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IMPROVING THE IMPACT OF EXISTING SUBSTATIONS ON THE ENVIRONMENT

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IMPROVING THE IMPACT OF EXISTING SUBSTATIONS ON THE ENVIRONMENT

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Improving the Impact of Existing Substations on the Environment

CIGRÉ Working Group B3-03 “Air-Insulated Substations” is under the umbrella of Study Committee B3 “Substations”. One of the main objectives of this Working Group has been to develop a comprehensive resource for engineers which addresses the aspects of existing substations that can exert a negative impact on the environment and to provide solutions and guidelines to improve the environmental impact of existing substations.

While the majority of effort to date has been directed towards ensuring the environmental compatibility of new installations, the environmental impact of existing substations is equally important to consider. The impact of existing substations on the environment may be on the rise due to changes in local land use, operation of aging equipment, changes in environmental laws and regulations and changes in community perception of substations.

CIGRÉ Technical Brochure 221 entitled; “Improving the Impact of Existing Substations on the Environment” is a product of the work of WG B3-03. This technical brochure aims to address the important aspects of existing substations that exert a negative impact on the environment and presents various methods to reduce their environmental impact. Also included are case studies of innovative efforts used across the globe to reduce the impact of existing substations on the environment.

We would like to express our great appreciation of the excellent work of the many scientists and engineers who have participated on this project.

April 2003

Auke Wiersma
Chairmen of CIGRE SC B3

IMPROVING THE IMPACT OF EXISTING SUBSTATIONS ON THE ENVIRONMENT

Technical Brochure No. 221

PREFACE

The purpose of this technical brochure is to address the important aspects of existing substations that exert a negative impact on the environment. Various methods to reduce the environmental impact of existing substations are discussed. This brochure also includes several case studies of innovative efforts used across the globe to reduce the impact of existing substations on the environment.

The following topic areas will be discussed in this brochure:
1. Aesthetics
2. Audible Noise
3. Release of Insulating Oil
4. Site Contaminants and Remediation
5. SF_6 Gas & Electromagnetic Fields

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This brochure was developed for the following target groups:

- **Technical Groups**, including Equipment Suppliers, Contractors, Consultants, Maintenance Providers, Grid Planners, and Grid Engineers.
- **Operators,** including operators of Power Systems, Generation-, Transmission-, Distribution- Stations, and Asset / Facility Managers.
- **Science, Education and Public Groups including** Universities, Research Institutes, Young Engineers, Managers and Others (not familiar with CIGRÉ SC B3 work), Tutorial participants, Authorities, Media, and NGOs.
- **International Organisations with Similar Scope**

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CONTENTS

1. INTRODUCTION

Environmental consciousness has increased manifold in today's society. Meeting the environmental requirements in the design of new substations and in the renovation and maintenance of existing substations is an increasing challenge for the electricity industry. Successful resolution of community acceptance issues and compliance with environmental regulations may become major milestones in the process of erecting new or renovating existing substations. Utilities in their increasing effort to satisfy their customers and to gain community acceptance for their facilities have employed various environmental management systems and impact evaluation studies to address these important issues and to assess the impact of substations on the environment.

Most efforts to date have focused on the environmental impact of new substations. However, existing substations have had and may continue to have a significant impact on the environment, if not adequately addressed. Furthermore, the impact of existing substations on the environment may be growing due to changes in the surrounding land use, operation of aging equipment, changes in environmental laws and regulations, and changes in the community perception of substations.

This technical brochure aims to address the important aspects of existing substations that exert a negative impact on the environment and presents various methods to reduce the environmental impact of existing substations. The environmental issues that arise for existing substations are often those that are typically addressed during the design of new substations. The following topic areas will be addressed in this brochure:

1. Aesthetics
2. Audible Noise
3. Release of Insulating Oil
4. Site Contaminants and Remediation
5. SF_6 Gas & Electromagnetic Fields

Although the imperative to address the environmental concerns of existing substations may be less than that for new substations, some aspects warrant attention and there exist effective methods to reduce the impact of what has already been installed. The extent and impetus for improvements will depend on the commitment of resources, and tends to be a function of the initiative of the community and the influence of governmental entities.

The principal community concerns are substation aesthetics and noise production. Government regulations continue to evolve in the areas of contamination of water and air, and migration of unwanted substances from contaminated soil.

This Brochure presents a variety of methods to reduce the environmental impact of existing substations. The applicability of a given method will depend on the specific environmental issues, local legislation, economic feasibility, and company policies. The options presented are described in a general manner and references are provided for more detailed resources. Case studies are included to provide the reader with examples of efforts used around the world to reduce the impact of existing substations on the environment.

2. AESTHETICS

2.1 INTRODUCTION

Substation aesthetics are a principal community concern. Community involvement in the early stages of a project is critical in order to achieve community acceptance and environmental compatibility.

Many of the existing substations were built tens of years ago and may not have had the benefit of an environmental impact evaluation during their initial installation. Furthermore, many existing substations which were originally located outside of population centers to limit their visual impact, have become surrounded by densely populated residential and commercial areas as a result of population growth and urban sprawl.

The purpose of this section is to identify aspects of existing substations that may negatively effect the overall visual impact of the substation and to present options to improve the aesthetics of a substation.

2.2 GENERAL BACKGROUND

Substations generally contain electrical switchyards, control gear, incoming and outgoing lines and buildings and transformers. The size of a substation is dependent on the voltage level and the number of outgoing and incoming lines. Conventional air-insulated substations for example may occupy an area of tens of hectares and include tall metallic gantry structures of heights up to 30 meters, which may have a significant negative visual impact on the surrounding landscape. Distribution substations in contrast generally do not require as much land area.

Measures to improve the aesthetics of existing substations can generally be categorized into two groups: conventional methods which aim to reduce the visual impact of the substation by concealing it from public view, and more creative methods which aim to enhance and celebrate the substation. Case study #4 provides an example of a substation which, has been concealed from public view. Case studies #1,2,3 demonstrate techniques to visually enhance the substation. If economically feasible, another option is to replace the air-insulated substation with a more compact design, such as an indoor or outdoor gas-insulated substation. Traditional gas-insulated substations can often blend into the surrounding landscape more effectively and offer a more compact, less imposing equipment design.

Cost is another important factor to consider. Aesthetic improvement of existing substations is increasingly influenced by economic constraints and environmental requirements. While meeting the demands of customers and gaining community acceptance of existing substations is critical, people may be less interested or willing to support plans to improve the aesthetic impact of a substation if the cost of such measures is not within their limits. Cost effective solutions, which address substation aesthetics and community acceptance are best identified and implemented during the design phase of new substations. Many good options exist for improving the visual impact of existing substations are often sidelined and not implemented due to low economic feasibility.

This section aims to present various options to reduce the visual impact of existing substations. Landscaping options are considered which address the land surrounding the substation and also the main elements of the substation itself including buildings and enclosures, access routes and entrance gates, gravel surfaces, lighting and plant cover. The ultimate objective is to improve the visual impact of an existing substation by blending it into its surrounding environment. Aesthetic improvement of existing substations will be influenced by the location of the substation, surrounding land use, availability of land, and characteristics of the building material etc and should be adapted to meet the needs of local environmental legislative bodies and the community in which it is located.

2.3 REQUIREMENTS

Prior to a discussion of landscaping options, one must first consider the many technical requirements, power regulations, company substation design guidelines, as well as landscaping legislation where available that may impact on the choice and extent of landscaping solution.

2.3.1 Power Regulations

Power regulations and substation standards exist all over the world and are generally specific to each country, such as the National Electrical Safety Code in the US and Canada, and the Electric Association Code in Japan.

The most important technical factors to consider when exploring landscaping options include:

a) Characteristics of the soil (earth works, anti dust measures etc.).
b) Substation perimeter fence, e.g. fence height.
c) Safety clearances that are required between the compound enclosure and the live equipment inside.
d) Type of lighting.

The presence of transmission and distribution lines may create additional constraints to landscaping solutions given the necessary safety clearances between:

a) conductors and the ground;
b) conductors and the surrounding tree trunks or branches;
c) Conductors and the substation perimeter fence.

2.3.2 Landscaping Legislation

Guidelines and regulations on substation landscaping requirements are lacking, as are recommendations for the proper management and protection of this resource.

Today's society is becoming increasingly concerned about the conservation of natural resources and the protection of the environment, and many substation-related projects are subjected to environmental impact assessments to address these concerns. There exist several corrective measures available to minimize the impact of the substation on the environment. A more detailed discussion of these options can be found in sections 2.7 and 5.0 of this brochure.

2.4 ANALYSIS OF THE SURROUNDING ENVIRONMENT

The first and foremost step to consider when planning a landscaping project is the surrounding environment in which the substation is set. The visual impact of an existing substation should be assessed based on the land use of the surrounding area. Specific aspects that should be taken into account include:

a) **Scale of other developments** in the area such as the buildings of closest proximity and their utility value.
b) **Local architectural styles** with particular emphasis on color and type of material used in construction.
c) **Distance** of the substation from the nearest population centre*.*
d) **Locations** from where the substation is most visible.
e) **Surrounding land use:** crop-fields (Figure 2.2) versus densely populated areas (Figure 2.1).
f) **Future developments**
It may be more economical to apply measures to enhance the aesthetic value of an existing substation in advance of a new development when possible.

Figure 2.1: Substation surrounded by densely populated area.

The aesthetic requirements of a substation surrounded by a park or nature reserve may be subject to specific governmental regulations. In this situation, the type of perimeter chosen will be an important factor to consider. A fence of vegetation may be a useful option to minimize the visual impact of a substation in such a location and will also help to blend the substation in with the natural surroundings. However, it is important to recognize that this option might increase the potential for animal-caused outages since it would provide an access route into the substation for small animals (squirrels, raccoons etc).

Figure 2.2: Example of a substation set in a rural location surrounded by crop fields.

2.5 ANALYSIS OF THE SUBSTATION

Once the environment surrounding the substation has been extensively studied, the next step is to focus on the primary elements of the substation itself. An analysis of the components of a substation and their impact on substation aesthetics should include:

a) Substation equipment and its layout;
b) Buildings;
c) Storage areas;
d) Characteristics of the perimeter fence;
e) Access roads and gates;
f) Gravel surfaces;
g) Lighting;
h) Conditioning of slopes;
i) Plants for screening.

Analysis of the contribution of each component to the visual impact of the substation as a whole will allow for the development of a detailed and site specific landscaping solution.

2.6 IMPROVING THE VISUAL IMPACT OF AN EXISTING SUBSTATION

After a thorough assessment of the substation and its surrounding environment, one can embark on the task of identifying the most appropriate and effective methods to improve the aesthetic impact of a given substation. Considering each component of the substation in turn will facilitate a comprehensive analysis of the work required.

2.6.1 Measures to be taken on Substation Equipment and Layout

The layout of the equipment in a substation, especially in air-insulated substations, can have a profound impact on substation aesthetics.

Incoming and outgoing transmission line gantries often produce the most negative visual impact. Although, the height of these gantries will depend on the voltage level of the substation, a typical 400 kV substation gantry can be 25-30m high.

Typical measures to reduce the visual impact of substation equipment include:

a) Converting an extension of an existing substation (or the outdoor substation itself) to a gas-insulated substation (GIS). This is a very costly option and may not be feasible.
b) A low-profile equipment layout with rigid tubular conductors supported on post insulators in place of conventional flexible strung conductors, and modified designs for the gantry and other equipment structures replacing the steel lattice structures can be another alternative. A rigid conductor layout has a better aesthetic appeal than do flexible strung conductors.
c) Painting large equipment such as transformers and supporting structures to blend them into the surrounding environment.

2.6.2 Measures to be taken on Buildings and Storage Areas

The aesthetic impact of buildings and storage areas can be effectively addressed during the design and implementation of a new substation, but can be quite a challenging task for existing substations.

