PREPARED FOR:
Zoning Administration Division
DPD/Fairfax County
12055 Government Center Parkway
Fairfax, VA 22035

Final Technical Report

ELECTRICAL SUBSTATIONS & BESS – NOISE FINDINGS & RECOMMENDATIONS

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PROJECT LOCATION:

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Background Information

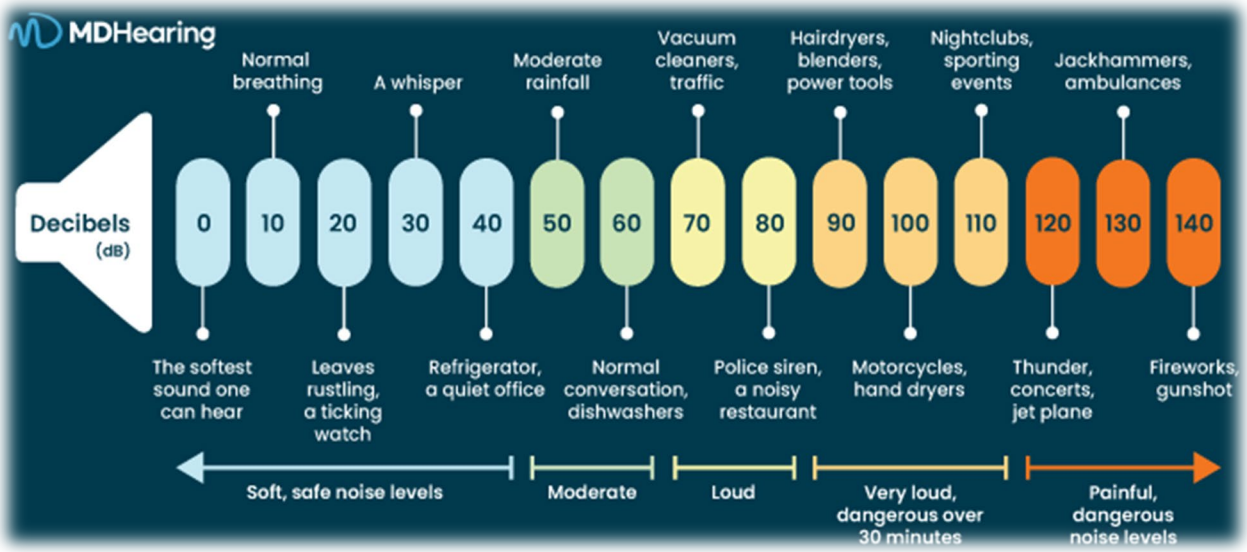
The Zoning Ordinance Work Program for Fairfax County, as approved by the Board of Supervisors in 2024, includes the review of zoning provisions for two separate items: Electrical Substations and Battery Energy Storage Systems (BESS). As requested by the Department of Planning and Development, ATCS PA, Inc. (ATCS), consulting with WGI, researched information regarding noise generated by electrical substations and BESS facilities. As part of these efforts, ATCS researched information on the sound generated by typical equipment at electrical substations, such as transformers, and typical equipment at BESS facilities, such as cooling equipment and transformers. To gain a full understanding of the proposed provisions, ATCS also reviewed the Fairfax County Zoning and Noise Ordinances to ensure both work seamlessly together. Finally, ATCS developed a list of point source noise study recommendations for consideration by the County to ensure a consistent approach to the submission of a noise study to demonstrate that the design of the substation or BESS will be in compliance with the noise ordinance. A summary of our findings, recommendations and professional opinions are included below and can be used as appropriate to help guide future decisions with the County and/or Board of Supervisors as appropriate.

Acoustics 101

Noise is defined as unwanted sound. It is emitted from many natural and man-made sources. When it comes to hearing, people are generally not as sensitive to lower-frequency sounds as they are to higher frequencies, most people lose the ability to hear high-frequency sounds as they age. To accommodate varying receptor sensitivities, frequency sound levels are commonly adjusted, or 'filtered', before being logarithmically added and reported as a single 'sound level' magnitude of that filtering scale. The 'A-weighted' decibel filtering scale applies numerical adjustments to sound frequencies to emphasize the frequencies at which human hearing is sensitive, and to minimize the frequencies to which human hearing is not as sensitive.

