



Transmission Line Design (Volume I) - Planning

An Online Continuing Education Course for Engineers

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Introduction

The primary purpose of this series of courses is to furnish engineering information for use in designing transmission lines. Good line design should result in high continuity of service, long life of physical equipment, low maintenance costs, and safe operation. These courses present a generalized “how to” guide for the design of a high voltage transmission line.

The engineering information in this course is for use in design of transmission lines for voltages 230 kV and below. Designs should be adapted to various conditions and local requirements. Engineers should investigate local weather information, soil conditions, operation of existing lines, local regulations, and environmental requirements and evaluate known pertinent factors in arriving at design recommendations.

This course is based on the requirements of the National Electrical Safety Code® (NESC®). However, since the NESC is a safety code and not a design guide, additional information and design criteria are provided in this course as guidance to the engineer. The additional design criteria are based on practices of many utilities in the United States.

This series includes five volumes. For the best understanding of the material, they should be studied in order. The volumes are generally divided into the following categories.

Volume I. This volume is an introduction to transmission line design and addresses siting issues, plan and profile drawings, loading, and distribution underbuild.

Volume II. This volume is all about clearances. Ground clearances, horizontal clearances, clearances from other live parts, and clearances to supporting structures are addressed.

Volume III. This volume discusses the materials involved in transmission line design and construction including insulators, conductors and hardware.

Volume IV. This volume in the series is concerned with the structural aspects of transmission line design and includes foundations and guyed structures.

Volume V. The final volume in the series is concerned with the structural aspects of transmission line design and includes single-pole structures and H-frame structures.

Chapter 1

Transmission Line Siting

Transmission line routing requires a thorough investigation and study of several different alternate routes to assure that the most practical route is selected, taking into consideration the environmental criteria, cost of construction, land use, impact to public, maintenance and engineering considerations.

To select and identify environmentally acceptable transmission line routes, it is necessary to identify all requirements imposed by State and Federal legislation. State public utility commissions and departments of natural resources may also designate avoidance and exclusion areas which have to be considered in the routing process.

Maps are developed in order to identify avoidance and exclusion areas and other requirements which might impinge on the line route. Ideally, all physical and environmental considerations should be plotted on one map so this information can be used for route evaluation. However, when there are a large number of areas to be identified or many relevant environmental concerns, more than one map may have to be prepared for clarity. The number of maps engineers need to refer to in order to analyze routing alternatives should be kept to a minimum.

Typical physical, biological and human environmental routing considerations are listed in Table 1. The order in which considerations are listed is not intended to imply any priority. In specific situations, environmental concerns other than those listed may be relevant. Suggested sources for such information are also included in the table. Sources of information include,

- United States Geological Service (USGS),
- Federal Emergency Management Agency (FEMA),
- United States Department of the Interior (USDI),
- United States Department of Agriculture (USDA),
- Natural Resource Conservation Service (NRCS), and
- Numerous local and state agencies.

For large projects, photogrammetry can contribute substantially to route selection and design of lines. Preliminary corridor location is improved when high altitude aerial photographs or satellite imagery are used to rapidly and accurately inventory existing land use. Once the preferred and alternative corridors have been identified, the engineer should consult USGS

maps, county soil maps, and plat and road maps in order to produce small scale maps to be used to identify additional obstructions and considerations for the preferred transmission line.

On smaller projects, the line lengths are often short and high altitude photograph and satellite imagery offer fewer benefits. For such projects, engineers should seek existing aerial photographs. Sources for such photographs include county planning agencies, pipeline companies, county highway departments, and land development corporations. A preliminary field survey should also be made to locate possible new features which do not appear on USGS maps or aerial photographs.