2.6.2.1 Buildings

There are several types of buildings that may be present within a substation including control buildings, relay shelters and enclosures for switchgear. Most substations contain at least one control building. Older substations can have several additional buildings including:

a) Three or four dwellings where operating and maintenance staff previously resided.
b) Pump houses-buildings to house water tanks and pumping equipment.
c) Workshop for on site maintenance and repair activities.

Although these buildings may be relatively small, without proper countermeasures to address shape, size, color etc., it may be difficult to blend them into the surrounding environment (Figure 2.3).

Figure 2.3: The control building painted red is difficult to camouflage.

As discussed earlier, it is much easier to blend a substation into its environment during the design stage than to do so after it is built. However, certain measures can be implemented to accomplish this including changing the color of the exterior of the building to reflect that of the surroundings.

Figure 2.4: This relay shelter has been designed to reflect local architectural styles.

2.6.2.2 Storage Areas

Substations may also have clearly demarcated areas for storing spare parts and waste products. Some substations may have waste products and spare parts scattered across the site in a disorderly manner, making it difficult for an outsider to distinguish spare part from waste product.

Figure2.5: Substation lacking waste storage area.

A better solution would be to create separate areas for the storage of spare parts and waste products. These areas should be clearly marked and wherever possible, should not be located in areas of great visibility. Routine upkeep of storage and waste areas is recommended to improve substation aesthetics and to gain community acceptance.

Figure 2.6: The area for storing the concrete covers of the cable troughs has been clearly demarcated by a chain-link fence and a sign.

2.6.3 Measures to be taken on Perimeter Fences

Power regulations and guidelines stipulate that all power substations be protected by a chain-link fence or brick wall of a certain height. The perimeter fence should include high voltage warning signs on all sides to warn non-substation workers against entering the site.

It is mandatory for substations to have one or more fences surrounding the entire site perimeter. In most cases, perimeter fencing is composed of reinforced galvanized steel chain-links. Alternatively, substations may be enclosed by concrete walls.

The advantage of using a chain –link fence is that it is transparent and hence may reduce the visual impact of the substation in more natural settings such as crop fields and farmlands. In addition, the average cost of a chain –link fence is less that of a wall of any type. Furthermore, use of a chain-link fence may encourage substation personnel to keep the interior tidy, as the content of the interior will be visible to the public.

Figure 2.7: The interior of the substation is visible through the chain-link fence.

Case studies #12 and #13 provide examples of creative solutions to reduce the visual impact of the substation by modifying the perimeter fence.

Figure2. 8: The chain-link fence is hardly noticeable.

2.6.4 Measures to be taken on Access Roads and Gates

Metal gates are generally used in substations for vehicular access. A single-leaf gate is typically used for personnel access. It is unlikely that one may be able to alter the design of the gate once it has been installed. Therefore, any changes to the design of existing gates will likely be limited to alterations in the color of paint used to decorate the gate.

2.6.5 Measures to be taken on Gravel Surfaces (Ballast)

Power regulations stipulate requirements for ground covering in substations. Specific measures must be taken to prevent the spread of dust and other particles from within the substation site. The three most common types of ground cover within substations are gravel, grass and asphalt paving.

Gravel is a very common ground covering in air-insulated switchyards. Care should be taken when selecting the colour of asphalt or gravel as too light a colour can cause the substation to stand out against the surrounding soil (Figure 2.9). A dark-colored gravel, which reflects the color tones in the surrounding environment, may be a better option to blend the substation in with its surroundings.

Figure 2.9: Poor choice of gravel colour has made the visual impact of this substation much greater.

Use of mica and glass is also not recommended, as these materials can produce a significant glare on sunny days drawing further attention to the substation and often disrupting the work of on-site personnel. Ochre-colored gravel may be a suitable alternative in certain contexts as it has a natural color tone that can blend in with natural environments.

When deciding on the choice of substation surface covering it is important to avoid choosing colors that may clash with the surrounding environment. Deeper soil layers are usually lighter in color than the natural land surface due to a lack of organic matter and the different oxidation rates of terrigenous material. This effect is accentuated when white colored ballast from quarry limestone is used as a substation floor covering.

Gravel also requires regular maintenance to control plant growth. Regular herbicide treatment to prevent the growth of plants within the substation has until recently been a mainstay of substation maintenance. In many countries, this has become a problematic issue as grid operators have been forced to minimize herbicide use to protect soil and natural water resources from contamination.

A unique alternative is the “dry-meadow” concept consisting of a mixture of crushed rock and soil. This approach requires little maintenance as grass growth is controlled by the presence of ballast in the soil. See Case Study #15 for a more detailed explanation of this method.

2.6.6 Measures to be taken on Lighting

Substations may be equipped with powerful lighting systems to permit emergency work at night and to deter break-ins and avoid thefts. Powerful lighting in a substation may become a nuisance to people living nearby by contributing to the level of light pollution in the area. The lighting may also affect the behavior of local fauna.

In order to avoid the above effects, a lighting control system should be installed to keep the lumens in the yard to a minimum. The use of special illumination effects during night- time periods, such as spot lighting, light guides, color lights etc. can be also be adopted. A distinction should be made between the level of lighting required for security reasons and that required for on-site work during special circumstances such as beak-downs or outages.

It is recommended that two complementary lighting systems be installed each with different light intensities so that the lighting in the substation can be modified to suit the circumstance.

It is recommended that the substation lighting system consist of one basic system of lower light intensity to deter break-ins and another secondary system to enhance the light available in the yard for substation visits and nighttime repairs. The secondary system may have a manual switch in the control building. An automatic lighting system connected to the substation control system could also be considered so that the substation may be floodlit in the event of unauthorized entry.

It is generally recommended to conduct a lighting study to identify the most efficient and appropriate lighting system for a substation taking into account electricity consumption, performance, cost and usability.

2.6.7 Conditioning of Slopes

Substations can occupy an area ranging from two to ten hectares and are rarely set on perfectly flat land. Maximum gradients should not exceed 5%. To achieve this, it is sometimes necessary to divide the site into several relatively flat aprons with the different levels connected by slopes or embankments. This is generally done in mountainous regions where site grading is not practical and also not economical.

Whether these slopes are cuttings or embankments, they will inevitably suffer from erosion with the passing of time. The extent of erosion will depend on the gradient, the weather conditions and the characteristics of the land. Maintenance work should be carried out on slopes to avoid erosion.

The visual impact of the substation will depend on the solutions adopted to condition the slopes. For example, the slopes may blend in more effectively with the surrounding landscape, if planted with shrubs, bushes or tree cover.

The above measures can be adopted individually or in combination depending on the requirements of a particular substation. Case study #16 depicts a substation with a “stepped” switchyard utilizing the natural slopes of the surrounding landscape. In this example, introducing a stepped switchyard drastically reduced the cost of land leveling of the substation.

2.7 USE OF PLANTS FOR SCREENING

Plant cover is the most effective way to reduce the visual impact of substations. It contributes to the aesthetics of the substation and also serves to conceal the substation from public view.

It is recommended that a thorough assessment of the land be carried out before beginning any plantation work. Such a study should assess the availability of land and water and should involve an analysis of soil types, plant species grown in the area, suitable planting techniques, etc. (refer to #17 of case study)

2.7.1 Availability of Land

Plants can be introduced within the substation along the perimeter fence or outside of the perimeter fence and along the property line of the substation.

Once an analysis has been made regarding the availability of land, one should identify the most appropriate location for the introduction of plants. It is important to remember that there will be areas of a substation site where the installation of plants will not be possible because of safety clearance requirements of certain equipment within the substation. In addition, there may be some areas in the substation that will require that height limitations be set on the size of plants introduced.

2.7.2 Availability of Water

Depending on where the substation is located, availability of water may be a critical factor influencing the feasibility of introducing plant coverage. In some cases there may be no water source other than that brought into the substation for sanitation purposes.

Ensuring that plant species have access to water will be critical for the survival of plant life. Requiring substation personnel to water the surrounding plant cover is not a suitable option. Water may also be a limiting factor in the years following the introduction of the plant species. The utility may consider stipulating contractually that plant maintenance be conducted for a certain critical period time to ensure the survival of the plant.

Drip irrigation system cannot be set up if there is no water source available. Drought resistant plant species may be the only option in those situations.

2.7.3 Selection of Plants

Before selecting the plant species to be introduced in the substation, a survey should be conducted of the plants growing in the surrounding environment. It is generally recommended that the plant species chosen be representative of the local fauna, and be hardy and highly adaptable to the environment.

The following guidelines are recommended for the selection of plants:

a) Quick growing species which grow high enough in a relatively short period of time to create a visual barrier.
b) Hardy species capable of withstanding local environmental conditions as it will be difficult afterwards to tend plantations on a regular basis.
c) Evergreen species selected in high proportion to avoid a build-up of fallen leaves in the substation.

If the substation location is conducive to tree and shrub screen, one may choose to introduce these types of plants around the entire substation perimeter to create a large visual screen. Plant cover used as a visual barrier is most effective if it is comprised of several tall trees planted in a staggered fashion. Introducing plants into the area of incoming and outgoing lines is a useful method to create a sense of continuity and to reduce the impression of a barrier however, the plants should be limited to shrubs and low growing trees not to interfere with the functionality of the substation.

Case study #17 provides examples of the use of plant cover to improve the visual impact of a substation.

For locations with native strains of trees and shrubs, a choice of tall and low growing trees, bushes and herbaceous plants, is recommended to form a “green barrier” that blends in with the surrounding landscape.

2.7.4 Planting Techniques

Planting techniques are generally specific to the type of plants used as well as to the location where they are to be planted. The following guidelines address the major points to be considered when planting:

a) **Reception of the plants**: plants should be planted on the day that they are received. If this is not possible sufficient care should be taken to see that the roots do not dry up, that the plant is bruised, broken or damaged. Plants should not be stacked on top of each other.
b) **Digging the hole**: the size of the hole is dependent on the height of the plant. The size of the hole should be sufficient to ensure that the roots are not bent when the plant is placed in the hole. For root ball planting, root balls should comfortably fit into the hole.
c) **Planting**: the plant should not be planted on days of frost or on days of high winds. Guidelines shall be followed for standard plantation blocks dictating specific inter-plant distances for planting trees, bushes, hedges and screens.

3. AUDIBLE NOISE

3.1 INTRODUCTION

The purpose of this section of the guide is to present the most common noise related concerns associated with existing substations and to provide mitigation methods to address these concerns.

There are two major sources of noise in substations: the continuous noise generated by the operation of power transformers and reactors and the momentary noise produced by the operation of high voltage circuit breakers or load interrupters. Other noise sources in substations include Corona discharges, arcing during operation of switches, etc.

By far the most important source of noise is that generated by power transformers and reactors. These pieces of equipment generate a continuous humming noise that might be disturbing for communities living near the substation. Usually, existing substations are equipped with older, vintage transformers and reactors. The technology used to manufacture such equipment typically results in relatively high levels of noise emission. Most of the existing substations were initially built far from residential areas to limit the effect of this noise on the pubic and the surrounding neighborhoods. However, in earlier years there were fewer guidelines and regulations regarding acceptable noise levels that were available during the construction of substations, and those that were enforced were considerably non-restrictive.

Expansion of urban and suburban areas in the last couple of decades has resulted in some of these substations being located within and in direct proximity to residential areas. In these new situations, the noise level generated by the equipment in the substation might not be found acceptable and corrective measures are often required to reduce the level of noise to acceptable levels. In addition, public concern regarding industrial noise has increased over the past few decades and new, more stringent regulations and bylaws have been introduced to limit noise levels in residential communities. These events make audible noise an important concern and one to which the utility industry must give full consideration during the planning and retrofitting of existing substations.