The A-weighted scale is commonly used because the typical frequency spectrum of substation and BESS noise is higher in magnitude at the frequencies at which human hearing is noise sensitive (1,000 Hz to 6,000 Hz). To perceive sounds of greatly varying pressure levels, human hearing has a non-linear sensitivity to sound pressure exposure. For example, doubling the sound pressure results in a three-decibel change in the noise level; however, variations of three decibels (3 dB(A)) or less are commonly considered "barely perceptible" to normal human hearing. A five decibel (5 dB(A)) change is more readily noticeable. By definition, a ten-fold increase in the sound pressure level correlates to a 10 decibel (10 dB(A)) noise level increase; however, it is judged by most people as only a doubling of the loudness – sounding "twice as loud". Several examples of common indoor and outdoor sound levels are shown in Figure 1 – Common Indoor and Outdoor Sound Levels and are expressed in dBA.

Figure 1 – Common Indoor and Outdoor Sound Levels in dBA



Source: Decibel Chart: All You Need to Know

Typical Noise Sources for Substations & BESS

Electrical Substation Facilities

The primary noise source in a high-voltage substation is typically the transformer(s), which produce a constant hum. This noise is primarily caused by the interaction of electric and magnetic forces within the transformer's core and windings, leading to mechanical vibrations. These vibrations are transmitted through the transformer's structure and are perceived as a low-frequency hum. In addition to the steady noise from the transformer, intermittent sounds may emerge from other components, such as the tap changer. The tap changer adjusts the transformer's voltage and can generate brief, sudden noises due to voltage fluctuations. Cooling fans also contribute to the overall noise, particularly when the transformer is under heavy load. These fans operate to regulate temperature and often produce a whirring or buzzing sound.

Based on information included in electrical substation applications submitted to the county, the typical sound levels generated from transformers can range from 55-75 dBA. After some additional research, in most cases, electrical substations produce approximately 60-80 dBA at the source and are often associated with transformers. Transformers can vary in sound due to size, voltage rating, design and number of units operating at a particular facility. Although the noise from electrical substations tends to be tonal in nature, these facilities are generally quieter compared to BESS facilities.

BESS Facilities

The primary noise sources at a BESS facility typically arise from three key areas: transformers, batteries, and power conversion devices. For a typical site design, depending on its size, one or two transformers are integrated into the BESS facility. These transformers emit a low humming sound,

which, although the quietest of the three primary sources, can still generate sound levels in the 70-75 dBA range near the source.

On the other hand, the battery section of the facility is often the largest contributor to overall noise levels. As the heart of any BESS facility, individual rechargeable battery units can number in the hundreds, with each unit featuring individual cooling systems to maintain optimal operational temperatures. These large container units, with their accompanying cooling fans and condensing units, can produce noise levels exceeding 90 dBA at the source. Weather conditions also play a role, as higher temperatures can cause the cooling fans to run more frequently and for longer periods, thereby increasing noise output.

Lastly, power conversion devices, which are responsible for converting direct current (DC) into alternating current (AC) for integration into the power grid, also contribute significantly to the overall noise. These devices generate continuous humming noise due to a series of enclosure fans designed to maintain proper cooling conditions. Sound levels from power conversion devices typically exceed 80 dBA at the source.

It is important to note that each individual substation and BESS facility is unique, and so are the sound levels associated with them. The range of sound levels can vary significantly depending on factors such as the type of equipment, specifications, size, number of units, and the layout and orientation of the facility. This variability underscores the importance of fully understanding all the parameters of the facility, including its operational power and other specific details, to accurately assess potential noise levels.

Zoning Ordinance Findings

Fairfax County Zoning & Noise Ordinances

ATCS performed a thorough review of the current Fairfax County Zoning Ordinance (v. 3/3/25), Noise Ordinance and draft amendment for substations (v. 3/28/25). ATCS agrees with the proposal that allows substation development, while noting that sound generated from a substation be classified as "Continuous Sound" for applicability to the County Noise Ordinance. Should there be a proposed substation or BESS development, ATCS recommends a point-source noise study, as outlined below, for all surrounding land uses. The purpose of this analysis is to ensure that maximum permissible sound levels from the proposed development do not exceed those listed in Section 108.1-4-2 of the County Noise Ordinance for the receiving zoning district classification.