Table 1	
Line Routing Considerations	
<p><u>Physical</u> Highways Streams, rivers, lakes Railroads Airstrips Topography Power Lines Underground Utilities Occupied buildings</p>	<p><u>Sources</u> USGS, state & county highway department maps USGS, Army Corps of Engineers, flood insurance maps USGS, railroad USGS, Federal Aviation Administration (FAA) USGS, flood insurance maps (FEMA), Army Corps of floodplains, etc.) Engineers USGS, local utility system maps USGS, local utility system maps Local tax maps, land use maps, local GIS maps</p>
<p><u>Biological</u> Woodlands Wetlands Resource Service, Waterfowl, wildlife refuge areas, endangered species & critical Habitat Areas</p>	<p><u>Sources</u> USGS, USDA - Forest Service, USGS, Army Corps of Engineers, USDA National Conservation USDI, Fish and Wildlife Service USDI, Fish and Wildlife Service, State Fish and Game Office</p>
<p><u>Human Environmental</u> Rangeland Cropland Urban development Industrial development Mining areas Recreation or aesthetic areas, national parks, state and local parks Prime or unique farmland Irrigation (existing & potential)</p>	<p><u>Sources</u></p> <div style="display: flex; align-items: center;"> <div style="font-size: 3em; margin-right: 10px;">}</div> <div style="flex-grow: 1;"> <p>USGS aerial survey, satellite mapping, county planning agencies, state planning agencies, state soil conservation NRCS U.S. Bureau of Land Management, USGS, soil surveys, USDA, NRCS, state department of agriculture, county extension agent</p> </div> </div> <p>Irrigation district maps, applications for electrical service, aerial survey, state departments of agriculture and natural resources, water management districts</p>

Historic and archaeological sites	National Register of Historic Sites (existing), state historic preservation officer, state historic and archeological societies
Wild and scenic rivers	USGS maps, state maps, state department of natural resources, Department of Interior
<u>Other</u>	<u>Sources</u>
Federal, state and county controlled lands	USGS, state maps, USDI Park Service, Bureau of Land Management, state department of natural resources, county maps, etc.

Many electric transmission utilities are using Geographic Information Systems (GIS) to automate the route identification process. GIS technology enables users to easily consolidate maps and attribute information from various sources and to efficiently analyze what has been collected. When used by routing experts, automated computer processes help standardize the route evaluation and selection process, promote objective quantitative analysis and help select defensible routes. GIS tools have proven very beneficial to utilities whose goals are to minimize impact on people and the natural environment while selecting a constructible, maintainable and cost effective route.

Final route selection, whether for a large or small project, is a matter of judgment and requires sound evaluation of divergent requirements, including costs of easements, cost of clearing, and ease of maintenance as well as the effect a line may have on the environment. Public relations and public input are necessary in the corridor selection and preliminary survey stages.

Preliminary Survey

Once the best route has been selected and a field examination made, aerial photos of the corridor should be reexamined to determine what corrections will be necessary for practical line location. Certain carefully located control points should then be established from an aerial reconnaissance. Once these control points have been made, a transit line using stakes with tack points should be laid in order to fix the alignment of the line. A considerable portion of this preliminary survey usually turns out to be the final location of the line.

In many instances, after route has been selected and a field examination made, digital design data on a known coordinate system such as the *State Plane* is used for centerline alignment and profile. This alignment is provided to surveyors in a universal drawing file format. The surveyors then convert it to a format used by their field recording equipment. Once the project location is known, base control monuments are established along the route at 2 to 5 mile intervals, depending on topography, with static Global Positioning System (GPS) sessions from

known horizontal and vertical control monuments. GPS equipment and radio transmitter equipment occupying the base monuments broadcast a corrected signal to roving GPS unit(s). These GPS units, with the use of an on-board field computer, allow any point or any line segment along the route to be reproduced. This method can be used to locate and verify wire height and existing utility lines, addressing concerns that may come up locally. The use of GPS points in open areas so that conventional surveying methods are not required in wooded areas for clearing purposes. Once the survey is complete, the data can be staked with the Real Time Kinematic (RTK) process. Since this entire process uses data of a known point, the data can be converted to various formats and used for other purposes.

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Right-of-Way

A right-of-way agent should acquaint property owners with the purpose of the survey and to run the survey line. The agent or surveyor should identify property boundaries crossed and for maintaining the survey line. Making any commitments for individual property owners. Structures are spotted on the plan and profile sheets. However, if the landowner feels particularly sensitive about placing a pole in a particular location along the alignment, then the agent should deliver that information to the engineer, and every reasonable effort should be made by the engineer to accommodate the landowner.

As the survey proceeds, a right-of-way agent should begin a check of the records (for faulty titles, transfers, joint owners, foreclosed mortgages, etc.) against the ownership information ascertained from the residents. This phase of the work requires close coordination between the engineer and the right-of-way agent. At this time, the right-of-way agent also has to consider any access easements necessary to construct or maintain the line.

Permission may also have to be obtained to cut danger trees located outside and inside the right-of-way. Costly details, misuse of survey time and effort, and misunderstanding on the part of the landowners should be avoided.