil Pipe Lines 2004). Telephone land lines are also used but do not necessarily follow the pipeline and any parallel transmission lines. Thus, induced voltages and currents on pipelines could damage individual communications components located on the pipeline but not interfere with communications per se.

Corrosion of steel due to 60-Hz currents to buried structures is estimated to be about 0.01 to 0.1% of that for a dc current of comparable magnitude (EPRI 1978a, p. 7-8). Cathodic protection systems tend to mitigate the effects of ac corrosion. Consequently ac corrosion is generally not a problem with pipelines buried near transmission systems.

However, coupled currents and voltage can affect cathodic protection system components, such as rectifiers. In areas with known potential for interference or with observed rectifier failures, testing of cathodic protection systems should take place more frequently with safety precautions implemented to protect workers (NACE 2000, pp. 15-16).

Personnel Safety (Section 12.3.6, Red Book)

Steady State

Personnel working on pipelines can be exposed to hazardous ac voltages due to coupling from adjacent power systems. The NACE Standard Recommended Practice for Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems cites 15 V (rms) as a level of anticipated shock hazard. This value is selected to limit currents to 10 mA through an assumed hand-to-hand or hand-to-foot resistance of 1500 for an adult male (NACE 2000, pp. i and 11).

The IEEE standard for exposure to electromagnetic fields, 0–3 kHz, sets a lower limit of 3 mA for the maximum permissible exposure (MPE) for a grasp contact in controlled (occupational) environments (IEEE 2002a, p. 15). The IEEE MPE for a touch contact is 1.5 mA in controlled environments and 0.5 mA for the general public. The lower limits for the IEEE standard reflect the choice of “discomfort” as the criterion for the limit. The NACE standard is based on the maximum safe let-go current for adult males.

When the voltage level on a pipeline (or other structure) exceeds the hazardous level, NACE (2000) calls for reduction of the voltage to safe levels or implementation of other measures to prevent shocks to pipeline workers or the general public. These measures include temporary grounding of pipelines during construction, installing ground mats at work locations, and restricting public access to possible contact points.

Fault Conditions

The following discussion of hazardous voltage levels during faults is drawn from the IEEE Guide for Safety in AC Substation Grounding (IEEE 2000). Although this guide applies to substation grounding, it can also be used to analyze hazardous conditions near pipelines.

The response of individuals to short-duration current shocks is dependent on the magnitude and duration of the shock current passing through the body. To estimate tolerable voltage levels for short-duration, rarely-occurring shock scenarios, the IEEE guide uses, as an allowable current level, the current at which 99.5 % of persons do not experience ventricular fibrillation. Empirical findings indicate that this current level is dependent on duration of the shock and body weight, as follows:

$$I_B = k / \sqrt{t_s} \qquad 5$$

Where: I_B is the current through the body in amperes.
k is a constant dependent on body weight (k = 0.116 for 50 kg, and k = 0.157 for 70 kg).
t_s is the shock duration in seconds.

The tolerable voltage is determined by the allowable current and the combined resistance of the body and the foot contacts. The tolerable voltage for step potentials is given by:

$$V_{step} = I_B\,(R_B + 2R_f) \qquad 6$$

Where: V_{step} is the voltage between the feet at a 1-m separation.
R_B is the body resistance.
R_f is the contact resistance of one foot.

The tolerable voltage for touch potentials, V_{touch}, is:

$$V_{touch} = I_B\,(R_B + R_f /2) \qquad 7$$

The IEEE guide (2000) assumes a body resistance of 1000   and a foot resistance standing on homogeneous soil of:

$$R_f = \rho/4b \qquad 8$$

Where: is the soil resistivity.
b is the radius of a metal disk equivalent to the foot contact, assumed to be 0.08 m.

If there is a layer of more insulating material spread over the soil, such as gravel in a substation, then the foot resistance is given by:

$$R_f = \rho_s C_s/4b \qquad 9$$

Where: s is the resistivity of the surface layer.
C_s is the surface layer derating factor that accounts for the finite thickness of the top layer.

The derating factor can be computed from models, determined from graphs, or determined from an empirical formula (IEEE 2000, pp. 22-23). For a homogeneous, single-layer earth, C_s = 1 and

$_s$ = .

Combining Equations 5, 6, and 9, and using a 1000   body resistance, yield the following limit for maximum allowable step potential:

$$V_{step} = (1000 + 6\rho_s C_s)k / \sqrt{t_s} \qquad 10$$

Similarly, for the maximum allowable touch potentials, combining Equations 5, 7, and 9 yields:

$$V_{touch} = (1000 + 1.5\rho_s C_s)k / \sqrt{t_s} \qquad 11$$

Actual step or touch potentials should be less than these values to ensure safety of personnel during fault currents.

Technical Evaluation

See Flowchart for Evaluation and Approval Process in the Administrative Guide.

Solicit inputs on issues and concerns from all impacted departments.