3.2 BACKGROUND

3.2.1 Characteristics of Transformer Noise

The primary source of noise from transformers is due to magnetostriction of the iron core. A secondary but much lower source arises from the electromagnetic forces between the individual turns of the windings. The principal frequency of the resulting vibration is twice that of the supply frequency (120 Hz) and, because the magnetostriction characteristic of iron is nonlinear, harmonics (240, 360 and 480 Hz) are also generated (this harmonic content of a noise plays a major role in contributing to the annoyance of the noise as perceived by individuals). The level and the number of significant harmonics and the probability of complaint about the noise increase with flux density. Since the flux density is controlled by the magnetizing current and the total noise output is proportional to the exciting voltage times the magnetizing current, the noise output remains essentially constant for a given voltage even though unpredictable variations in the radiation pattern occur with time. The noise output is normally unaffected by load.

3.2.2 Propagation of Sound

In an unobstructed outdoor environment, the energy from a point source of sound propagates as the "inverse-square law" - this means that as the sound spreads outwards from the source, the energy decreases as the square of the distance. Thus for each doubling of the distance, the sound energy decreases by a factor 4, i.e., 6 dB. This theoretical attenuation usually applies quite well for distances ranging up to 150 m and greater. Beyond this distance, it is subject to the effects of ground and atmospheric absorption, inhomogenities such as these are associated with turbulence, moderate and high winds and temperature gradients.

In addition to the foregoing, the increase in noise level propagated due to temperature inversion seldom remains constant and normally varies with time over periods ranging from a few seconds to a few minutes due to changing conditions in the atmosphere. This modulation of the noise, particularly of the type generated by transformers, is another factor that increases the subjective reaction as compared with that for a steady noise.

3.3 CRITERIA FOR COMMUNITY NOISE LEVELS

There are a wide variety of regulations and bylaws in use in different corners of the globe to control for audible noise levels in the community. In some countries many noise level regulations have been developed to suit local conditions. The majority of these are qualitative, although a number of the larger communities and some cities have had quantitative regulations in various forms.

In most industrialized countries qualitative regulations and/or bylaws are commonly used. Some of the larger cities have quantitative regulations of varying degrees of complexity.

Generally, transformer noise should be slightly audible during the quietest period of the day and inaudible during the rest of the day when people are normally active. Experience shows that transformer noise levels 10 dB above the lowest ambient frequency result in complaints from the community while a 5 dB increase does not normally produce a response. A 5 dB cushion, however, is considered to be the minimum required to accommodate the temporal variations in radiation pattern and the atmospheric effects previously discussed.

The above general rule has been found to apply particularly in the design of new installations. It is also applicable to old installations, but there will be some existing stations where noise treatments will be difficult to install due to space and clearance limitations.

3.4 REQUIREMENTS

Existing substations have to comply with newer, more restrictive noise regulations sooner or later, especially when complaints are being received about the elevated noise level of a certain substation.

While in some countries the new regulations might not apply to existing installations in general, utilities are concerned with community acceptance and as “good corporate citizens” will modernize their installations to meet the requirements of the latest regulations and bylaws.

Methods used to mitigate noise problems in existing substations will depend on factors such as:

a) The level of noise exceeding the approved level for the area in which the substations is located,
b) The economics of various solutions – the analysis has to take into account the life cycle cost of the installation, as well as, the benefits the utility may acquire by addressing concerns of the community.
c) Operational and maintenance implications of installing a certain sound mitigation solution around transformers and/or reactors,
d) Issues related to the constructability of the sound mitigating solution (can it be done with the equipment live, is there a need for rerouting of power and/or control cables, etc.).

The following Table gives typical noise limits specific to particular settings:

Table 3.1: Typical Noise Limits

Location	Time of Day	Noise Limits
I. Purely Residential	Day	45-50 dB
	Early Morning/ Evening	40-45 dB
	Night	35-45 dB
II. Mixed Residential	Day	50-60 dB
	Early Morning/ Evening	45-50 dB
	Evening	40-50 dB
III. Commercial/ Industrial	Day	60-65 dB
	Early Morning/ Evening	55-65 dB
	Night	45-55 dB
IV. Industrial	Day	65-70 dB
	Early Morning/ Evening	60-70 dB
	Night	55-70 dB

3.5 METHODS OF MEASUREMENT

This following represents a guideline for measuring noise levels.

a) Number of measuring points

It is recommended to establish measuring points at equal distance along the property line. As an example, the total number of measuring points for various lengths of property line are given in Table 2.

Table 3.2: Number of measuring points for substations

Length of property line of substation	≤300m	300- 500m	500 to 1000m	1000 –to 2000m	2000 to 3000m	≥ 3000m
Number of measuring points	12	16	20	24	32	40

b) Location of measuring the noise level

The noise level of substations should be measured at the property line.

The exact measuring point is generally recommended to be1.2 m above ground level. If the sound is shielded by a fence or any other structure, a measurement point of 0.3 m above that of the fence/ structure is recommended.

c) Ideal Measuring Environment

a) Ambient temperature: 5 to 35 ^{0}C
HUMIDITY: 45 TO 85%
b) In the event that the wind velocity exceeds 3m/s, outdoor measurement is not recommended. This is because the background noise is not constant and is changing.

d) Measuring equipment

Measurement equipment should have valid calibration.

3.5.1 An Analytical Method for Noise Calculation

In general, the energy from a point source of sound decreases as the square of the distance increases. However, that is influenced by the reflection and/or absorption by buildings and equipment in the substation.

The energy of sound generated from equipment under operation can be reduced by the type, location and distribution of the surrounding equipment.

An assessment of equipment noise levels can be performed using CAD software to identify the distribution of substation equipment, which produces the lowest level of noise.

An example of such an assessment is shown below (CAD software package CS21/ J care of Chubu Electric Power Co., Japan).

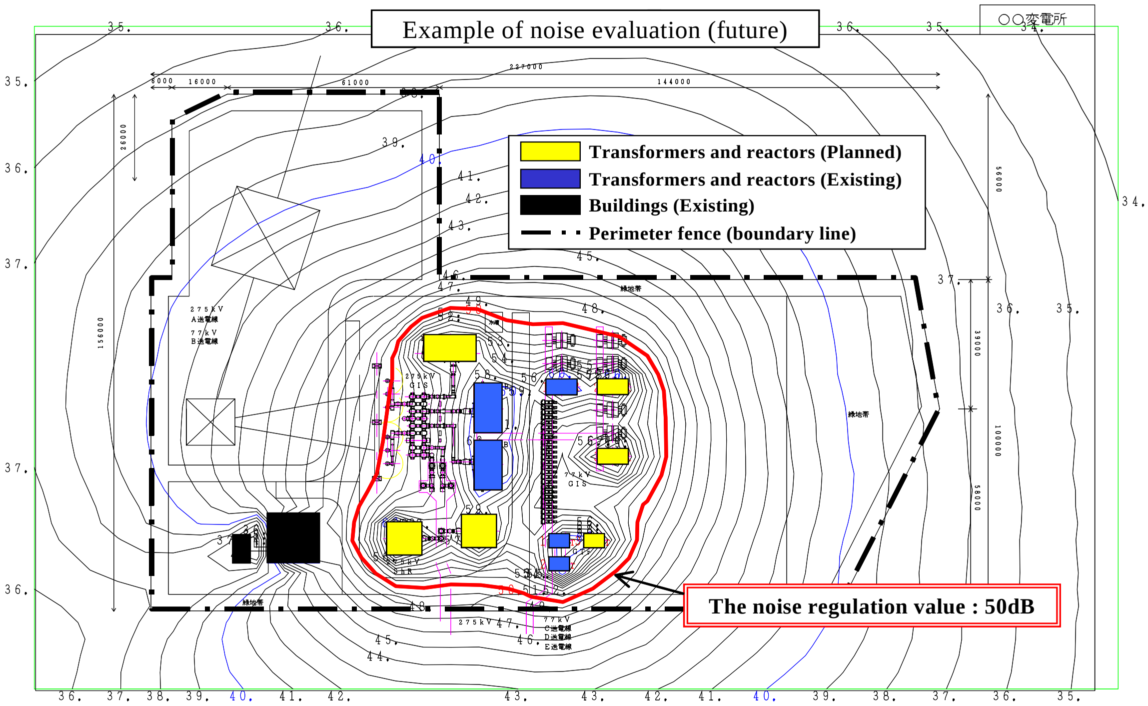


Figure 3.1: Example of a noise assessment.

Application of this method for noise reduction to existing substations may become useful during substation refurbishment or expansion.

3.6 METHODS OF SUBSTATION NOISE CONTROL

This Guide does not address when a noise mitigation method shall be used, but rather gives a range of solutions from which a user could select the most appropriate one that satisfies the local and economical constraints.

The first step in the process of mitigating a noise problem at an existing substation is to determine the noise reduction required at the point of the recipient, which is usually the most critical location on the property line of the station. Noise reduction is the total level of untreated transformer noise minus attenuation with distance minus lowest ambient level or the permitted community level. Once the noise reduction has been established, the most appropriate measures for producing the required noise reduction must be selected.

At a 230 kV station with up to four 100 MVA units, noise reductions in the range of 15 to 25 dB are normally required. For the larger units, associated with 500 and 750 kV stations in the range of 500 to 1000 MVA, the required reduction ranges from 20 to 35 dB. These reductions are in addition to the 6 dB or so reduction below the standard NEMA levels at which transformers are being purchased.

The following represents the most widely used methods available for minimizing noise levels created by transformers at existing substations. The newer methods are described in greater detail.

a) **Replacement of Existing Old Transformers** with new units with low noise levels. Manufacturers made in the last period of time significant steps toward reduction of basic noise levels of power transformers and reactors. Replacement of an old unit with a new, low noise unit might prove to be the best solution if the replacement is dictated also by other factors (end of life of transformer, history of failures of the unit, chronic oil leaks, etc.). Levels up to 10 dB below the standard levels are practical and the costs range up to 1 per cent of the cost of a standard transformer per decibel depending on the size. Higher reductions are not normally economically viable compared with other methods of control.

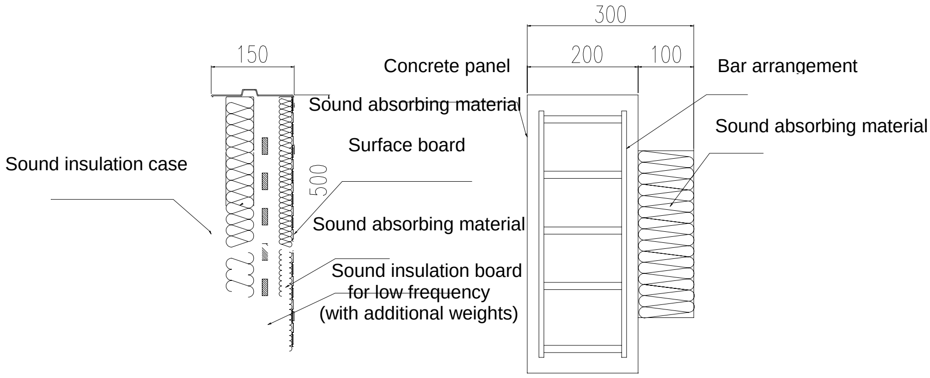
b) **Landscaping:** Planting of grown up trees on the outside of the fence line in the direction of the desired noise reduction – is one of the solutions that would provide moderate noise reduction. If space is available around an existing substation, landscaped soil berms covered with grass and with bushes on the crown is another noise reducing solution, while also providing means of blending the substation into the community.

c) **Simple Open Roof Barriers**: The level of noise reduction obtained with this solution depends on the height of the barrier above the transformer and its relation to the elevation of the neighborhood that is targeted for noise reduction. Typically 8 to 13 dB noise reduction could be achieved with such a barrier. The barrier may be constructed from a variety of materials, such as steel plate, cement asbestos sheet or masonry, etc.

d) **Sound Enclosure:** This enclosure is installed around all four sides of a transformer. Depending on the level and directions of noise reduction needed, the enclosure can be without or with a roof. The roof of such a sound enclosure has to be custom designed for a particular transformer. Adequate space must be provided between the tank of the transformer and the walls of the enclosure for maintenance staff to pass. Also, sufficient space must be provided to enable the opening of the doors of the mechanical box of the transformer. Reductions of up to 20 dB are possible if proper attention is given to the details of the construction. Coolers of the transformer are installed outside the enclosure to assure the design rating of the transformer.

e) **Low Frequency Sound Insulation Panel (LFSI)**: An effective countermeasure for an existing shunt reactor and/or transformer is the Low Frequency Sound-Insulation Panel (LFSI panel), designed to minimize low frequency noise production.

