

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

Sponsor
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of the
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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, hazardous material, industrial zone, noise, permitting process, residential zone, wetlands

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Introduction

(This introduction is not part of IEEE Std 1127-1998, IEEE Guide for the Design, Construction, and Operation of Electric Power Substations for Community Acceptance and Environmental Compatibility.)

This guide was revised by members of Working Group G2—Design and Location of Substations for Community Acceptance, and is under the sponsorship of the Substations Environmental Subcommittee of the Substations Committee of the IEEE Power Engineering Society.

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

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 telecommunications facilities are not considered.

1.2 Purpose

Approvals for new substations or even expansions of existing facilities can be subjected to extensive review for community acceptance and environmental compatibility. A variety of permits are often required by the governing bodies before construction of a substation may begin. Concerns are being voiced by governmental agencies and community groups in areas not considered necessary heretofore in the permitting process. In some instances, land acquired for substations years in advance of construction is deemed impossible to build on under present expectations and requirements.

This guide has been divided into three major parts with the goal of providing guidance on acceptable practices for

- a) Planning and design (Clause 4.);
- b) Construction (Clause 6.); and
- c) Operation of safe and reliable substations (Clause 7.).

For community acceptance and environmental compatibility, several considerations should be satisfactorily addressed, including the following:

- Noise;
- Site preparation;
- Aesthetics;
- Fire protection;
- Potable water and sewage;
- Hazardous materials;
- Electric and magnetic fields;
- Safety and security.

2. References

This guide shall be used in conjunction with the following publications.

Accredited Standards Committee C2-1997, National Electrical Safety Code® (NESC®) (ANSI).¹

IEEE Std 80-1986 (Reaff 1991), IEEE Guide for Safety in AC Substation Grounding.²

IEEE Std 100-1996, The IEEE Standard Dictionary of Electrical and Electronics Terms.

IEEE Std 644-1994, IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines.

IEEE Std 979-1994, IEEE Guide for Substation Fire Protection.

IEEE Std 980-1994, IEEE Guide for Containment and Control of Oil Spills in Substations.

IEEE P1402/D8, DRAFT Guide for Electric Power Substation Physical and Electronic Security, dated April 1997.³

IEEE Std C37.123-1996, IEEE Guide to Specifications for Gas-Insulated, Electric Power Substation Equipment.

3. Definitions

Definitions of terms pertinent to the subject matter are listed here. Definitions as given herein apply specifically to the application of this guide. For additional definitions, see IEEE Std 100-1996.

3.1 A-weighted sound level: 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 as dBA.

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

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²IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

³This IEEE standards project was not approved by the IEEE Standards Board at the time this publication went to press. For information about obtaining a draft, contact the IEEE.

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

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

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

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

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

4. Planning strategies and design

A project to successfully design, construct, and operate a substation begins with proper planning. The substation's location and proximity to wetlands, other sensitive areas, and contaminated soils; its aesthetic impact; and the concerns of nearby residents over noise and electric and magnetic fields (EMF) 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 all 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 problems, and measurement of ambient noise and 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, in the extreme, stop a project completely.

4.1 Site location, selection, and preparation

4.1.1 Site location and selection

The station location (especially for new substations) has increasingly become a key factor in determining the success of any substation project. Initially, the site location will be selected based on developing electrical loads, the proximity of nearby electric transmission and distribution lines, costs, accessibility, and consultation with governmental agencies. In recent years, a number of major projects have been delayed or blocked by public opposition. In some instances, substations have been built but never used.

The final site location may ultimately depend upon the ability of the user to successfully satisfy the public and resolve potential community acceptance and environmental compatibility concerns. If the user determines it is prudent to involve the public in the decision-making process of site selection, a proactive public involvement program should be developed and implemented. The best site location, and placement of the substation on that site are influenced by several factors, including but not limited to the following:

- a) Community attitudes and perceptions;
- b) Location of nearby wetlands or bodies of water or environmentally sensitive areas;
- c) Site contamination (obvious or hidden);
- d) Commercial, industrial, and residential neighbors, including airports;
- e) Permit requirements and ordinances;
- f) Substation layout (including future expansions) and placement of noise sources;
- g) Levels of electric and magnetic fields;
- h) Availability and site clearing requirements for construction staging;
- i) Access to water and sewer;

- j) Drainage patterns and storm water management;
- k) Potential interference with radio, television, and other communication installations;
- l) Disturbance of archaeological, historical, or culturally significant sites;
- m) Underground services and geology;
- n) Accessibility;
- o) Aesthetic and screening considerations.

