Middletown Solar Farm Site

Inverter and Transformer Equipment Noise Study

Middletown, Rhode Island

Prepared for:

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Executive Summary

Dr. Howard Quin has completed a detailed noise modeling study for solar farm inverter and transformer equipment for Green Development LLC, located to the east of a proposed Solar Farm Site at Middletown RI. In this report, we have reviewed applicable noise standards and criteria and described the modeling used to project noise emissions from the selected inverter and transformer equipment to assess potential sound levels from the project.

Based on this study, we conclude that the proposed inverter and transformer equipment will produce very low sound levels (below 25 dBA) in the surrounding residential area. These will be well below the typical background levels recorded on site during daytime solar operational hours, and should be virtually inaudible at all nearby residences. The equipment will readily comply with the Middletown noise ordinance standards.

1 Introduction

Green Development is installing a 2 MW solar farm at a site in Middletown, RI. This site will have new inverter and transformer equipment on the east side of the site. In this report, we review applicable noise standards and criteria, and describe the modeling used to project noise emissions from the selected equipment. We modeled the peak operational sound level for the equipment. Appendix A provides a description of the various noise metrics used in this report.

2 Noise Standards and Criteria

Applicable noise standards for the proposed Inverter equipment are the Town of Middletown noise regulations applying to the proposed Inverter equipment. The Town of Middletown noise regulations are contained in town ordinance 130.75 to 130.91. The appropriate limits are 55 dBA for nighttime sound and 65 dBA for daytime sound. It is expected that the transformers and inverters will run mostly during daytime hours; however, there may be some times in the early morning hours when they would operate during nighttime hours as well.

§ 130.80 MAXIMUM PERMISSIBLE SOUND LEVELS BY RECEIVING LAND USE.

(A) With the exception of sound levels elsewhere specifically authorized or allowed in this subcha
at or within the real property boundary of a receiving land use:

SOUND LEVELS BY RECEIVING LAND USE		
Location of Receiving Land Use	**Time**	**Sound Limit**
Zoning District: Residential	7 a.m. to 10 p.m. 10 p.m to 7 a.m.	65 dBA 55 dBA
Zoning District: General Business, Office Business, Limited Business, Light Industrial, and Municipal Industrial Park	At all times	75 dBA
Other: Public Water	At all times	65 dBA
Other: Noise Sensitive Area	7 a.m. to 10 p.m. 10 p.m. to 7 a.m.	65 dBA 55 dBA

3 Predicted Equipment Noise Levels

The operational noise levels from the proposed inverter and transformer equipment were predicted in the Middletown study area using 1) reference noise emissions information for the proposed equipment provided from the manufacturer, 2) aerial photography from Google Earth, and 3) the SoundPlan® noise prediction model.

3.1 Noise Prediction Model and Noise Source Characteristics

The SoundPlan® computer noise model was used for computing sound levels from the proposed inverter and transformer equipment throughout the surrounding community. An industry standard, SoundPlan provides estimates of sound levels at distances from specific noise sources, taking into account the effects of terrain features including relative elevations of noise sources, receivers, and intervening objects (buildings, hills, trees), and ground effects due to areas of hard ground (pavement, water) and soft ground (grass, field, forest). In addition to computing sound levels at specific receiver positions, SoundPlan can compute noise contours showing areas of equal and similar sound level.

The sound propagation model within SoundPlan that was used for this study was ISO 9613-2.[1] This international standard propagation model is used nearly universally in the U.S. for equipment noise studies, due to its conservative propagation equations. ISO 9613-2 uses "worst-case" downwind propagation conditions in all directions, and accounts for variations in terrain and ground type input. SoundPlan incorporated a *geometric model* of the study area, reference *noise source* levels. SoundPlan uses a *sound propagation model* to project noise levels from equipment operations into the surrounding community.

Sound propagation was modeled from the inverters and transformers both through the solar array and into the surrounding area. When propagating through the solar array area, sound is blocked by the panels as barriers, reflected up into the sky away from receptors by tilted panels, and also refracted upward from the panels on calm sunny days due to slightly higher temperatures above the dark absorptive panels (similar to higher temperatures over an asphalt parking lot). Consequently, the panels have the effect of blocking almost all ground reflection to nearby receptors. They are therefore modeled with a G value of 1 for highly absorptive or ground blocking regions, but are not modeled as barriers, as sound travels both under and around the panels.