The new soundproof panel is composed of sound absorbing materials and a sound-insulation board with additional weights that are necessary to reduce the vibration created by the sound-insulation board.



(a) LFSI panel (New Method) (b) Concrete panel (Conventional Method)

Figure 3.2: Structure of soundproof panel. New application using LFSI panel as per (a); and conventional method using concrete panel is shown in (b).

Although, the conventional concrete panel does provide some insulation by way of the mass-effect of its heavy material, the LFSI panel has a higher permeable reduction in low frequency noise in spite of its lightweight design.

f) **Tight Fitting Enclosure:** This solution comprises a total steel plate enclosure (including a steel roof) around the transformer. This solution is commonly known as the "tea cozy" solution. In this arrangement, the walls are installed close to the tank, there being typically a 10 to 15 cm space filled with acoustically absorbing material. Strategically placed doors allow access to the mechanical box of the transformer, to the tap changer, etc. Such enclosures could provide a noise reduction of up to 22 dB.

With solutions c), d) and f), it is necessary to provide means for absorbing the build up of sound within the barrier or enclosure. This can be accomplished by providing a lining of 8 to 10 cm of glass or mineral wool or by forming resonators (by drilling a suitably proportioned hole) in some of the cells of the concrete block for construction of the walls of the barrier or enclosure.

Transformers installed inside barriers or enclosures have to be mounted on vibration isolators. Most commonly used isolators are steel springs. These insulators prevent vibration of the barrier or enclosure (and creation of additional noise) due to ground borne vibration from the transformer.

Consideration must also be given to the ventilation of the sound enclosures. Heat generated by the operation of transformers builds up in the enclosure and appropriate ventilation is required to remove the heat from the enclosure. Low noise and low speed fans have to be installed so that they do not affect the overall performance of the enclosure.

Coolers are not normally a problem but when reductions of 20 dB or more are required, it is necessary to provide suitable flexible connections in the oil piping to minimize the transmission of vibration and thus the generation of noise by the coolers. Installation of high efficiency, low noise type of fans on the coolers has to be considered in such situations.

g) **Active Sound Cancellation:** This method uses a separate sound using an amplifier and speaker system that is equal in amplitude and opposite in phase to the unwanted noise in order to provide cancellation. The method has been demonstrated to be feasible and to provide useful reductions in the range of 10 dB. Outside this sector, the noise level increases because energy is being added to the local environment.

3.7 EXAMPLE OF A TYPICAL NOISE BARRIER

Figure 3.3: Example of a Sound Enclosure (Canada)

4. RELEASE OF INSULATING OIL

4.1 INTRODUCTION

The purpose of this section of the Guide is to present the most common environmental concerns related to the use of insulating oil in existing substations that were built tens of years ago.

Older substations were built under environmental regulation that was less stringent than present regulation. Often there were no requirements to contain any potential leaks of electric insulating liquids within the substation perimeter or limits to the level of contaminants in the drainage systems of these substations.

Containment and control of oil spills at substations is becoming an increasing concern for most electric utilities. Beyond the threat to the environment and potential legal consequences, cleanup costs associated with oil spills could be significant, and the adverse community response to any spill is becoming increasingly unacceptable.

The probability of an oil spill occurring in a substation is very low. However, certain substations, due to their proximity to ground water resources, open water or designated wetlands, the quantity of oil on site, surrounding topography, soil characteristics, etc., have or will have a higher potential for discharging harmful quantities of oil into the environment.

Increased awareness of the public to the environmental aspects related to substations as well as newer, more stringent environmental regulations force utilities to take measures to reduce the environmental impact of these older substations. This article suggests some of possible measures that can be taken to mitigate the environmental impact of oil spills that might occur in existing substations.

The solutions presented in this chapter are presented only qualitatively. Details of the solutions are not presented. It is up to each individual user to interpret and apply the recommendations offered in the chapter, and find solutions, which suit the national and regional laws and regulations in his/her own country.

4.2 EVALUATING THE NEED FOR A SPILL CONTAINMENT

Evaluation of the need for retrofitting of oil filled equipment with spill containments must be part of a well thought out plan that has to be developed by the utility that owns the substations. Due to the high cost of retrofitting of spill containments, a risk assessment of all the substations of a utility has to be performed in order to rank the substations based on the probability of failure of the equipment located in a particular substation, on the probability of a spill to leave the perimeter of the station and the impact a potential oil release would have on the environment around the substation. Some of the criteria that a risk assessment must evaluate in the ranking of substations for retrofitting with spill containments are:

a) proximity of drinking water source or watermains;
b) proximity of populated areas, navigable waters, environmentally protected zones;
c) potential contamination of ground water;
d) soil permeability in the vicinity of the station;
e) potential contamination of storm runoff through existing drainage system;
f) emergency response time if oil spill occurs;
g) failure probability based on age, type and operating history (spill records) of the considered oil-filled equipment;
h) anticipated cost of implementing the containment relatively to extent of environmental impact by oil spill.

Such a ranking will allow the management of a utility to identify the substations that are most likely to cause significant environmental impacts during a spill and to develop a long-term plan that will address the spill containment retrofits in the most critical substations.

4.3 BASIC DESIGN CONCEPTS FOR SPILL CONTAINMENT SYSTEMS

Once the decision has been made that a spill containment is needed, the engineer must weigh the advantages and disadvantages that each containment solution may have at a particular substation.

Before a containment system is devised, the designer must first be thoroughly aware of the national, provincial and municipal environmental requirements. Knowledge of these requirements will allow the designer to narrow down the containment solutions that will meet the requirements of the land.

The selected containment solution should balance the cost and sophistication of the system with the risk to the surrounding environment if oil were to escape into soil, ground water or even outside the boundaries of the substation. Some of the most important risks have been listed in the subsection 4.2. above.

Selection of a retrofit solution should be considered given that most of the construction activities of the containment are likely to be performed within an energized environment, to minimize outages. If the choice is not to underpin the existing foundations, then caution should be exerted during the installation of the containment not to compromise the characteristics of these foundations by causing changes in the soil conditions. Clearance restrictions on construction equipment in an energized substation may also affect the containment solution. There might be substations where a crane can not be safely used, which would preclude installation of heavy components of containment solutions (i.e. holding tank, large oil/water separators, etc.). Selection of a spill containment retrofit solution is also significantly affected by the fact that most of the soil digging has to be done manually (due to closeness to live electrical equipment no mechanical means would be acceptable) and that a considerable number of control and station services cables have to be dug out and rerouted during the retrofit process.

When retrofitting transformers with spill containments, the issue of directly buried power and control cables connected to the mechanical box of the transformer must also be taken in account. Such cables have to be identified and located, dug out and temporarily supported during construction of the containment. These activities are in most cases performed with the equipment energized and fully operational. A new cable supporting system has to be installed along with the containment and all the cables have to be routed through this new system. The activities specified above are labour intensive and will add to the cost of spill containment retrofits.

In most situations, during the installation of retrofit spill containment, the soil removed during the process is contaminated with oil that leaked from the equipment. Disposal of such contaminated soil will definitely add to the cost of the containment retrofit project.

Each of the containment systems that are described below should be considered based on their relative merits to the facility under consideration.

Thus, one system will not always be the best choice for all situations and circumstances.

4.4 SPILL CONTAINMENT SOLUTIONS FOR EXISTING SUBSTATIONS

4.4.1 Substation Ditching

One of the simplest methods of collecting potential oil spills in a substation is the construction of a ditch around the outside perimeter of the substation. This solution serves to contain oil spills within the substation and prevents leakage outside the substation perimeter however, it cannot prevent contamination of soil or ground water within the substation. The size of the ditch should be designed to contain all surface run-off due to rain plus the volume of insulating oil from the largest piece of oil filled electric equipment used in the substation. Such a solution requires unused land all around and inside the property lines of a substation to be available for construction of an adequate ditch. Such ditches are economical to built, but may not be adequate in porous soil conditions and the standing water in the ditch might breed insects. These ditches may be periodically drained by the use of valves.

4.4.2 Collecting Pits with Separate Containment Pit Holding Tanks

This containment solution is comprised of collection pits installed underneath the electrical equipment susceptible to leak/spill insulating oil, drains that connect these pits to a containment pit/holding tank and an oil trap/oil-water separator and the discharge drain. The collection pits surrounding the equipment can be filled with crushed stones for fire quenching purposes and designed only deep enough to extinguish burning oil (usually 200 mm to 450 mm). There are other solutions, which avoid beds of crushed stones such as using shallow pits and long pipes leading to the holding tank. These collection pits can be shallower if fire-quenching stones are not used (i.e. stand-alone transformers far away from other major equipment or buildings, etc.). The bottom of these pits is sloped to allow for drainage of the oil into the drainpipe leading to a containment pit/holding tank. This latter pit/holding tank is sized to handle a volume oil comparable to the largest piece of oil-insulated equipment in the substation plus a certain quantity of rain (usually the quantity of rain over 24 hours with a 25-year rate of return).

To maintain a dry system in the collecting units, the invert of the intake pipe to the containment pit should be at least the maximum elevation of the oil level.

Oil collection and containment pits must be sealed from the surrounding area of the substation in order to contain and hold any spilled oil. Different types of pit liners (plastic, rubber, clay liners or spray on) have been used for this purpose.

a) **Plastic or rubber liners** - these liners may be purchased in various thickness and sizes. It is recommended to select a liner that is resistant to mechanical injury which may occur due to construction and installation, equipment, chemical attacks on surrounding media, and oil products.

b) **Bentonite (Clay**) - these materials can be placed directly in 100 to 150 mm (4 to 6 in.) layers or may be mixed with the existing subsoil to obtain an overall soil permeability of less than 10^{-3} cm/sec.
c) **Spray-on Fiberglass** – spray-on fiberglass is one of the most expensive pit liners available, but in some cases the costs may be justifiable in areas which are environmentally sensitive. This material offers very good mechanical strength properties and provides excellent oil retention.

These liners have to be compatible with insulating oil (they should not be affected by a long lasting contact with insulating oil) and they should be able to withstand the contact with hot oil during a potential oil spill associated with fire. Most of the liners used in the recent past were found ineffective due to their unreliability and short lifetime.

A successful alternative to the use of liners is reinforced concrete - the entire containment pit structure (walls, curbs, floor, sump, etc.) consists of reinforced concrete. Most of the utilities are now using reinforced concrete as the preferred material for spill containment retrofits in substations.

4.4.3 Oil Containment Pits

One of the most extensively used methods to ensure containment of oil leakages within the substation property is by placing containment pits around all major oil filled equipment in the substation. These pits will confine the spilled oil to relatively small areas that in most cases will greatly reduce the cleanup costs. A sump with a pump (or a similar solution) is a required component in these containment pits in order to remove rainwater accumulated in the pit. The sump pump can be manually operated during periods of heavy rain or automatically operated. If automatic operation is preferred, special precautions must be included to insure that oil is not pumped from the pits. This can be accomplished with either an oil-sensing probe and/or by having all major equipment provided with oil level sensing switches (an option available from equipment suppliers). These level sensing switches are located just below the minimum top oil line in the equipment and will open when the oil level drops below this point.

