

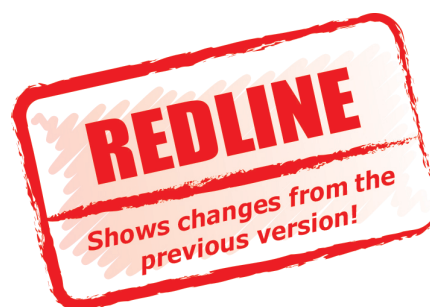


IEEE Guide for the Design, Construction, and Operation of Electric Power Substations for Community Acceptance and Environmental Compatibility

IEEE Power and Energy Society

Developed by the
Substation Committee

IEEE Std 1127™-2023
(Revision of IEEE Std 1127-2013)



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Developed by the

Substation Committee
of the
IEEE Power and Engineering Society

Approved 6 December 2023

IEEE SA Standards Board

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Abstract: Significant community acceptance and environmental compatibility items to be considered during the planning and design phases, the construction period, and the operation of electric supply substations are identified, and ways to address these concerns to obtain community acceptance and environmental compatibility are documented. On-site generation and telecommunication facilities are not considered.

Keywords: A-weighted sound level, commercial zone, community involvement, hazardous material, IEEE 1127™, industrial zone, noise, permitting process, residential zone, wetlands

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Introduction

This introduction is not part of IEEE Std 1127-2023, IEEE Guide for the Design, Construction, and Operation of Electric Power Substations for Community Acceptance and Environmental Compatibility.

This introduction provides some background on the rationale used to develop this guide. This information is meant to aid in the understanding and usage of this guide.

This guide provides guidance and information to substation engineers on factors to consider for the public acceptance and environmental compatibility of electric substations. Major changes in this revision include reformatting the document so that community involvement is discussed under each phase of project development instead of as a stand-alone clause. The site-selection clause (Clause 4) has also been significantly expanded. Finally, a separate design clause (Clause 6) has been added.

Acknowledgments

The working group gratefully acknowledges the contributions of the following:

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Contents

1. Overview	10
1.1 Scope	10
1.2 Purpose	10
1.3 Word usage	10
1.4 Organization	11
2. Normative references	11
3. Definitions, acronyms, and abbreviations	11
4. Site selection	12
4.1 General	12
4.2 Community considerations	19
5. Permits	20
5.1 General	20
5.2 Public involvement	20
6. Design	21
6.1 Aesthetics	21
6.2 Noise	28
6.3 Electric and magnetic fields	35
6.4 Environmental considerations	40
7. Construction	40
7.1 Site preparation	40
7.2 Noise	42
7.3 Physical site security	42
7.4 Traffic control	43
7.5 Site housekeeping	43
7.6 Environmental concerns	43
7.7 Oil containment	44
7.8 Community involvement	44
7.9 Means and methods of construction	44
8. Operations and maintenance	44
8.1 Site housekeeping	44
8.2 Noise	45
8.3 Physical site security	45
8.4 Fire protection	46
8.5 Environmental concerns	47
Annex A (informative) Bibliography	48
Annex B (informative) Noise	50
B.1 General	50
B.2 Use of walls or barriers to control noise	50
Annex C (informative) Representative list of required permits	53
Annex D (informative) Example list of regulatory agencies	55

IEEE Guide for the Design, Construction, and Operation of Electric Power Substations for Community Acceptance and Environmental Compatibility

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1. Overview

1.1 Scope

This guide identifies significant community acceptance and environmental compatibility items to be considered during the planning and design phases, the construction period, and the operation of electric supply substations, and documents ways to address these concerns to obtain community acceptance and environmental compatibility. On-site generation and telecommunication facilities are not considered.

1.2 Purpose

This guide provides guidance on community acceptance and environmental compatibility for new substations or substation expansions.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{6,7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

1.4 Organization

The guide is generally organized in chronological order from *site selection* to *design* and *construction* and finally *operations and maintenance*; however, many of the activities discussed in the guide overlap. For example, the permitting activities in Clause 5 occur throughout the process with some permit considerations occurring at the beginning of site selection and others taking place during construction. Also, many design considerations require more of an iterative process rather than a chronological one. Therefore, users of this guide should be aware that some overlap of information exists between clauses.