In the area surrounding the panels, in order to be conservative about noise attenuation from ground effects, we have used a ground attenuation G factor of 0.5 at soft ground locations. This is actually somewhat harder than an examination of the vegetation of the site would suggest; however, it allows for the possibility of occasional higher ground reflection during winter snow pack or ice conditions. This is consistent with G values used in other similar solar and wind turbine modeling studies in this area.

All of the transformer and inverter equipment are included in the sound modeling. The inverters are Sungrow SG125HV 125 Kw units; a total of 20 of them will be used on-site. The transformers consist of two Schneider/Square D Substation 1000 KvA units, each of which will have 8 inverters attached, and one Schneider/Square D Substation 500 kVA unit, which will have 4 inverters attached. Each of the transformer units are air cooled (they do not have cooling fans).

The reference total noise source levels for the new equipment were obtained from the client, as measured by the manufacturer. The equipment references are given in Appendix B. Data for the transformers were obtained using NEMA ST20 standard measurements at a distance of 1 foot. This gives a total of 58 dB for each 1000 kVA transformer, and 56 dB for the 500 kVA transformer. The inverters sound levels were measured by the manufacturer at a distance of 1 meter; they have been converted to sound power levels using the formula SPL=dB(avg)+10*LOG(S)+10*LOG(N) where S is the surface area containing the measurements, and N is the total number of inverters. This gave a total sound power level of 79 dB for the inverters.

The actual octave band sound power levels for the equipment in this study were not available; the inverter data spectra have been obtained from the inverter at a Calverton, NY 2 MW solar array, which are very similar, and normalized to the correct overall level. The transformer octave band levels have been obtained from a similar transformer in Vermont recorded by RSG, and normalized to the correct measured total sound level. These data show the same pronounced peaks in the 125 Hz. bands shown by all US transformers due to 120 Hz. hum (twice the line frequency, at which transformers resonate). The sound power spectral levels for both pieces of equipment are shown in Table 1 as included in the SoundPlan noise prediction model.

[1] International Organization for Standardization (ISO), International Standard ISO 9613-2, "Acoustics – Attenuation of Sound during Propagation Outdoors", Part 2: General Method of Calculation, 1996-12-15.

Table 1.

Reference Equipment Sound Power Levels

Octave-band Center Frequency (Hz)	1000 MVa Transformer	500 MVa Transformer	20 125 kw Inverters
32	52	50	58
63	47	45	66
125	56	54	73
250	46	44	74
500	40	38	73
1000	36	34	70
2000	27	25	66
4000	24	22	59
8000	20	18	50
Total (dBZ)	**58**	**56**	**79**

3.2 Predicted Equipment Noise Levels in the Community

Figure 1 shows the predicted equipment noise levels in the form of noise contours on the solar site layout of the study area. The predicted sound levels at nearby receptors on Busher Drive and along Amesbury circle are typically in the high teens to low twenties dBA range, barely audible under any conditions, and are well below the observed background levels.

3.3 Comparison with Ambient L90 levels

Ambient is defined as the background L90 measured during equipment operating hours. The background levels for comparison are taken from the lowest daytime measured background levels measured on site at locations L1 on Amesbury Circle and L2 on Busher Drive on March 22-23 2021, which both happen to be 37 dBA, also nearly the average of the short term measured L90 levels, as described in the accompanying Monitoring Report.

The computed levels are shown compared to the background in Table 2. The results show that the proposed equipment should be well below the measured background levels. In fact it appears likely that the proposed equipment will be almost completely inaudible during operational noise periods. It will readily comply with the town of Middletown noise ordinance.

Figure 1.

Noise Contours for Proposed Middletown Solar Inverter and Transformer Equipment Area