The containment pits in this containment system should be designed to:

a) contain 100% of spilled oil;
b) contain the quantity of a 24-hour rain-fall with a return rate of one in 25 years;
c) contain the amount of liquid used by automatic fire extinction devices;
d) share the volume of spilled oil between two adjacent containment pits.

Oil containment pits in this containment system solution use the same materials as the collection and containment pits in the system presented in clause 4.4.2. above.

Since this containment solution is widely used in retrofitting of oil filled equipment with spill containments, we will address in the next clauses of this article the most important issues related to the design of this type of oil containment system. The design guidelines highlighted in this article cover an application of spill containment for power transformers, since the overwhelming majority of containment pit retrofits are built around power transformers that contain substantial volumes of insulating oil.

4.4.3.1 Layout of a Spill Containment

The basic principles of the design of spill containments are as follows:

a) Spill containment should have a regular shape (rectangle, quadrant); irregularly shaped structures significantly increase cost of construction;

b) Transformer and oil-filled equipment associated with transformer operation (coolers, oil conservator tanks, etc.) have to be included within the boundaries of the containment pit;

c) The containment pit (internal face of the containment curb) has to extend to a reasonable distance from the face of any oil-filled piece of equipment included in the containment pit to collect oil that might gush out during a spill. However, the extent of containment may be limited by existing roads, buildings, underground utilities, etc. Potential interferences, as well as the limitation of containment areas and proposed solutions will be discussed further in the article;

d) Unless there is a reasonable clearance (indicated in relevant national and/or international standards and approved by local Fire Department) between adjacent transformers or transformers and buildings, a fire barrier is should be installed (fire barrier design is not being discussed in this article);

e) Two or more equipment containment pits could be interconnected in order to reduce the volume of each individual containment. The total volume of the interconnected containments must be sufficient to contain a volume of oil comparable to that contained in the largest piece of oil-insulated piece of equipment located in the interconnected containments.

A majority of the larger power transformers oil spills are associated with fires. Such fires will most likely destroy the equipment involved in the spill. Other equipment and/or buildings located in the vicinity of burning oil filled equipment might be affected due to the intense heat radiated by the fire. Therefore, measures have to be taken to eliminate or dramatically reduce the effects of such a fire. Pooling of burning oil inside a containment pit is the most dangerous source of radiated heat during a fire. Elimination of pool fires can be achieved by:

a) fire quenching stones inside the pit;
b) foam or water spray deluge system;
c) draining the escaping oil to remote detention facility (holding tank, reservoir, etc.).

Containment pits covered with crushed stones are the most cost effective and frequently used method of extinguishing flames when a piece of oil-filled equipment catches on fire. The volume of the containment, the thickness of the stone layer, as well as the size and form of stones (round or crushed) are important factors to consider as they can affect the ability of the stones to extinguish the flames of a transformer fire. The duration of the fire is another limiting factor, since a prolonged exposure of the stones to intense heat reduces their fire quenching performance.

4.4.3.2 Capacity of a Spill Containment Pit

The volume of a spill containment pit must be selected based on the volume of oil in the largest oil-insulated equipment in the substation plus the quantity of rain that may fall during a given period of time during the spill.

If two or more pits are interconnected, they should be constructed to contain a volume of oil equivalent to the largest piece of equipment located within the interconnected containment pits, as it is assumed that only one piece of oil-insulated equipment served by the pits will leak at one time. Therefore, it is reasonable to size interconnected pits to contain the volume of oil in the single largest transformer, plus any accumulated water as a result of rainfall and/or water spray discharge from a fire protection system.

Initial data to be assumed or pre-determined to calculate the necessary volume of the spill containment are:

a) area of spill containment (outline);
b) total area of existing footings within the boundary of spill containment;
c) gradation and void ratio of crushed stone;
d) final oil level elevation (assuming a total discharge) in respect to the top elevation of the stone;
e) intensity and duration of rainfall;
f) water spray discharge from fire protection system.

It is sound design practice to interconnect adjacent containment pits in order to share the oil discharge and to reduce the volume of containment required for each individual pit. However, it is important that each pit is designed for separate drainage and that the volume of the combined pits is sufficient to handle overflow.

4.4.3.3 Structural Integrity and Imperviousness

As concrete slabs of spill containments are relatively shallow (which means that they might be exposed to vertical movements over time), special attention has to be given to the design and installation of joints in the retrofit containment pits, as well as the joints within the existing foundations. The sealing performance of containment pits is largely dependent on the design and workmanship of these joints. Therefore, the number of joints should be kept to a minimum. Combination of construction joints and expansion type water stops will provide control of potential cracking in the slab and will minimize potential leaks through these cracks.

Compacted granular fill and insulation slab will respectively provide a bearing capacity and prevent heaving effect. Thickness and extent of the insulation slab should be carefully determined to protect the soil down to the frost line from freezing.

It is very important to provide structural integrity to the spill containment by specifying concrete mix, reinforcing steel arrangement and sequences of pouring

A quality control procedure during construction of the entire containment system will ensure that the containment will retain its sealing characteristics for a long time.

4.4.3.4 Discharge Control System

Control of the discharge fluid from a spill containment pit is an important component of the system. Insulating oil will accumulate over time in a containment pit due to chronic minor leaks of oil (aged sealings for example) or accidental releases caused by oil handling. At the same time, water accumulation due to rainfall must be removed form the containment pit regularly to keep the entire volume of the pit available in the event of a major spill. Liquid discharged from a spill containment after rainfall may contain oil in concentrations exceeding normal due to chronic leaks of oil within spill containment area.

Some examples of frequently used discharge control systems are as follows:

i) Oil-Water Separator Systems
Oil-water separator systems rely on the difference in specific gravity between oil and water. Because of that difference, the oil will naturally float on top of the water, allowing the water to act as a barrier and block the discharge of the oil.

The separator consists of a concrete enclosure, located inside a collecting or retention pit and connected to it through an opening located at the bottom of the pit. The enclosure is also connected to the drainage system of the substation. The elevation of the top of the concrete weir in the enclosure is selected so as to be slightly above the maximum elevation of discharged oil in the pit. In this way the level of liquid in the pit will be under a layer of fire quenching stones where a stone-filled pit is used. During heavy accumulation of water, the liquid will flow over the top of the weir into the drainage system of the station. A valve is incorporated in the weir. This normally closed, manually operated valve allows for a controlled discharge of water from the pit when the level of liquid in the pit and enclosure is below the top of the weir.

The applied solution strongly depends on national laws and regulations, which usually define the maximum concentration of oil in water allowed to be discharged. Depending on these allowances, separators based on gravity-effects only may not be effective enough. However, there are more advanced techniques, which use additional physical or chemical effects to reach concentrations lower than 20 mg/l.

ii) Oil-Flow Blocking Systems

These systems detect the presence of oil and block all flow (both water and oil) through the discharge system. Two of the solutions using these systems are:

a) **Oil stop valve installed inside a manhole** - the valve has only one moving part; a ballasted float set at a specific gravity between that of oil and water. When oil reaches the manhole, the float in the valve loses buoyancy and sinks as the oil level increases until it sits on the discharge opening of the valve and blocks any further discharge. When the oil level in the manhole decreases, the float will rise automatically and allow discharge of water from the manhole. Some of the oil stop valves have a weep hole in the bottom of the valve that allows the ballasted float to be released after the oil is removed. This can cause oil to discharge if the level of the oil is above the invert of the discharge pipe.

b) **A discharge control system** - consisting of an oil-detecting device and a pump installed in a sump connected to the collecting or retention pits of the oil-containment system. The oil-detecting device may use different methods of oil sensing (e.g., capacitance probes, turbidimeters, and fluorescence meters). The capacitance probe for example detects the presence of oil on the surface of the water, based on the significant capacitance difference of these two liquids and, in combination with a logic of liquid level switches, stops the sump pump when the water-oil separation layer reaches a preset height in the sump. Transformer low oil level or gas protection can be added into the control diagram of the pump in order to increase the reliability of the system during major spills.

4.5 EXAMPLE OF A TYPICAL OIL-SPILL CONTAINMENT SYSTEM

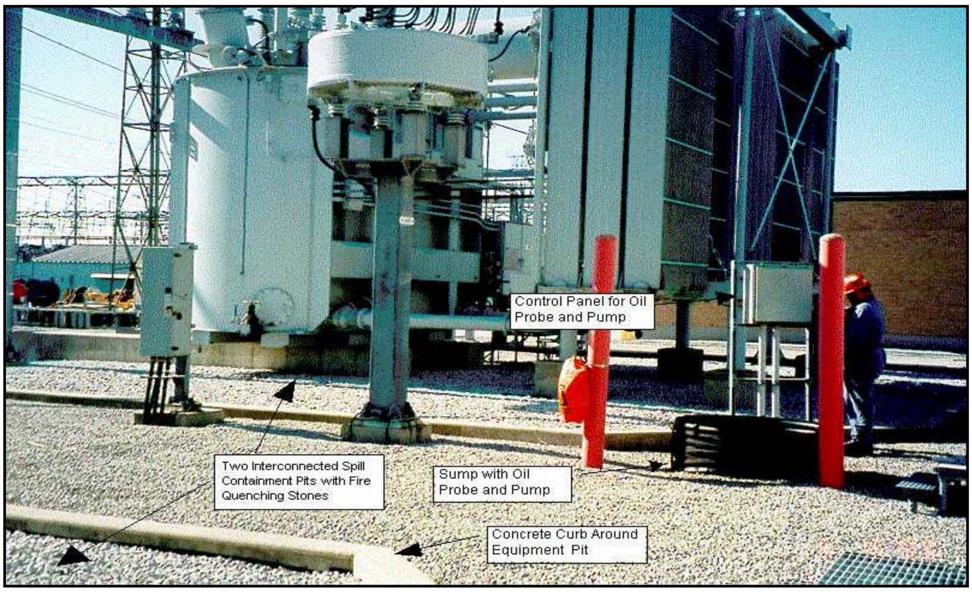


Figure 5.1 - Example of two interconnected Spill Containment pits with fire quenching stones.

5.SITE CONTAMINANTS AND REMEDIATION

5.1 INTRODUCTION

Most actively used land sites, including substations are likely to have been exposed to some form of contamination during their use. In addition, some substations may have been built upon sites that had previously been used as land fill sites or oil wells and may contain contaminants from these earlier uses. Common contaminants that can be found in substations include mineral insulating oils, polychlorinated byphenols (PCBs) and asbestos, as well as, arsenic and other herbicides and pesticides that may have been used to manage the plant life within and surrounding the substation. It is important that utilities consider the existence of chemical compounds that may have potentially adverse human and/ or ecological effects. Management of contaminated sites may have a direct impact on worker health and safety, and the selling of such sites may very well have associated liability issues.

5.2 REMEDIATION OF CONTAMINATED SITES

To address these environmental issues, it is recommended that a site assessment and remediation process be conducted to identify, qualify, quantify and manage the existence of chemical compounds within and/ or surrounding substation sites that may have potentially adverse human/ and or ecological effects. This can be achieved through various air, soil, surface water and/ or ground water sampling and testing programs (See Appendix B for typical site assessment process). Following the identification of any potentially hazardous compound on site, there are various remedial technologies that can be considered.

Site remediation should be considered if there is any reason to suspect that the presence of specific chemical compounds on site and/or leakage of chemicals off-site might have potentially adverse human and/or ecological effects. If tests indicate the presence of chemical compounds above the legislated limits, site remediation should be considered however, the urgency of the required remediation may depend on the criticality of the specific site. Remediation may also become important during the de-commissioning and selling of substations as the selling of contaminated sites may have associated liability issues.