⁶ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷ The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

Accredited Standards Committee C2, National Electrical Safety Code® (NESC®).^{8,9} ~~1,2~~

[IEEE Std 1402™, IEEE Guide for Physical Security of Electric Power Substations.](#)^{10, 11}

3. Definitions, [acronyms, and abbreviations](#)

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.¹² ~~3~~

[authority having jurisdiction \(AHJ\):](#) Local, state or federal governing body, i.e., inspectors, permitting agencies, etc.

A-weighted sound level (dBA): The representation of the sound pressure level that has as much as 40 dB of the sound below 100 Hz and a similar amount above 10 000 Hz filtered out. This level best approximates the response of the average young ear when listening to most ordinary, everyday sounds. Generally designated in dBA.

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commercial zone: A zone that includes offices, shops, hotels, motels, service establishments, or other retail/commercial facilities as defined by local ordinances.

hazardous material: Any material that has been so designated by governmental agencies or adversely impacts human health or the environment.

industrial zone: A zone that includes manufacturing plants where fabrication or original manufacturing is done, as defined by local ordinances.

noise: Undesirable sound emissions or undesirable electromagnetic signals/emissions.

residential zone: A zone that includes single-family and multi-family residential units, as defined by local ordinances.

wetlands: Any land that has been so designated by governmental agencies. Characteristically, such land contains vegetation associated with saturated types of soil.

4. Site selection

4.1 General

A project to successfully design, construct, and operate a substation begins with proper planning. Site selection can significantly impact the ability to achieve community acceptance and environmental compatibility. Public perceptions and attitudes toward both real and perceived issues can affect the ability to obtain necessary approvals and permits.

These issues can be addressed through presentations to ~~the~~ governmental officials and the public. Deciding on the location of the site and where to place equipment on that site, inspections of the proposed site for potential environmental impacts, and measurement of ambient noise and electromagnetic field (EMF) levels are some of the steps that can be initiated early in the project. Failure to obtain community acceptance can delay the schedule or, ultimately, stop a project completely.

4.1.1 Site location and selection

The best site location and placement of the substation on a project site are influenced by [many](#) ~~several~~ factors, each of which can affect the time and cost required to construct the substation project. ~~, including but not limited to~~ The following [list of factors is not all inclusive, but it shows the variety of expertise required for substation site selection. Due to the large variety of expertise required to be knowledgeable and effectively be able to address each factor, a team effort is often the most effective method of selecting the best substation site.](#) ÷

- Proximity to electric load or generation
- Proximity to transmission and distribution lines and availability of access for future lines
- Substation size requirements—initial and ultimate layout (future expansion)
- Availability of adequate property and willing seller
- Vegetation—clearing requirements
- Community attitudes and perceptions
- Location of nearby wetlands or bodies of water or environmentally sensitive areas
- Topography and soil conditions
- Site contamination (obvious or hidden).
- Seismic considerations
- Proximity to airports
- Local zoning, commercial, industrial, and residential neighbors
- Permit requirements and ordinances
- Proximity to other utilities—phone, water, and sewer

- Drainage patterns and storm-water management
- Disturbance of archaeological, historical, or culturally significant sites
- Site accessibility—proximity to roads, [overpasses](#) and railways—[insulation contamination concerns](#)
- Aesthetic and screening considerations

4.1.1.1 Proximity to electric load or generation

There are benefits to both community acceptance and the electrical system in locating substations near the electrical load or generation site due to shorter lines required. Typically, the overhead lines (both transmission and distribution) provide more concerns to the public than the substation. However, [the](#) location of the substation dictates some line routing considerations.

4.1.1.2 Proximity to transmission and distribution lines and availability of access for future lines

The substation site selection affects the line routing for both transmission and distribution lines. The line routing and right-of-way (ROW) requirements typically have a significantly larger impact on the public than the substation as the ROW is adjacent to much more area. Siting a new substation in an area where all the lines enter and leave the substation in the same direction can create a new transmission corridor with several lines constructed in the same area. This not only impacts the public with the corridor area with many lines, but it may have system reliability issues as well.