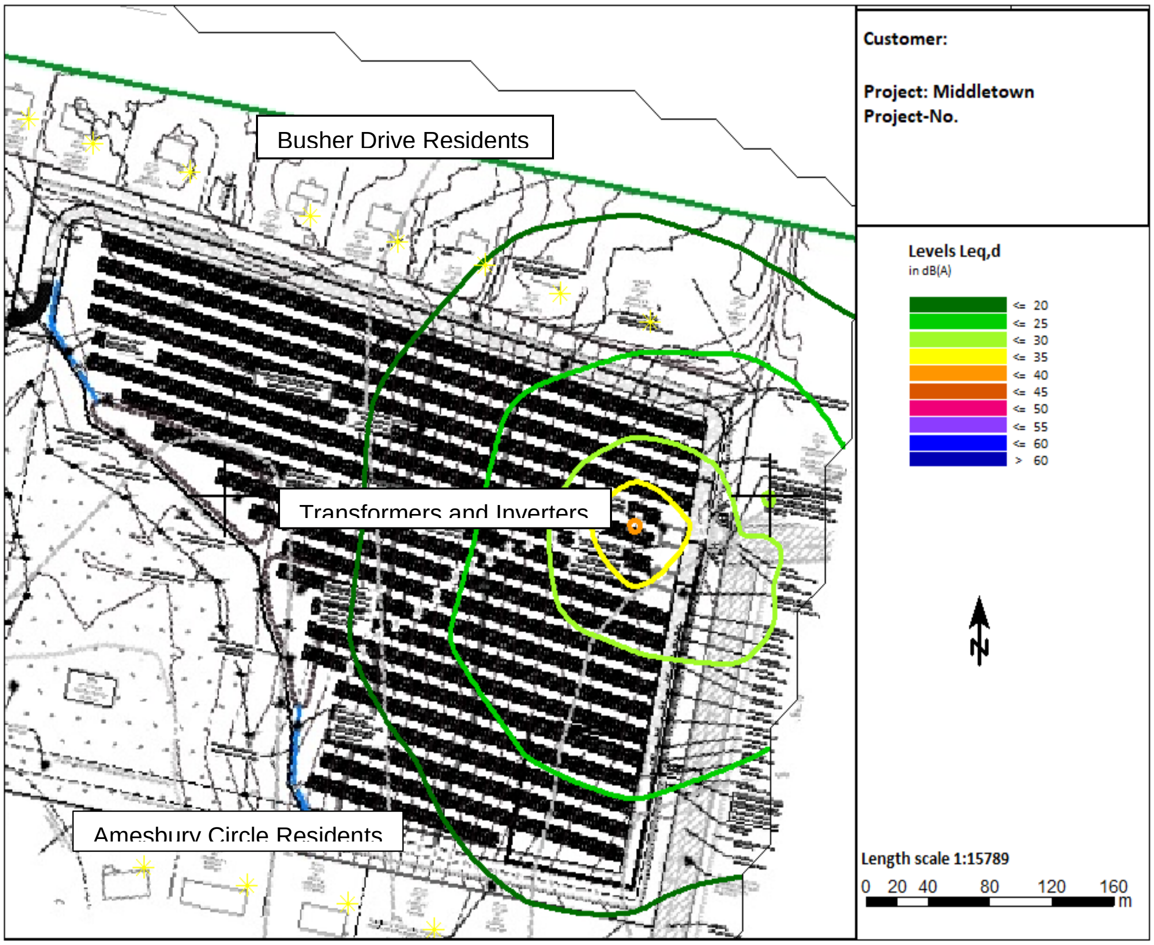

Table 2.

Predicted Noise Levels from Proposed Inverter and Transformer Equipment

Receptor Name	Predicted Equipment Leq dB(A)	Lowest Measured Daytime Background L90 dB(A)
Busher Drive behind SE corner residence	20	37
Busher Drive SE corner residence	22	37
Busher Drive 1st from SE corner residence	20	37
Busher Drive 1st from SE corner residence	19	37
Busher Drive 1st from SE corner residence	17	37
Busher Drive 1st from SE corner residence	15	37
Amesbury Circle NE corner residence	14	37
Amesbury Circle 1st from NE corner residence	16	37
Amesbury Circle 2nd from NE corner residence	16	37
Amesbury Circle 3rd from NE corner residence	15	37
Amesbury Circle 4th from NE corner residence	14	37
Amesbury Circle 5th from NE corner residence	13	37

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. Appendix A. Description of Noise Metrics

This Appendix describes the noise metrics used in this report.

1. A-weighted Sound Level, dBA

Loudness is a subjective quantity that enables a listener to order the magnitude of different sounds on a scale from soft to loud. Although the perceived loudness of a sound is based somewhat on its frequency and duration, chiefly it depends upon the sound pressure level. Sound pressure level is a measure of the sound pressure at a point relative to a standard reference value; sound pressure level is always expressed in decibels (dB), a logarithmic quantity.

Another important characteristic of sound is its frequency, or "pitch." This is the rate of repetition of sound pressure oscillations as they reach our ears. Frequency is expressed in units known as Hertz (abbreviated "Hz" and equivalent to one cycle per second). Sounds heard in the environment usually consist of a range of frequencies. The distribution of sound energy as a function of frequency is termed the "frequency spectrum."