Northern Virginia Noise Ordinances

In addition to reviewing the local noise and zoning ordinances for Fairfax County, VA., ATCS also performed a thorough review of noise ordinances within adjacent jurisdictions across Northern Virginia. When reviewing the maximum permissible sound levels at the property line for stationary sources in areas around Northern Virginia, in many cases, it aligns well with Fairfax County's maximum permissible sound levels. Through our research, Prince William and Stafford Counties currently enforce the daytime and nighttime maximum permissible sound levels of 60 dBA and 55 dBA, respectively for Residential areas. However, Loudoun County does have slightly stricter daytime and nighttime maximum permissible sound levels of 55 dBA and 55 dBA, respectively for

Residential areas. Conversely, Culpeper County is less strict in residential areas as it lumps in agricultural and rural areas and has daytime and nighttime maximum permissible sound levels of 75 dBA and 65 dBA, respectively. **Table 1** below provides a summary of a few counties in Northern Virginia and offers a closer comparison to other jurisdictions adjacent to Fairfax County.

Table 1
Northern Virginia Maximum Permissible Sound Levels

	Zoning District Classification	Daytime Maximum dBA	Nighttime Maximum dBA
Fairfax County	Residential	60	55
	Non-Residential in Residential Districts	60	60
	Mixed Use Area	65	60
	Commercial	65	65
	Industrial	72	65
Prince William County	Residential	60	55
	Mixed Use District	60	55
	Commercial	65	60
	Office	65	60
	Industrial	79	72
Loudoun County	Mixed Use Residential	60	60
	Residential and Rural	55	55
	Commercial, Civic, & Institutional	65	65
	Industrial	70	70
Stafford County	Residential	60	55
	Commercial	65	60
	Office	65	60
	Industrial	79	72
Culpeper County	Agricultural, Rural Area, Residential	75	65
	Planned Unit Development	75	65
	Commercial	80	70
	Light Industrial	85	75

Note: This table represents the maximum permissible sound levels for stationary sources at the property line.

To gain a broader perspective, ATCS researched and downloaded various noise ordinances from around the country. Similar to the areas identified in Northern Virginia, Norfolk had slightly stricter daytime and nighttime maximum permissible sound levels of 57 dBA and 52 dBA, respectively for Residential areas. The rest of those surveyed had similar sound level restrictions. **Table 2** provides a summary of additional areas around the country.

Table 2
Other Areas Maximum Permissible Sound Levels

	Zoning District Classification	Daytime Maximum dBA	Nighttime Maximum dBA
Norfolk Virginia	Noise Sensitive Zone	55	50
	Residential	57	52
	Parks and Recreational	67	62
	Business (Commercial)	67	62
	Industrial	77	77
Orlando Florida	Residential	60	55
	Mixed-Use	65	55
	Commercial	70	65
	Industrial	75	75
Sioux Falls South Dakota	Noise Sensitive Zone	60	50
	Residential	60	55
	Commercial	65	65
	Industrial	75	75
	Agricultural	75	55
Flower Mound Texas	Residential	62	52
	Office / Retail	62	62
	Commercial	67	67
	Industrial	70	70

Note: This table represents the maximum permissible sound levels for stationary sources at the property line.

Recommendations For Future Consideration

Future Evaluation of the Noise Ordinance

Future evaluation of the County Noise Ordinance may be appropriate to ensure that there are sufficient guidelines for the development of substations, BESS, and data centers into the appropriate zoning districts. Since there is so much variability in the sound levels produced by these three sources, setback distances are not a viable measure to ensure sound levels remain within ordinance requirements. Rather, it is our recommendation that development proposals be accompanied by point-source noise studies, ensuring sound level compliance for the approved use. These point source noise studies will use site specific parameters and operating conditions unique to that specific facility. This approach is a proven method for compliance and will be the sole responsibility of the Developer prior to receiving an operating permit.

Additionally, as viable parcels become scarcer, the trends in the industry have seen developers encroaching on residential areas more than ever before, as available rural parcels become scarcer. As an additional tool for the County, ATCS suggests discussing and evaluating an "increase over existing" maximum sound level as a secondary criterion for current zoning districts where peace and sanctity are valued. This could ensure developers pursue projects closer to the appropriate zoning district and ensures alignment with the county zoning and noise ordinances and issuing less Special Exceptions.