Substation layout considerations also may have an impact on line routing. Space limitations inside the substation can [restrict](#) ~~limit~~ where specific lines enter the substation, and the substation layout may require unwanted line crossings or additional ROW requirements outside the substation.

Some transmission line designs utilize double-circuit structures to carry two transmission lines on the same structure. This can have permit approval and system reliability implications. Some governmental agencies are aware of the reliability issues and limit the amount of double-circuit installation on high-voltage transmission lines. This can create the need for wider transmission corridors to accommodate the number of lines entering a substation.

4.1.1.3 Substation size requirements

It is important to consider the initial substation construction requirements as well as future substation expansion per the ultimate design in order to determine the substation size requirements. The ultimate substation may require more area than what is inside the initial fenced area. It is important to be aware of the number of existing and future transmission and distribution lines and associated ROW requirements. There may be storm-water runoff requirements to consider such as construction of a retention pond based on permitting. Accessibility to and from the site location with respect to access roads is also a key factor. The transmission or distribution lines may require additional ROW. There are benefits for substation design engineers to have more space to accommodate different layouts or configurations to reduce ROW requirements from line routing.

4.1.1.4 Availability of adequate property and willing seller

The availability of adequately sized property with a willing seller can be an important aspect in site selection. This may provide the utility with a partner in the community and may be a crucial aspect of the ability to obtain permit approval to construct the substation on a preferred site. This will also provide a communication point for developing community acceptance at any public hearings.

4.1.1.5 Site vegetation

Proposed sites with heavy vegetation or a large number of trees should be evaluated for several issues other than the cost of clearing. If the site is large enough to retain the vegetation as screening around the site, consideration should also be given to the concern for security of a site that is not readily visible for observation. An evaluation of the fire hazard created by the retention of such vegetation should also be included. Permitting requirements and mitigation methods for the removal of the vegetation or trees may be required. Water runoff considerations and the possible need to permit the creation of wetlands should also be considered if clearing is required. In initial site evaluation, the abundance of heavy vegetation may hinder the ability to provide a valid assessment of the acceptability of the site due to the unknown topography behind or under the vegetation. In cases where vegetation is left to screen the substation, transmission and/or distribution line ROW clearing requirements should be considered to avoid future conflicts. [Vegetation clearing, management, or other perturbances in and/or around the proposed site and ROW may require further evaluations by the authority having jurisdiction \(AHJ\) for protected species. Protection of any identified species may require additional mitigation efforts. These requirements may prevent an economical site development or prevent development of the site at all. AHJs may also require that any removal of vegetation be replaced with native species and/or species that match species within the site or area.](#)

4.1.1.6 Community attitudes and perceptions

Consulting local community representatives helps develop a sense of their values and concerns, providing important information for the site selection team to consider. In addition, this assists in developing a good working relationship with the community.

[Also consider the proximity to schools, playgrounds, parks, etc. where children are expected to be. Substations have hazardous voltages within and can be an attraction to children.](#)

4.1.1.7 Wetlands

The design of any new substation should consider the protection of wetlands and groundwater from sedimentation runoff, insulating fluid, and changes in storm-water discharge flows. Mapping wetland boundaries and designing a facility that will minimize construction activities within or adjacent to designated wetlands should be a priority. Use of an alternative site, when available, may be considered, as government agencies may prohibit any disturbance to a designated wetland area. The development of wetland delineation maps for the area may require field inspection during the growing season. In northern areas snow can cover wetland areas and the delineation of wetlands cannot be determined until warmer weather allows for vegetation and soil analysis.

A site-development plan is necessary for a substation project that borders wetlands. Such a plan for the site and its immediate surroundings may include but is not limited to the following:

- a) Land-use description
- b) Grades and contours
- c) Location of any wetland boundaries and stream-channel encroachment lines
- d) Indication of flood-prone areas and vertical distance or access to groundwater
- e) Indication of existing wildlife habitats and migratory patterns.

The plan should describe how site preparation will modify or otherwise impact these areas and what permanent control measures will be employed, including groundwater protection.