Prepare Engineering Evaluation

- Check pipeline plan
  - Determine type of pipeline (all possible materials to be transported).
  - Determine diameter of pipe.
  - Determine material of pipe.
  - Determine thickness of pipe.
  - Determine coating of pipe.
  - Determine depth of pipe.
  - Determine plan of pipeline including all insulated joints, discontinuities, exposures (above ground equipment), cathodic protection, and grounding.
- Determine design parameters
  - Maximum steady-state induced voltage.
  - Maximum fault induced voltage.
  - Available mitigation options.
- Check operating clearances
  - Determine line voltage.
  - Determine location, span, structure numbers.

  - Get design profile / mapping.
  - Verify that line clearances meet standard clearance.
  - Establish work rules for pipeline installation to ensure electrical safety.
- Check physical configuration of transmission line
  - Structure profile.
  - Conductor positions.
  - Conductor types.
  - Alignment.
- Check transmission line electrical properties
  - Determine voltages and impedances for all phase wires.
  - Overhead ground wires.
  - Steady state currents.
  - Fault currents.
  - Fault clearing times.
  - Reclosing schemes
- Check industry work standards
  - Determine line voltage.
  - Refer to industry/electrical safety regulations for minimum working clearance to transmission conductors.
- Check future line criteria
  - Review electric system plan for future lines on ROW and capacity upgrades.
  - Contact System Planning for updated information.
- Check plant protection and internal policies and standards
  - No parking within a zone of _____ ft horizontally from any transmission structure.
  - Specify structure protection if necessary.
  - Review power company policies.
  - Check roads parallel and within ROW against future use requirements.
  - Good engineering practice.
  - Environmental/social acceptability.
  - Compliance with fire and electrical codes.
- Evaluate induction and grounding concerns
  - Perform graphic evaluation

    - Using the graphic evaluation produced by EPRI in 1983 (EL-3106-V2), updated for recent developments, and restructured to permit much easier application (to be completed).
  - Model ROW if necessary.
  - Model mitigation options.
- Check hard criteria
  - Clearance to vehicle (including load and reach) must exceed the minimum operating clearance.
  - Maximum induced current from the largest anticipated vehicle must be below 5 mA.
- Check soft criteria
  - If clearance is insufficient, suggest alternative location, lower ground elevation, raise conductors.
  - Limit vehicle size by installing height barriers.
  - Increase tolerance to nuisance shocks by increasing electric field limit criteria (if acceptable).
  - Install shielding device to lower electric field levels.

Assemble Responses and Engineering Evaluation

- Assemble responses from all departments and assure all pertinent technical issues are addressed.
- Select applicable general conditions.
- Compile all findings.

Prepare Engineering Report and Recommendations

Analysis criteria shall include standards of acceptance and the following as a minimum:

- Conductor to ground clearances.
- Horizontal clearance from conductors, structures and related plant.
- Local, national and internal standards.
- Work safety regulations.
- Access for maintenance.
- Provision for future plant.
- Environmental protection.
- Public image.
- Assessment of technical risk issues.

- All relevant information received from others.

Review Report

- Review report for accuracy, consistency and coverage.
- Transmit report to Property Services with copies to appropriate internal stakeholders.

Related Guidelines, Standards and Documents

Internal guidelines should be established and used for all installation on power company ROWs. The following is a list of relevant internal guidelines covering topics such as:

- General conditions
  - Contact the power company at least ______ days prior to working on ROW.
  - Power company not responsible for damage to works caused by normal activities.
  - Power company reserves the right to terminate consent.
  - Applicant responsible for all costs for plant alterations/protection.
  - Below ground works designed to withstand heavy loads.
  - Works must not approach within ______ ft of power company plant.
  - "As constructed" drawings required within ____ days.
  - Survey plan of works is required showing relation to ROW boundaries.
  - Proposed road/park shall not be dedicated.
  - Remove or relocate works upon issue of ____ days' written notice from the power company.
  - Works must not be enlarged, moved or added to without the consent of the power company.
  - Metal fences must be grounded according to the power company guidelines.
- Personal safety
  - Safe working distance from transmission line conductors (e.g., 20' for 500 kV lines).
  - Maximum height of vehicles, including load and reach, not to exceed _____ ft.
  - Levels of induction in objects near transmission lines.
- Plant security and maintenance
  - Access to be maintained.
  - Grade elevation changes not to exceed _____ ft.
  - No parking within a zone of _____ ft horizontally from any transmission structure.
  - No deterioration of drainage patterns or soil stability.

- ROW to be restored to transmission specifications at applicant's expense.
- Other uses of ROW require written consent from the power company.
- Trees, shrubs and plants not to exceed _____ ft (e.g., 10') in height at maturity.
- Temporary or permanent structures larger than __(size and height)__ are not allowed on ROW.

Relevant transmission maintenance and construction standards covering topics such as:

- Working clearances from energized conductors.
- Minimum operating line to ground clearances.
- Grounding of fences, buildings and objects near transmission lines.

National, state and local relevant industry standards and codes covering topics such as:

- National Electric Safety Code.
- Fire and electrical codes.
- Work regulations or electrical safety code for working near energized conductors.

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Attachments

- Frequently asked questions.
- Definitions/glossary.
- Terms of reference.

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