Point Source Noise Study Elements

To ensure a comprehensive evaluation of predictive point source noise impacts, a thorough noise study is recommended to be required by the zoning ordinance. Our recommendation is to require a point source noise study for all proposed facilities, as well as the expansion of existing facilities, as expansions often introduce new noise sources to the area. Minor upgrades to existing facilities should be evaluated on a case-by-case basis in consultation with the County. The detailed point source noise study should be prepared by a reputable firm specializing in these types of analyses. It is recommended that the study should contain the following components as outlined in detail below.

Ambient Noise Monitoring

The goal of ambient noise monitoring is to establish baseline noise conditions in the area prior to any new development or operations to be approved for construction. This information establishes a current baseline decibel level of the ambient noise environment for the parcel proposed for development. This level is also used to gauge how much additional noise the proposed facility is predicted to induce to the neighboring parcels.

- **Requirements:**
  - **Minimum Monitoring Duration:** Ambient noise measurements must be taken for **at least 24 hours** at all four quadrants of the property line to ensure accurate representation of typical noise levels during normal operation. This period should encompass variations in activity levels, including daytime and nighttime conditions.
    - Measurements should include both **daytime (7 AM - 10 PM)** and **nighttime (10 PM - 7 AM)** periods, capturing fluctuations in noise levels due to typical activities, such as traffic or operational activities in the area.
  - Measurements should be taken at locations near sensitive receptors and along the property boundary. For consistency, measurements should be made in **dBA (A-weighted decibels)**, which is the standard for environmental noise assessments.
    - **Metrics to be Recorded:**
      - $\mathbf{L_{eq}}$ (equivalent continuous sound level)
      - $\mathbf{L_{max}}$ (maximum sound level)
      - $\mathbf{L_{10}}$ (the level exceeded 10% of the time)
      - $\mathbf{L_{90}}$ (the level exceeded 90% of the time)
      - $\mathbf{L_{dn}}$ (day-night average level)
  - Additional measurements shall be conducted at the professional discretion of the developer for representative locations surrounding the site where the project will be developed. Locations should be chosen to account for varying land uses, sensitive receptors (e.g., residences, schools, hospitals), and potential areas of concern.
  - Ensure that measurements are conducted in a manner that minimizes the influence of atypical noise events (e.g., construction or unusual traffic).
  - If the ambient noise monitoring is conducted in multiple phases (e.g., pre-construction and post-construction), clear distinction of baseline and post-project condition documentation is necessary.

Computer Modeling of Worst-Case Noise Operation

Computer modeling simulates potential noise impacts from proposed projects under worst-case operational conditions (facility operating at full capacity), aiding noise propagation predications and the effect proposed developments will have on surrounding parcels.

- **Software Tools**:
  - **SoundPLAN** and/or **CadnA** are the preferred modeling software packages to analyze sound propagation and noise levels based on project specifics (e.g., type of machinery, hours of operation, site layout).
  - The model should simulate noise from all point sources (e.g., machinery, exhausts, ventilation, etc.) under typical operational scenarios, with an emphasis on worst-case operational conditions (e.g., maximum machinery use and continuous operations).
- **Modeling Scenarios**:
  - **Daytime and nighttime scenarios** should be considered separately, as noise sensitivity often differs depending on the time of day.
  - **Worst-case operational scenarios** should account for maximum machinery usage and noise levels from operations that generate the highest sound output. The study should focus on the worst-case operational noise levels solely based on equipment sound power levels, site layout, and distances to sensitive receptors.
  - **Key variables should include**:
    - **Sound power levels** of each noise source (e.g., machinery, compressors, exhaust fans).
    - **Distance** from noise sources to sensitive receptors.
    - **Receptors and noise contours** should be modeled 5ft above the ground.
    - **Topography** and **site layout**, as terrain and physical features can impact sound propagation.
    - **Building structures** or other barriers that may impact sound transmission.
- **Compliance Thresholds**: Ensure modeled noise levels are compared to the County's noise ordinance permissible limits. Noise levels shall be modeled at key receptor locations to ensure compliance with permissible thresholds.
  - The model should demonstrate operational compliance within the set thresholds at the nearest sensitive receptor locations, including both the boundary of the property and at sensitive receptor points surrounding the parcel.
  - If necessary, additional modeling may be required to demonstrate post mitigation compliance (should such measures be needed for compliance).