4.1.1.8 Topography

The selection of an elevation for a substation yard should include consideration of environmental factors in addition to accessibility, construction, and cost factors. A lower elevation in relation to surrounding terrain and vegetation may improve concealment. This, however, can significantly increase the impact on construction if the water table is high, if there is a ledge to be excavated and removed, or if there is a flooding potential [where storm hardening may be employed](#) at the lower elevation. Also, consideration should be given to balancing cut and fill quantities, to [reduce the minimize](#) export and/or import of soil.

A flat substation yard is most desirable when considering substation design and operability. When steep slopes are encountered, a stepped substation of two or more levels can be designed to achieve flat areas within the yard. The slope of a substation yard should be designed to minimize erosion and sedimentation potentials and should retard oil-spill containment in the more impermeable soils. A sloped yard or swale will also lessen the extent to which side-sloped or retaining walls are required to provide yard transition to the existing grade. Minimized slopes allow easier access of vehicles and maintenance equipment required for effective operation and maintenance of facilities.

The soil conditions can have significant effects on the substation construction and resulting grading design requirements. If there is a large amount of topsoil to be removed to provide adequate support for the substation equipment, there may be benefits to purchase adequate property to spread the unusable topsoil, or foundation spoils, outside the substation graded area.

Sedimentation potential is likely to exist on sites. For exterior side slopes, the erosion potential increases with both the length and the steepness of the slope. Because slope length decreases as the steepness increases, a common solution for overall economy and minimal environmental impact is to provide the steepest structurally stable slope, thus minimizing slope length. This is especially the case where existing tree screening is important. Secondary measures to curb slope erosion include the installation of top-slope diversion channels and intermediate benches cut into the slopes. Both of these measures require additional cleared space. A solution that does not take space is the placement of a layer of medium to coarse sand over the finer materials and beneath the topsoil. This solution also assists in reducing the amount of moisture that could facilitate the growth of unwanted vegetation.

4.1.1.9 Site contamination

There are many substances that if found on or under a substation site would make the site unusable or require excessive funds to remediate the site before it would be usable. Some of the substances under consideration are as follows:

- a) Polychlorinated biphenyls (PCBs)
- b) Asbestos
- c) Lead and other heavy metals
- d) Pesticides and herbicides
- e) Radioactive materials
- f) Petrochemicals
- g) Dioxin
- h) Oil

In addition to the preceding list, any substance that a government agency has determined to be a hazardous material should be considered. Governmental guidelines for the levels of these substances should be used to determine if the substance is present in large enough quantities to be of concern.

All potential sites should have a historical review completed to review prior landowners and prior use. In addition, all potential sites should be visited by personnel trained to identify potential contamination sources at the site and from nearby areas. Soil samples from a substation site, as well as samples of the materials used in the construction of any existing buildings or structures, should be tested before acquiring or developing the site to determine if any substance listed above is present in large enough concentration to require removal. It should be recognized that substantial excavation and soil removal and disposal are normally required due to the installation of foundations for new equipment and structures.

The cost of this removal and disposal should be considered before acquiring or developing the site. If a cleanup is needed, the acquisition of another site should be considered since governmental regulations can hold the current owner or user of a site responsible for clean-up of any contamination present, even if substances were deposited prior to acquisition. If a cleanup is initiated, all applicable governmental guidelines and procedures should be followed.

[There can be a benefit to publicly cleaning up contaminated sites for the betterment of the overall community. The substation owner is and then appears environmentally responsible to the community.](#)

4.1.1.10 Seismic considerations

Although the risk for seismic activity will likely be the same for the general area requiring a substation, soil type, and distance from the fault line are two key considerations to reduce the response impact from an event. [Guidelines for the design of substation structures in a seismic area are provided in IEEE Std 693 \[B8\]. Local building codes should be followed for control enclosures.](#)

4.1.1.11 Proximity to airports

The proximity of a substation and associated overhead lines can be negatively affected by their proximity to airports. The airport location will require height limitations on both substation and overhead line structures. These limitations can impact the number and height of transmission line structures and the line route. Consideration should be given to potential interference with air navigation system facilities.

4.1.1.12 Local zoning

Local zoning ordinances may place limitations on property usage or require zoning revisions to property prior to obtaining approval to construct substation facilities. Other area property zoning or property usage may also affect the permit approval process. For more information on permitting, refer to Clause 5.