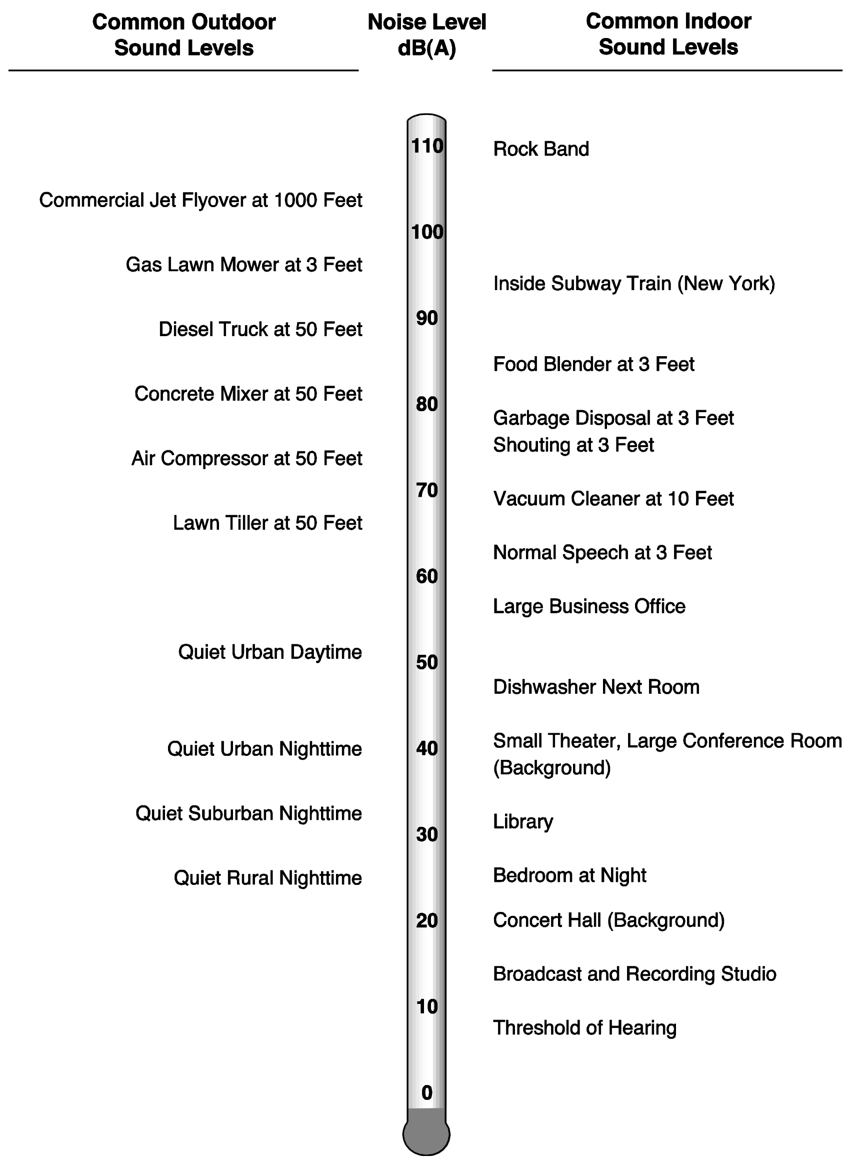
The human ear does not respond equally to identical noise levels at different frequencies. Although the normal frequency range of hearing for most people extends from a low of about 20 Hz to a high of 10,000 Hz to 20,000 Hz, people are most sensitive to sounds in the voice range, between about 500 Hz to 2,000 Hz. Therefore, to correlate the amplitude of a sound with its level as perceived by people, the sound energy spectrum is adjusted, or "weighted."

The weighting system most commonly used to correlate with people's response to noise is "A-weighting" (or the "A-filter") and the resultant noise level is called the "A-weighted noise level" (dBA). A-weighting significantly de-emphasizes those parts of the frequency spectrum from a noise source that occurs both at lower frequencies (those below about 500 Hz) and at very high frequencies (above 10,000 Hz) where we do not hear as well. The filter has very little effect, or is nearly "flat," in the middle range of frequencies between 500 and 10,000 Hz. A-weighted sound levels have been found to correlate better than other weighting networks with human perception of "noisiness." One of the primary reasons for this is that the A-weighting network emphasizes the frequency range where human speech occurs, and noise in this range interferes with speech communication. The figure below shows common indoor and outdoor A-weighted sound levels and the environments or sources that produce them.