4.1.1.1 Wetlands

The design of any new substation should protect wetlands and ground water from sedimentation runoff, oil spills, 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 where available should be strongly considered, as government agencies may prohibit any disturbance to a designated wetland area. If no alternative exists to utilizing a wetland location, design consideration should be given to preserving and improving surrounding wetlands as a compromise for community acceptance.

A site-development plan is necessary for a substation project that borders wetlands. Such a plan for the site and its immediate surroundings should include 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 ground water;
- 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 ground water protection.

4.1.1.2 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 above, 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.

As a minimum, all potential sites should be visited by personnel trained to spot 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 as governmental regulations can hold the current owner or user of a site responsible for cleanup 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.

4.1.1.3 Potable water and sewage

The substation site may need potable water and sewage disposal facilities.

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 must 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 local, state, and federal regulations.

4.1.2 Site preparation

4.1.2.1 Grade

The selection of a design elevation for a substation yard should include consideration of environmental factors in addition to 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 at the lower elevation. The finished grade of the substation should be designed to minimize flooding and presence of standing water on the substation site. The slope of a substation yard should be designed to lessen 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. The slope of the substation should not be excessive to allow easy access of vehicle and maintenance equipment required for safe operation and maintenance of facilities.

4.1.2.2 Sediment control

Sedimentation potential is more likely to exist on sites consisting of fine sand or silty soil, and sites that have side slopes. A layer of medium to coarse sand or geotextile fabric beneath a crushed stone surface can minimize this potential within a substation yard area that is long and steeply sloped. 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 top soil. This solution also assists in reducing the amount of moisture that could facilitate the growth of unwanted vegetation.

Many governmental agencies have published erosion and sedimentation-control guidelines that should be followed in substation design.

4.1.2.3 Oil-spill containment and control

IEEE Std 980-1994 provides guidance for the detection, containment, and control of non-PCB insulating-oil spills in substations. Where federal, state, and/or local government regulations exist, the substation design must comply.

4.1.2.4 Access roads

For environmental compatibility, access roads can be designed to be unobtrusive. Width can be limited to one lane except for turnouts at intervals from 60 m to 120 m (200 ft to 400 ft), and widened to two lanes at vertical and horizontal curves with short sight distances. Design shall consider 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.

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

A satisfactory surfacing material is a well graded crushed stone. Roads can be hard paved if

- a) Matching the appearance of neighboring entryways is important;
- b) Required by local ordinance;
- c) On a steep grade subject to erosion;
- d) Required for equipment transportation.

Roads should be provided with appropriate surface drainage control.

4.1.2.5 Potable water and sewage

These facilities should be designed using good engineering practices and constructed to avoid freezing. The design should consider local climate and soil conditions and provide systems that will not adversely affect ground water, adjacent land owners, or inhabitants. Care should be taken during the design of the substation to prevent the possibility of hazardous discharges, when present, from entering ground water, drains, or the substation's sewer system. Septic tank design should not interfere with buried ground and power distribution during installation and maintenance.

4.1.3 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, minimize changes to the natural flow of storm water entering and leaving the site. Open storm-water 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 must conform to governmental agency requirements.

4.1.3.1 Upstream considerations

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 must 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 must 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.

4.1.3.2 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.

4.1.3.3 General design considerations

Where space permits, open ditch storm-water systems are generally preferable to pipe systems because they are less costly, 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 Aesthetics

It is helpful to develop an aesthetic image of the substation so that it can be accepted by the community. Sites can be selected that fit into the context of present and future community patterns.

Community acceptability of a site is influenced by

- a) Concerns about compatibility with present and future land uses;
- b) Building styles in the surrounding environment;
- c) Landscape of the site terrain;
- d) Allowance for buffer zones for effective blending, landscaping, and safety;
- e) Site access that harmonizes with the community.

In addition, the site may need to be large enough to accommodate mobile emergency units and future expansions without becoming congested and therefore be perceived as untidy and displeasing.

4.2.1 Visual simulation

Traditionally, site rendering was an artist's sketch, drawing, painting, or photomontage with airbrush retouching, preferably in color, as accurate and realistic as possible. In recent years, these traditional techniques, although still employed, have given way to two- and three-dimensional computer-generated images, photorealism, modeling, and animation to simulate and predict the impact of proposed developments.

This has led to increased accuracy and speed of image generation in the portrayal of new facilities for multiple-viewing (observer) positions, allowing changes to be made early in the decision-making process while avoiding costly alterations that sometimes occur later during construction.