Mitigation Modeling and Compliance Demonstration

The mitigation analysis should demonstrate the effectiveness of noise reduction measures that ensure compliance with the County's noise ordinance.

- **Requirements**:
  - Identify and model noise mitigation measures (strategies include noise barriers, enclosures, quieter equipment, operational modifications, earthen berm etc.) that will reduce noise levels to acceptable limits.

- As noted previously, software packages such as SoundPLAN or CadnA are required to model the effectiveness of each mitigation measure and demonstrate to the county how the proposed strategies will reduce operational noise to permissible limits.
- **Mitigation measures may include**:
  - **Barriers and walls**: Modeling the height, material, and placement of noise barriers to reduce sound transmission.
  - **Earth Berms**: Modeling the height and placement of the earth berm to reduce sound transmission.
  - **Equipment modifications**: Incorporating quieter equipment or retrofitting existing equipment with noise-reducing technologies.
  - **Operational adjustments**: Shifting hours of operation, reducing machinery speed, or modifying processes to lower noise emissions.
- **Vegetative Screening**: Although vegetative screening can offer a psychological benefit, it is not a recommended mitigation strategy since it takes approximately 100 feet of thick evergreen trees and underbrush to provide an approximate 3 dBA reduction.
- **Noise Level Compliance**: Demonstrate through modeling that noise levels at sensitive receptor locations will not exceed the ordinance's allowable noise thresholds, both during typical operations and worst-case scenarios.
  - Establish clear compliance criteria based on local ordinance noise limits.
  - The model should show compliance with these limits at property boundaries and/or at the nearest sensitive receptors.

- **Effectiveness**: Provide a detailed analysis of the predicted noise levels before and after mitigation, including how each mitigation measure will reduce noise levels and whether the residual noise is within the permissible limits set by the ordinance.

Reporting and Documentation Requirements

The noise technical report or memorandum should contain the following elements as outlined below.

- **Final Noise Study Report**:
  - Provide a detailed report that includes all methodologies, assumptions, and data sources used for the noise analysis.
  - The report should include:
    - A summary of ambient noise monitoring results, ensuring a minimum of 24 hours of monitoring as outlined.
    - Detailed computer modeling results, including predictive noise levels at key receptor locations and worst-case noise scenarios.
    - A summary of proposed mitigation measures and their predicted effectiveness in reducing noise.
    - Tables, graphs, and maps showing model predictions and actual noise levels at sensitive receptor locations.
  - Include an analysis of the project's noise impact relative to the County's noise ordinance requirements.

- If the project cannot meet the noise limits with the proposed mitigation measures, provide an alternative strategy, or consider a phased plan for further noise control measures.

Point Source Noise Study Conclusion

This guide recommends procedures to ensure a comprehensive point source noise study, including mandatory 24-hour ambient noise monitoring and rigorous modeling excluding weather-based variables. The findings will effectively address the potential noise impacts of proposed developments. The inclusion of mitigation strategies and detailed reporting shall provide the zoning commission with a clear depiction of operational compliance by the developer. This compliance may be unmitigated or mitigated operational adherence depending on the level impact predicted by the facility and the strategies implemented to operate within permissible limits.

References

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Flower Mound, Texas – Code of Ordinances, Subpart A – General Ordinances / Chapter 34-Environment / Article III – Noise Control – Section 34-181 – Noise Standards. Table 34-1 Limiting Sound Levels for Land Use Districts. (Code 1989, ch. 1, § 10.04). ARTICLE III. - NOISE CONTROL | Code of Ordinances | Flower Mound, TX | Municode Library. Referenced 4/3/2025

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Stafford County, Virginia – Code of Ordinances, Section 16-4 *Maximum permissible sound levels generally*. (Ord. No. 094-12(R), 5-24-94; Ord. No. 002-35, 12-18-02; Ord. No. O10-44, 10-5-10; Ord. No. O15-12, 6-2-15). Chapter 16 - NOISE | Code of Ordinances | Stafford County, VA | Municode Library – Referenced 3/24/2025.

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