2. Equivalent Sound Level, Leq

The Equivalent Sound Level, abbreviated L_{eq}, is a measure of the total exposure resulting from the accumulation of A-weighted sound levels over a particular period of interest -- for example, an hour, an 8-hour school day, evening, or a full 24-hour day. However, because the length of the period can be different depending on the time frame of interest, the applicable period should always be identified or clearly understood when discussing the metric. Such durations are often identified through a subscript, for example L_{eq1h}, or $L_{eq(24)}$.

L_{eq} may be thought of as a constant sound level over the period of interest that contains as much sound energy as (is "equivalent" to) the actual time-varying sound level with its normal peaks and valleys. It is important to recognize, however, that the two signals (the constant one and the time-varying one) would sound very different from each other. Also, the "average" sound level suggested by L_{eq} is not an



arithmetic value, but a logarithmic, or "energy-averaged" sound level. Thus, the loudest events may dominate the noise environment described by the metric, depending on the relative loudness of the events.

3. Statistical Sound Level Descriptors

Statistical descriptors of the time-varying sound level are often used instead of, or in addition to L_{eq} to provide more information about how the sound level varied during the time period of interest. The descriptor includes a subscript that indicates the percentage of time the sound level is exceeded during the period. The L_{50} is an example, which represents the sound level exceeded 50 percent of the time, and equals the median sound level. Another commonly used descriptor is the L_{10}, which represents the sound level exceeded 10 percent of the measurement period and describes the sound level during the louder portions of the period. The L_{90} is often used to describe the quieter background sound levels that occurred, since it represents the level exceeded 90 percent of the period.

Appendix B. Equipment Specification Data

Transformers

Liquid-Filled Substation Transformers

Application (cont.)

Sound Levels

kVA Rating	Self Cooled Rating (dB)	Fan Cooled Rating (dB)
225-300 kVA 500 kVA	55 56	61 61
750 kVA 1,000 kVA	58 58	61 61
2,000 kVA 2,000 kVA	60 62	63 64
2,500 kVA 3,000 kVA	62 63	65 66
3,750 kVA 5,000 kVA	64 66	67 70
7,500 kVA 10,000 kVA	67 68	70 71

SG125HV Noise Level Test Report

Version	Date	Author	Approved by
V10	2017,May, 28	Bale, Yang	Chen W

1.Introduction

This document describes the noise level test for SG125HV.The test is conducted in the Sungrow Testing Center, which is a WMT testing lab (Witnessed Manufacturer's Testing) accredited by TUV, CSA and UL.

The test procedures are in accordance with the standard ISO3746 and the sound pressure level fulfills the requirements in the IEC62109-1 standard.

2.Noise Level Test

The noise test was completed in the shielding room using the test platform shown below:

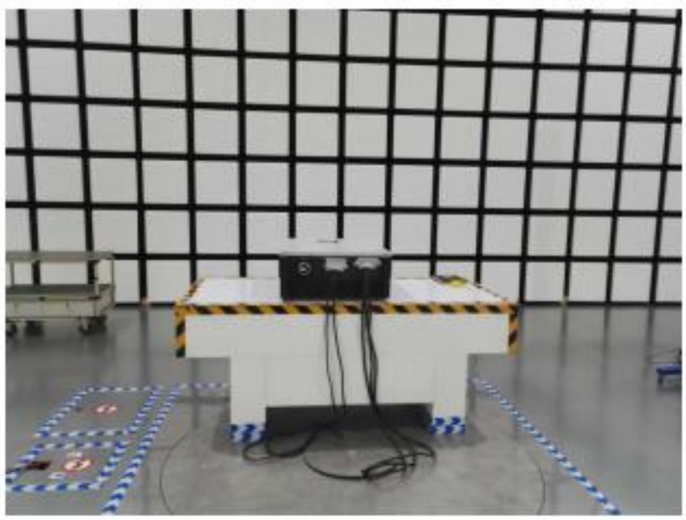


Fig-1 Noise Test Platform

During the test, the noise test instrument is located at a distance of 1m from the inverter, the inverter's operating DC voltage is 1050V and its output power is 125kW.The test data for the four directions and background noise are as follows:

Direction	Test Data
Bottom	61.6dB
Left Side	56.9dB
Top	53.7dB
Right Side	53.2dB
Background Noise	31.1dB

Appendix: Testing Pictures

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