Waste management can be very costly, and presents a significant challenge to the environmental performance of substations. Sound waste management practices that outline how to identify and manage these potential problems are thus critical for optimal environmental performance of substations.

5.3 REMEDIAL TECHNOLOGIES

Remedial technologies fall into two basic categories, passive remediation methods such as bioremediation and active remediation methods such as source removal. These categories can be further subdivided into those, which can be conducted on site, referred to as in-situ and those, which occur off site or ex-situ. These terms are common to both soil and ground water remediation techniques

A brief description of the commonly used remedial technologies is given below. This list however, is not definitive and should only be used as a guideline.

5.3.1 Active Remediation Methods

Active remediation methods generally involve removal of the source of contamination from the contaminated site.

a) Dig and Dump

This is the most common remedial option for both soil and groundwater. It entails the removal of all contaminated material and its subsequent disposal to an off-site location. The owner of the site also transfers ownership of the material to the receiving facility. This is considered an ex-situ option. It is for the most part expedient in terms of timeframe and results in a clean site free of contamination that generally will not require continued monitoring as is often required with other more involved remedial options. Most commonly, due to the use of mechanized equipment, this remedial option would require the substation or parts of it be de-energized. Thus, this option can become quite costly and the Utility is well advised to pursue other technologies. Furthermore, special care should be taken with underground installations including substation ground grids and underground power and control cables.

b) Pump and Treat Systems

This in-situ treatment is used for sites with groundwater issues. It is custom designed and system specific to the contaminant being remediated. The system generally requires the installation of extraction wells in the area of contamination. Groundwater is then re-routed to a series of bioreactors, where treatment of water takes place. Treated water is then re-injected through gravity injection systems to its original location.

Such systems need to be monitored regularly and use consumables such as electricity, filters etc. Often, this represents a long-term solution and targets or goals are frequently difficult to attain.

c) Dual Phase Extraction

This treatment option has been used in recent years with good success. It operates with large vacuum pumps that extract both groundwater and soil vapors at the same time. The system has been shown to have high chemical compound recovery rates for hydrocarbons and chlorinated solvents. The design and maintenance of these systems however, require good engineering expertise and relatively high capital costs as well as, consumables such as electricity.

5.3.2 Passive Remediation Methods

Passive remediation methods naturally attenuate soil and ground water contamination.

5.3.2.1 Bioremediation

Bioremediation is a process by which living organisms act to degrade hazardous organic contaminants, or transform hazardous inorganic contaminants to environmentally safe levels in soils, subsurface materials, and water. The various organisms that act as bioremediating agents include bacteria, algae, fungi, and viruses. The ability of certain microorganisms to transform natural or synthetic chemicals into sources of energy for their own growth may represent a promising alternative to expensive chemical or physical remediation efforts.

The organisms usually used for remediation are Class 1 organisms. Class 1 organisms are naturally occurring and are not genetically engineered. They are non-pathogenic, and also non-opportunistic, i.e., will not cause disease in a compromised host.

Bioremediation is best accomplished with bio-augmentation, the addition of a large number of selected microorganisms grown in the production laboratory. In addition to augmentation, several physical and chemical parameters have to be controlled in order to obtain optimal growth and maximum degradation of soil contaminants.

The major factors to be controlled during bio-remediation are:

a) Microbial population
A sufficient amount of product is applied to the initial inocula to ensure rapid growth of the organisms. It is not the intent to provide a ready-made population to immediately digest the contaminants.

b) Nutrient concentrations
Nitrogen is needed for biosynthesis of amino acid etc. and can be obtained by microorganisms from either inorganic or organic sources. Most commonly used nitrogen sources are ammonia and nitrate.

c) Oxygen supply
The breakdown of aliphatic hydrocarbons is an aerobic process, i.e., requires oxygen. Microbial activity can be limited by insufficient oxygen concentrations due to the typically slow rate of oxygen diffusion into the inner layers of the soil. More rapid and complete cleanup can be obtained if a greater mass of oxygen is distributed in the soil.

d) Temperature and moisture control
Soil and laboratory studies have shown that soil temperature of around 28^0C and soil moisture of 15-20% is ideal for growth of microorganisms.

Application of the micro- organisms will vary from site to site and will depend on environmental factors, as well as the extent of the contamination. Usually topsoil and subsurface soil methods are applied. In topsoil bioremediation, the product and the nutrients are applied to the contaminated site by merely spraying the mixture on the surface of the soil while simultaneously roto-tilling the mixture into the soil. In subsurface soil bioremediation, the product and nutrients are injected under pressure to the same depth as that of the contamination. The above methods are in-situ methods where the entire bioremediation process can be completed without any excavation or soil removal.

Various methods covered under bioremediation are:

a) Bio-cells

Soil treatment to date, has been primarily directed towards organic contaminants such as hydrocarbons. This process involves the extraction and placement of contaminated soil in a bio-cell for treatment. This method requires a considerable amount of space on-site to develop bio-cells. In addition, the cost of bio-cell development must be weighed against the tipping costs of the soil.

b) Injections

This is an in-situ treatment involving the injecting of nutrients and/or organisms or chemicals into the subsurface to encourage the degradation of organic compounds, usually hydrocarbons. This option is attractive in areas that are inaccessible such as under buildings, transformers and cap banks. There is mixed reaction to the results of this option. Research is still continuing with considerable effort towards developing oxygen and hydrogen compounds for release into the subsurface to accelerate the bioremediation of both hydrocarbons and chlorinated solvents.

c) Monitored Natural Attenuation

Where possible, the source of the contaminant should be located, the reason for the problem diagnosed and a solution remedied. Monitoring is then implemented to measure the decline of the residual contamination. Monitored Natural Attenuation (MNA) is best suited to organic compounds that are moderately to highly degradable, but can also be used for metals. MNA is considered where full clean up seems impossible and/or unnecessary. Although seemingly a low up front capital cost and therefore an attractive option, monitoring can prove to be costly depending upon the number of monitoring locations, duration of monitoring and any expectations placed upon the owner by regulatory agencies.

5.3.2.2 Phytoremediation

Phytoremediation involves the use of plants to remediate soil and groundwater by removing contaminants from the environment or rendering the contaminants harmless. It is generally used for sites with low to moderate levels of contamination that are within the reach of plant roots. Plant physiology, agronomy, microbiology, hydrogeology and engineering are combined to select the proper plant and conditions for each site. Plants are used to clean up contamination in the following ways:

a) **Phyto-filtration:** Organic contaminants are absorbed inside the plant and metabolized into non-toxic molecules by natural chemical processes within the plant.
b) **Phyto-extraction**: Plant roots can remove metals from contaminated sites and transport them to the leaves and stem for harvesting and disposal**.**
c) **Phyto-stimulation** or microorganism stimulation: Plants generate enzymes and organic substances from their roots that stimulate the growth of microorganisms such as fungi and bacteria. The microorganisms in the root zone then metabolize the organic contaminants.
d) **Volatilization:** Plants can take up water and organic contaminants through their roots, transport them to the leaves, and release the contaminants as non-toxic gaseous compounds into the atmosphere.
e) **Phyto-stabilization**: Plants can prevent contaminants from migrating by reducing run-off, surface erosion, and ground water flow rates. The ability of desert plants to remove uranium, plutonium and other radioactive isotopes is also being used for remediation**.**

Phytoremediation offers several advantages including enhancement of site aesthetics, relatively low labour costs, and an inherently non-intrusive, environmentally based approach. Furthermore, phytoremediation can be used as a stand-alone method or in conjunction with other remedial technologies.

Phytoremediation will likely involve some degree of landscape redesign, which will add to the duration of the project. Due to its lengthy nature, it is not suited for sites that pose an immediate risk to human health and the environment where an immediate solution is required.

5.3.3 Electro kinetics

An in-situ technology involving the application of low intensity direct electric current across electrode pairs implanted in the ground on each side of a contaminated area, causing electro-osmosis and ion migration. Contaminants migrate towards respective electrodes depending on heir charge. The process may be enhanced by using surfactants or reagents to increase contaminant removal rates at the electrodes. This technique separates and extracts heavy metals, radionuclides, and organic contaminants from soil.

5.3.4 Barriers

This is a very common approach that involves materials such as geo-textile covers and liners, storage containers, pavement and cement. Due to its invasiveness, it is generally applied as a preventative method in new sites, and is less commonly introduced as a remedial option for existing substations. As such, we include this section for the reader's information only.

The barrier is intended to separate receptors from contaminated sources. This works well for soil where the contaminant has little to no mobility (most metals and some organic compounds). Barriers are not as effective in isolating groundwater situations. Attempts in this regard have seen the use of interceptor wells and collection trenches to assist in the capture and collection of groundwater. Newer technologies such as walls, which direct groundwater to an in-ground treatment location, are proving to be quite effective. Barriers however, do not treat the source of the contaminant(s).

5.4 SELECTING A METHOD FOR REMEDIATION

Site remediation can be very costly, regardless of how simple the solution might seem. It is highly suggested that sufficient planning be allotted for this effort to ensure that the most effective and efficient remedial option is selected. This can be accomplished by undertaking an 'Option Evaluation' process. This process identifies candidate options, evaluating their merits and selection.

5.4.1 Options Evaluation

Once an approach is selected it is important to evaluate the remedial options available. The purpose of the Remedial Options Evaluation is to provide the utility with an evaluation of remedial alternatives and/or risk management options and the associated costs required to remove, treat and/or manage areas of identified environmental concern. The following provides a suggestion of how this might be accomplished.

a) Areas of Environmental Concern
b) Evaluation and Reporting of Findings
c) Detailed Analysis of Remedial Option(s) including Cost Assessment
d) Recommended Remedial Options

5.4.2 Factors to be Considered

In developing and evaluating the remedial option(s), there are a number of constraints that must be considered to ensure that the options being considered are realistic and appropriate. The following list of constraints may serve to guide the identification of viable options and the selection of a preferred option (note a preferred option may contain a number or suitable options).

a) **Time**: External pressures (government), internal budget allocations, and corporate direction/policy may impose time restrictions. The remedial options presented vary in their time requirements i.e. bioremediation vs. dig and dump.
b) **Costs:** Although, bioremediation or monitoring natural attenuation may be far cheaper than a dig and dump procedure, the former approach may take years to complete, whereas a dig and dump approach is quite expedient.
c) **Space:** The space available at a site will most certainly influence the options available. For example soil sorting which may save 40% in costs will require room on site for the excavated material to be stockpiled for the sorting process.
d) **Disruption/Location:** What is the surrounding land uses? Will the remedial option be compatible within this setting?
e) **Permits:** many remedial options may require approval by relevant committees and organizations.

6. OTHER ENVIRONMENTAL CONSIDERATIONS

6. 1 SULPHUR-HEXAFLORIDE GAS (SF_6)

6.1.1 Introduction

SF_6 gas has become an environmental concern in recent years, as scientists begin to document changes in the temperature of the earth. SF_6 gas has a high global warming potential and is considered to be one of the most potent greenhouse gases due to its molecular properties. However, research has shown that SF_6 is emitted in comparatively small quantities and contributes only marginally to the total green house effect. Despite this, concern still remains regarding its effect over the long-term as SF_6 gas is known to have a considerably long atmospheric lifetime.

These issues have stimulated much discussion in political and scientific arenas regarding its continued use. In reponse to these concerns, various efforts have been instituted to reduce the emission of SF_6 from transmission and distribution substation equipment. Concerted actions include the use of equipment with improved sealing, procedures for appropriate gas handling and recycling, voluntary agreements on the use of SF_6 and on measures for SF_6 emission reduction made in collaboration with existing governmental bodies, and improved emission control, monitoring and reduction programs.