The number of residences or other buildings and structures within a certain distance of the proposed substation may have an impact on site selection. Where several sites are selected as may be required by permit requirements, governmental agencies may require documentation of affected commercial properties, industrial properties, and residential properties as well as environmental areas affected by the different solutions in order to select a site for permit approval.

4.1.1.13 Permit requirements and ordinances

There are federal, state, and local permit requirements that vary greatly. It is very important for the site selection team to include someone familiar with the permit requirements for the area to be considered prior to selecting a substation site. Refer to Clause 5, [Annex C](#), and [Annex D](#) for further permitting details.

4.1.1.14 Proximity to other utilities

The substation site may need [communication](#) ~~phone~~ service, potable water, or sewage disposal facilities.

The proximity of a substation ~~for to local phone lines or~~ access to communications systems can impact obtaining service, and providing the Zone of Influence for isolation.

Water may be obtained from municipal or cooperative water utilities or from private wells. The quality of water supplied by municipal or cooperative water utilities is beyond the control of the substation owner. The quality of water from private wells, however, can be controlled by location, depth, and treatment. The limits on contaminants in well water should be in compliance with any applicable governmental agency regulations before the well water is used.

Sewage may be disposed of by municipal services or septic systems, or the site could be routinely serviced by portable toilet facilities, which are often used during construction. Where municipal services are used for either water or sewer service, the requirements of that municipality should be met. The municipality may consider the substation owner as a developer and apply the same requirements for water or sewer main extensions that would be required of a typical developer before service taps can be made.

Septic systems, when used, should meet all applicable governmental regulations.

4.1.1.15 Environmentally sensitive areas

Substation site selection should consider the impacts of sites near any navigable waterways or other environmentally sensitive areas and may need special considerations to control water runoff and contain oil spills from existing waterways.

Consideration of species and habitats that are protected by governmental regulation should also be given when locating substation facilities. Efforts should be made to avoid or at least minimize impact to protected species and avoid or reduce habitat loss. Regulatory permitting may be necessary if avoidance cannot be achieved.

4.1.1.16 Archaeological, historical, or culturally significant sites

Substation site selection should attempt to avoid disturbance to identified archaeological, historical, or culturally significant areas. If unavoidable, permits may require documentation and mitigation of these areas.

4.1.1.17 Site accessibility

Site selection should consider the existing roads and new access requirements for the installation and removal of the longest piece of equipment including maximum slope and turning radius for the transporting equipment. An equipment removal plan should be prepared for all major equipment in the substation prior to deciding upon appropriate access roads.

It is important that substation access for construction, operation, and maintenance equipment minimizes the effects on the local traffic flow. Blind road access can create traffic issues. The provision of off-road parking for operations and maintenance vehicles can facilitate community acceptance by promoting considerations of safety for both the public as well as the maintenance and operations personnel who travel to the substation worksite.

Long access roads have been known to become meeting sites for illegal activities and dumping of solid or hazardous wastes. These activities can be a concern to the nearby residents. The installation of locked gates and fencing or vehicular barriers at access road entrances may be helpful in this situation.

[See IEEE Std 1402¹³ for additional suggestions regarding substation security.](#)

4.1.1.18 Aesthetic and screening considerations

Some substation site requirements require special considerations to provide screening from the public for new substations. This may be a permit requirement.

¹³ [Information on references can be found in Clause 2.](#)

Where tree screening is available, horizontal curves can be provided to block the view of the substation from the street.

There are many aesthetic considerations that may benefit the site selection team to provide a priority or preference rating on one site over another.

The aesthetic considerations are covered in detail in [Clause 6.1](#).

4.1.1.19 Storm-water management

Where rapid scour by storm-water flow entering or leaving a substation yard is not a problem, sedimentation-control features of substation design will be adequate by themselves. Where this is a potential problem, site design should, to the extent possible, [reduce the](#) ~~minimize~~ changes to the natural flow of storm water entering and leaving the site. Open stormwater flows across the substation yard should be avoided. Drainage should be designed to route water runoff from the substation to designated places to avoid flooding of access roads and nearby areas. Storm-water management should conform to governmental agency requirements.