6.1.2 Facts about SF_6

SF_6 is a synthetic gas formed by 6 atoms of fluor, gathered around a centrally situated atom of sulphur. For over 40 years the substance has been used in the electric industry by Original Equipment Manufacturers – OEM – and users of electric power equipment for current interruption and insulation in both HV power transmission and MV distribution equipment. SF_6 gas is strongly electronegative (i.e., tends to attract free electrons). It has a unique combination of physical properties that contribute to its high functional performance including a high dielectric strength (about 3 times that of air), high interruption capabilities (about 10 times that of air), and high heat transfer characteristics (about 2 times that of air).

It is for these reasons that the application of SF_6 in the electric industry has been constantly growing. Currently, with regard to high voltage systems, SF_6 is used not only in gas-insulated equipment and circuit breakers but also in various instrument and power transformers. The electric industry is reported to be the main SF_6 user (K. Smithe, 2002), purchasing approximately 80% of the known volume of SF_6 (the actual worldwide volume of SF_6 produced is unknown). Nevertheless emissions of “electric” SF_6 are negligible, as it is used in a closed loop. In 1999 the ratio of “electric” SF_6 gas emission to total man-made greenhouse gas emissions was reported to be 50 Mton/y (CO2 equivalent) / 43000 Mton/y ~ 0.1%. Researchers suggest that if the electric industry were to adopt full implementation of conservative and environmentally friendly SF_6 gas handling procedures, SF_6 gas emissions could be further reduced to 23 Mton/y (CO2 equivalent) by the year 2010 (O’Connell et al., 2001).

Pure SF_6 is a non-toxic, odour-free, colourless and tasteless gas. It is non-flammable and in ambient temperature chemically inert. However, the products of SF_6 decomposition can be harmful to biological organisms. Discharge phenomena (i.e.: corona, streamers, leaders, sparks, etc) or power arcs cause decomposition of SF_6 resulting in the production of acid by-products. Depending on their concentration, these decomposition products may adversely affect the health of individuals who come in contact with the gas by causing irritation of the respiratory tract mucosa, and irritation of the eyes and skin. Exposure to high concentrations of the gas for long periods of time can lead to the development of asthma in some individuals (IEC 61634).

6.1.3 Impact on the Environment

SF_6 gas does not contribute to the depletion of the ozone layer (Ozone Depletion Potential – ODP = 0). However, it is a potent and persistent greenhouse gas. SF_6 has a Global Warming Potential (GWP) of 23900 times that of CO2 and an atmospheric lifetime (ALT) of 3200 years (IPCC 1995). Recent calculations indicate an improved outlook. Owens (2001) reported that the current concentration of SF_6 in the atmosphere is associated with a GWP of 22500 and ALT of 650 years.

However, the above estimates do not provide an accurate picture of the overall environmental effects of SF_6 gas. The overall environmental impact of a substation should be evaluated from the perspective of the impact of the substation as a whole. Life Cycle Assessment (LCA) procedures (according to ISO 14040) which assess the integral environmental impact of a technology based on the relative contribution of its components, are a useful evaluative measure in this context. For example, although the properties of SF_6 gas may impact negatively on the environment, when assessed from the perspective of the environmental impact of the substation as a whole, use of SF_6 gas has yielded positive environmental gains. Use of SF_6 gas as an insulation medium has led to more compact and space efficient equipment design, resulting in material savings and lower energy losses. The results of a recent life-cycle assessment study revealed that the use of SF_6 technology in GIS installations lead has led to considerable environmental benefit over the use of SF_6-free switchgear (“Electricity supply using SF_6 Technology”, 1999). The superior electric properties of SF_6, an appropriately low leakage rate from current GIS, and the implementation of best practices with regard to SF_6 handling and recycling enable the synergetic effect of saving land occupation, materials, and energy losses.

6.1.4 Methods to reduce SF_6 emission in existing substations

a) Improvement of SF_6 gas handling procedures. Implementation of conservative gas handling procedures in test laboratories, factories and construction sites has led to a 50% reduction in SF_6 emissions from original equipment manufacturers (O’Connell et al., 2001).
b) Recycling of SF_6 insulated equipment.
c) Introduction of SF_6 inventories to monitor production and use.

A systematic search for environmental friendly alternatives to SF_6 is ongoing within the international scientific community (see for example: Proceeding of XIV GD, 2002). Presently, no alternative medium exists with comparable electric performance and functional capability. Less ideal substitutes have been identified and all require that electric equipment be redesigned to allow for increased operating pressure and insulation distance to comply with IEC Standards in force. The additional cost, weight and dimensions of such options would result in an increase in the overall environmental impact.

Therefore, discontinued use of SF_6 in electric industry is not an ideal option at this stage. However, there exist numerous guidelines for environmentally responsible handling of SF_6 in the electric industry prepared by such reputable organisations as the IEC, IEEE and CIGRE. Sound waste management practices are critical and recycling of SF_6 should be common practice given the existence of effective recycling and waste management guidelines. Promotion of safe and environmentally responsible SF_6 handling procedures in the electric power industry should continue, as should efforts toward SF_6 reduction, improved equipment design to reduce leakage and SF_6 use, as well as research into viable alternatives.

6.2 ELECTRO-MAGNETIC FIELDS (EMF)

6.2.1 Introduction

Electromagnetic fields (EMF) are another important issue to consider when assessing the impact of existing substations on the environment. Government regulations and guidelines concerning EMF levels may exist, and where they do, they mainly apply to new substations. However, there may be cases where existing substations are extended or modernized and regulations regarding EMF levels would then come into consideration.

6.2.2 Typical Sources of EMF

Typical sources of electric and magnetic fields in substations include: transmission and distribution lines entering and exiting the substation, buswork, transformers, air-core reactors, switchgear and cabling, line traps, circuit breakers, ground grid, capacitors, battery chargers and computers.

6.2.3 Methods to reduce EMF levels in existing substations

Usually in an existing substation, when EMF levels need to be addressed, it is recommended that measurements be taken for both electrical and magnetic fields. In enclosed substations, the electric field levels in the immediate vicinity of the substation building are negligible due to the shielding effect of the building material. In open-air substations, the electric field levels outside the substation fence are more or less the same intensity as the electric fields associated with the incoming and outgoing transmission lines. However, in both enclosed and open-air substations, the highest magnetic field levels can be found directly underneath or above the incoming and outgoing overhead or underground lines.

Although the reduction in EMF levels within existing substations cannot be done without costly, intrusive and extensive modifications, there are common techniques in practice. Reductions in electric field levels can be accomplished by increasing the height of the buses; decreasing the phase spacing and bus diameter; lowering the operating system voltage; and making use of vegetation as shielding. Methods for reducing magnetic field levels include increasing the distance from the sources; optimizing phase configuration to achieve magnetic field cancellation; minimizing currents by increasing operating system voltages, minimizing power transfers and providing reactive load transfers and/or alternate line power flow paths. In addition, magnetic field levels can be further reduced by balancing currents on lines, and by shielding conductors and buses.

The health effects of electromagnetic fields have been studied extensively over the last 40 years. The results of these studies have been inconclusive and there is no general consensus on the possible adverse health effects of these fields. Despite this, the electrical utility industry has taken a decidedly proactive stance and is committed to reducing public exposure to EMF.

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APPENDIX A- SUBSTATION AESTHETICS CASE STUDIES

This section provides additional examples of measures that have been used around the world to enhance substation aesthetics. Most of the case studies presented illustrate measures that have been applied to existing substations. However, some of the case studies included in this section provide examples of substations which had "aesthetic-enhancing" measures incorporated into their original design. They are included for illustrative purposes only.

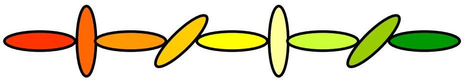
A.1 Substations located near an Entertainment Park

a) Case Study#1: Celebrate it!

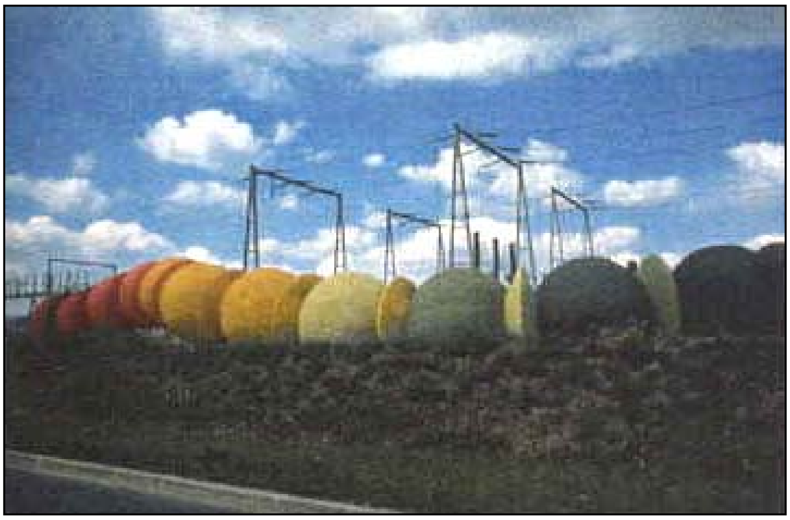
The 69/12.47kV substation depicted below is located near an Entertainment Park in the USA. The colorful pictures and compact design of the gantry and equipment structures help to blend the substation in with the theme park in the background.

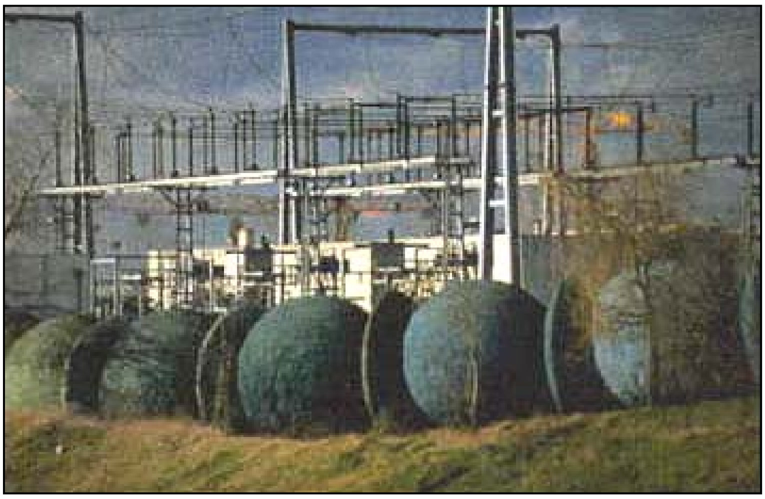
b) Case Study #2: Celebrate it!

This case study is of a 225/20kV substation located near an Entertainment Park in France. The colorful and innovative design of the perimeter fence provides a dramatic visual impact. The fence is made of painted concrete discs. When viewed from frontal and lateral angles, the following image is seen:



This colorful fence was installed along the side of the substation facing the main road. A regular chain-link fence was installed along the remainder of the substation perimeter to reduce the cost of fence construction.





c) Case Study #3: Celebrate it!

This case study is of a 77/6.6kV substation adjacent to a Children's Park in Japan. The wall of the substation facing the Children's Park is painted with pictures of animals reflective of the environment and atmosphere of the park. The fence prevents unauthorized entry into the substation and the wall also serves as a noise barrier for the substation.

A.2 Role of the Surrounding Environment

a) Case Study #4: Hide it.

This case study is an excellent example of the effect of the surrounding environment on the visual impact of the substation. This substation is built in a mountainous location. It is completely camouflaged by the industrial building in the background and is scarcely visible in the enclosed aerial view.

A.3 Substation Equipment and Layout

a) Case Study #5: Improve line entrance structure appearance

This case study is of a transmission substation built on a mountain. Due to its location, a compact equipment design was employed to reduce construction costs. The 275kV GIS was positioned on the roof of 275/154kV-transformer building and the take-off gantry were distributed on either side of the GIS.

b) Case Study #6: Harmonizing the color of the equipment

The following two case studies are of substations in Japan. In each example, substation aesthetics were improved by harmonizing the color of the equipment with the surrounding landscape. The first example is of a 275/77kV substation built in a mountainous area. Harmony with the surrounding was achieved by painting the equipment brown.