[Considerations should be given to storm harden the substation to minimize outages and/or loss of equipment due to severe storms. Hardening can include the following:](#)

- [— Raising equipment, structures, and enclosures above the 100 year flood plain or in coastal areas above storm surge levels.](#)
- [— Creating flood walls and gates to reduce water entry into the site. This approach may require pumping facilities and backup power sources such as generation.](#)

4.1.1.20 Upstream considerations

~~Many~~ ~~Most, if not all,~~ communities have flood maps prepared under the auspices of governmental agencies. These maps indicate stream floodways where construction is discouraged or prohibited, and floodway fringes where construction is limited and subject to the approval of some governing agency. If the substation site is outside of these floodway zones, the most frequent source of concern is when the site includes stream control measures for a wetland that should be maintained. Lowering or raising the elevation of this control affects the water level in the wetland. Since the position of the control may, in the future, vary with the quantity of flow, the control should be located, and its position preserved, throughout the entire range of stream flows. A substation yard should not be situated where control would be affected. However, the access road may sometimes be permitted to remain in the general area of the control if it is situated exactly at existing grade and any stream crossing is made with a bridge. For wetland preservation, such a bridge and its abutments need to be outside of the watercourse during normal flows, but not necessarily outside of the stream's floodway. This same bridge concept can be used to help preserve existing conditions downstream.

4.1.1.21 Downstream considerations

It is often necessary to select those aspects of drainage changes least likely to adversely affect critical downstream activities. The design should hold changes to a minimum at the point of these activities, even at the expense of greater changes for less sensitive areas. The most common problem is the acceleration of runoff due to pipe flow channelization, elimination of natural hills by smooth grading, and hard paving. Corrective flow-retarding measures include providing rough channel bottoms, usually in the form of large angular rocks, lengthening channels and thereby decreasing slopes, and retention basins. Excessive retention will rarely cause a downstream problem except in extremely arid areas where evaporation is significant.

4.1.1.22 General design considerations

Where space permits, open ditch storm-water systems are generally preferable to pipe systems because they are less costly, [reduce](#) ~~minimize~~ blockage problems, and usually provide better retardation of runoff. The possibility of oil spills or the contribution of degreasers or solvents should be considered in storm-water system designs. The consequences of not having adequate storm drainage within a working area are usually limited to temporary shallow flooding and ice hazards. Both of these consequences can be mitigated by applying additional crushed stone to problem areas. Underground storage systems may be a cost-effective alternative when space is a concern.

4.2 Community considerations

Consider the optimal timing for meeting with local government and community officials to inform them of the community need or electrical system need. These meetings are an excellent method of soliciting feedback to determine critical issues regarding substation site selection, and help strengthen working relationships with the local community. [When acquiring substation property near residential areas, perhaps partner with a third-party consultant to conduct a routing and/or site study for determining optimal site location and transmission line path. Having a third party who is unaffiliated with the utility conduct the study can demonstrate impartiality if condemnation becomes necessary.](#)

If appropriate or necessary, public open houses may be beneficial. The open house process should be well planned and the team attending or presenting information should be well informed on the project needs and requirements prior to the event.

[The use of eminent domain or condemnation should be considered as a last resort if no compromise can be made with landowners.](#)

5. Permits

5.1 General

A variety of permits may be required by governing bodies before construction of a substation may begin. For the permitting process to be successful, the impact of the following factors on the community and the environment may have to be addressed:

- a) Site location
- b) Level of groundwater
- c) Proximity of wetlands and other bodies of water
- d) Potential of existing hazardous materials
- e) Need for potable water and sewage
- f) Noise sound level
- g) Proximity to airports
- h) Aesthetics
- i) EMF
- j) [Protected species and habitats](#)

Additional factors influencing the number of permits required and complexity of the permitting process for a project include (1) if the project is a new substation, (2) if it is an addition to an existing facility, (3) if the substation is to be built within existing property boundaries, and (4) if the substation is associated with a larger project, such as a transmission line, generating plant, or other facility. For new substations, part of the site selection process should be to find, when possible, a location where substations fall within acceptable land uses based on local zoning codes.