The following example is of a 77/6.6kV substation built amidst a tea garden. The substation equipment was painted green and plants were installed along the perimeter fence to harmonize the substation with its surroundings.

c) Case Study #7: Low profile equipment arrangement

This is an example of a 110kV substation located in a suburb in Poland.
The single bus bar substation was initially composed of conventional flexible string bus conductors before refurbishment. The substation was refurbished to a two-bus bar system with low profile, rigid tubular conductors supported on the post insulators. A positive visual impact was achieved by adopting a low profile equipment arrangement.

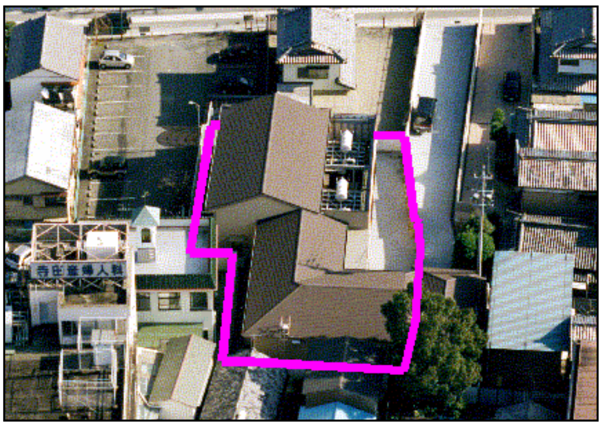
A.4 Substation Buildings

a) Case Study #8: A substation in a Nature Park

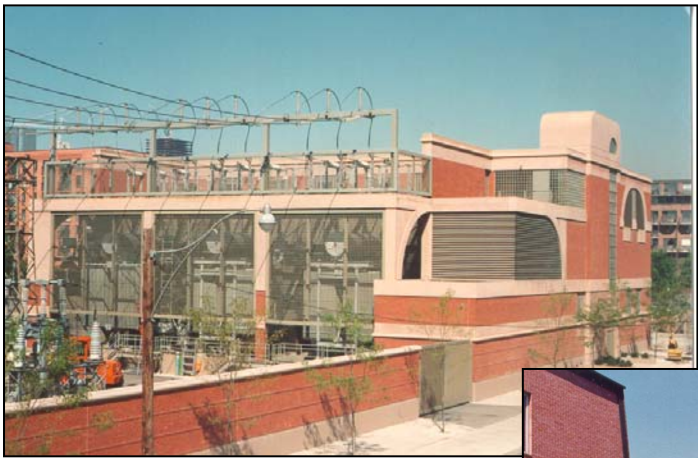
This is an example of a 77/6.6kV substation built within a nature park in a mountainous region in Japan. Local regulations do not permit the construction of “ordinary” buildings in nature areas. Therefore the architecture of the substation building was designed to reflect a mountain cottage to suit the natural locale.

b) Case Study #9: Substations in densely populated areas.

This case study depicts a 77/6.6kV substation located in a densely populated residential area. The architecture of the substation has been designed to reflect the architectural style of the surrounding houses.



The following two examples are of substations located in densely populated residential areas in Toronto, Canada. The architecture of both substations was designed to reflect local architectural styles.



c) Case Study #10: Substations in suburban areas

This case study illustrates a 400/220kV-transmission substation built in a suburb in the Czech Republic. The paintings on the wall of the substation make the building appear smaller and similar to the surrounding rural houses.

APPENDIX B SITE ASSESSMENT PROCESS

Please Note: the following is an example of a site assessment process that is presently in use in Canada. It is included for references purposes only and should be interpreted merely as a guideline.

Environmental Site Assessments (ESA) represent a process that identifies, qualifies, quantifies and manages liabilities related to chemical compounds that may have a potentially adverse effect on human and/or ecological health, aesthetics and the environment. This is done through a review of historical documents to identify issues related to compliance, protocols, spills, adjacent land uses etc, and the testing of soil, air, surface water and groundwater through sampling programs to verify/negate possible issues. Where exceedences or non-compliances are found, the investigator then must determine if there are legal, health and/or ecological effects and if so, adopt an approach for managing the impact of these adverse effects or non-compliances.

Most commonly, Environmental Site Assessment is divided into three main phases.

Phase I ESA

The primary purpose of a Phase I ESA, is to ***Identify and Qualify Environmental Liability*****.** This is generally involves a review of all records both historical and present regarding what has taken place on and adjacent to the site. This review should address compliance issues associated with air, water, waste and designated substances; site protocols for documenting and reporting incidents, records (if available) from previous occupancy, review of data bases, etc. Where possible, site workers or individuals familiar with the site are interviewed and the investigator makes a site visit to confirm as much information as possible.

Phase II ESA

The purpose of a Phase II ESA is to ***Quantify Environmental Liabilities*** that were identified and outlined in Phase I. This is achieved through a soil and groundwater sampling program**.** A Phase II ESA essentially serves to verify and quantify the extent of environmental concerns associated with the site. There are various forms and types of Phase II ESAs. Generally, Phase II ESA's do not require that the substation be de-energized. The following provides a description of the major Phase II ESA investigative types, which are common to the industry.

A. **Limited Phase II**: The purpose of the limited Phase II ESA is to provide a quick and economical evaluation of environmental concerns on the site. This is generally achieved through a non-intrusive soil investigation procedure, referred to as a *Shallow Soil Investigation.*

B. **General Phase II:** The purpose a general phase II ESA is to broadly categorize the environmental concerns and liabilities of the substation site and to provide a broad delineation for both soil and groundwater. The focus of this investigation is limited to on-site concerns. The potential for off-site migration of environmental contaminants is not explored in this option.

The results of a General Phase II examination should provide sufficient detail to assess the need for remedial actions, evaluate remedial options and determine remedial costs. It should also provide relevant information to establish site-specific work health and safety practices for any on-site work that may be required.

C. **Comprehensive Phase II:** A comprehensive Phase II ESA involves all of the components of a General Phase II, in addition to, a detailed examination of the potential for, and impact of, any off-site migration of substation site contaminants. The information derived from this ESA should be sufficient to a) determine the potential for off-site migration of environmental concerns, b) the need for supplemental soil/groundwater sampling and c) to evaluate remedial options.

D. **Supplemental Phase II ESA:** Supplemental Phase II ESAs are simply further soil/groundwater sampling, which is undertaken to more fully define an environmental concern identified during the original investigation.

Phase III ESAs

Phase III addresses the remediation of the environmental concern(s). The various remedial approaches presented in this brochure may be considered at this stage while taking into account the factors outlined in Section 5.4.2.

d) Case Study #11: Substations in mountain regions.

This is a case study of a substation built in the Alps region in France. The substation building is made of wood similar to the houses in the area and the distinct shape of the building is intended to reflect that of the surrounding mountains.

The substation building below was designed to reflect the architecture of cottages in the area.

A.5 Substation Perimeter Fence

a) Case Study #12: Natural fence

This is a case study of a substation in a suburb in France. Plants were installed along the perimeter of the chain-link fence to create a fence of vegetation to visually screen the substation with natural features in the environment.

b) Case Study #13: Wooden fence

This case study is of a 400/ 220kV-transmission substation in a suburb in the Czech Republic. The interior of the substation is lined with trees.

A wooden fence surrounds the perimeter of the substation.

A.6 Access Roads

a) Case Study #14: The 'Biotope' Method

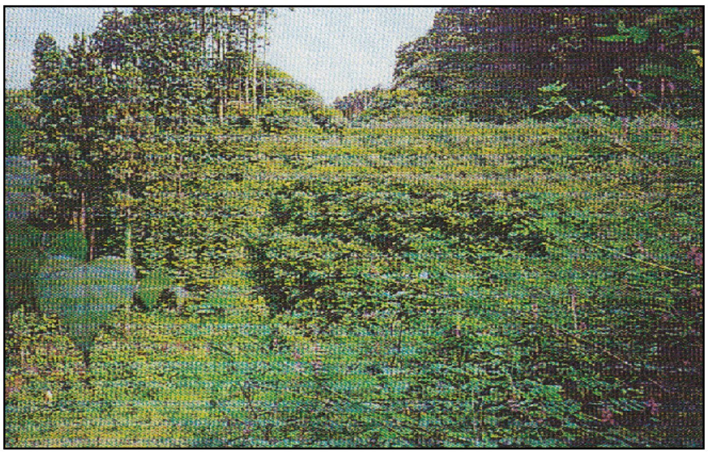
This is an example of an access road leading to a substation built in a nature park in Japan. Specific regulations in Japan require that a certain volume of trees be planted within a substation site located in a forested area. The *Biotope Method*, which is used in this case study, is an excellent option to employ to meet these environmental requirements.

The goal of the Biotope method is to return the site and its surrounding landscape to its original state and scenic view.

The pictures shown below depict slopes, which have been installed to create a foundation for plant growth to replace the plant life lost during construction and to create a visual screen along the access road.

(a) Under construction

(b) After one year



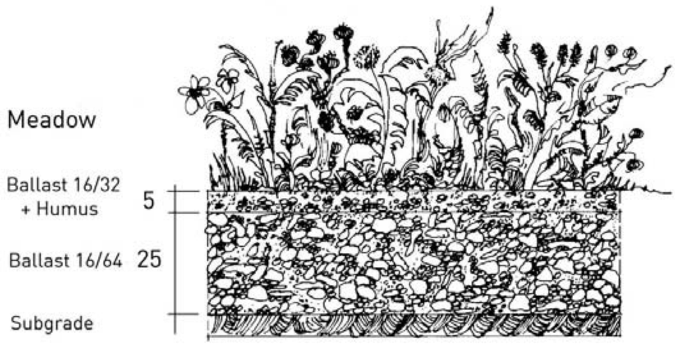
(c) Present

A.7 Gravel Surfaces

a) Case Study #15: The 'Dry meadow' Method

Gravel is commonly used as ground cover in air-insulated switchyards. However, gravel requires regular herbicide treatment to prevent plant growth. This has become a problematic issue in many countries as grid operators have been forced to reduce the use of herbicides to protect the soil and natural water resources from contamination.

The use of grass as a ground cover can be an ecological and cost effective alternative if the grass requires minimal maintenance.



Favorable experience has been gained by use of the 'dry meadow' concept. Mixtures of crushed rock (ballast) and soil (humus) specific to local ground and rain conditions have been used as a substation ground cover. A typical composition is shown in the adjoining figure.
The mixture is easily compressed, enabling maintenance vehicles to drive on the surface. Use of this mixture as a ground cover for the interior of the substation and the access roads may reduce the necessity of road construction within the substation. The image below depicts a substation, which has employed "dry meadow" ground cover.

A.8 Slopes and Banks

a) Case Study #16: The steeped switchyard in a substation

This case study is of a 275/154/77kV substation built on a mountain in Japan. There are two important aspects to consider when locating a substation on a mountain: securing a flat substation site of adequate area: and the effect of the substation on the surrounding landscape. Both issues can be addressed using a "stepped" switchyard.

The steps of the substation were built as follows:

1st Layer	275kV switchgear and 275/ 154kV transformer yard
2nd Layer	154/77kV transformer and 77kV shunt reactor
3rd Layer	154 kV switchyard
4th Layer	Control/ protection room and 77kV switchyard

Minimal impact on the natural environment and drastic curtailment of land reclamation expenditure were achieved.

A.9 Use of Plants for Screening

a) Case Study #17: Use of plants for screening

This case study is of a 220/110/20kV-transmission substation in a farming area in Germany. Over the years, the residential area has expanded to the boarder of the substation. As a visual screen, a line of trees and bushes has been planted along the perimeter of the substation. This plant cover has also served to reduce the noise level within the near-by residential area.