A BRIEF STUDY OF THE ACOUSTIC IMPACTS OF SOLAR POWER GENERATION FACILITIES

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Figure 1 - Aerial View of Inverters and Transformers Located Throughout a Solar Facility (2025) DNV.com

Executive Summary

This report examines the relevant literature to assess the acoustic impacts of solar power generation facilities and performs a simplified calculation to give a general idea of how far away from neighboring properties solar equipment should be located in order to protect the safety and health of the public and to avoid unnecessary annoyance. In general, there are two main sources of sound emanating from solar power generation equipment: the inverters and the transformers, although if a Battery Energy Storage System (BESS) is included in the project, it could also be a significant source of sound. To accurately predict the effect on surrounding properties of a proposed solar project, which can vary significantly based on the equipment specified for use, the location, topography, groundcover type, and intervening structures, a detailed acoustic impact report should be generated by a qualified acoustic engineer.

A simplified sound propagation model is used in this report to give a general idea of how sound from inverters and transformers are attenuated by the atmosphere over the distance to the boundary of a proposed solar project. Based on generally accepted EPA guidelines to protect the health and safety of the public, a daytime limit of 55 dBA and a nighttime limit of 45 dBA has been assumed. In general, inverters only operate during the day, while transformers operate both day and night. Estimated sound levels of transformers were taken from the NEMA- TR-1 standard, while typical sound levels of inverters were taken from recent manufacturer literature. With these simplifying assumptions, it was found that central inverters should be located no less than 147 feet from neighboring properties to remain below the 55 dBA daytime limit. The substation transformer should be located at least 196 feet from neighboring properties to remain below the 45 dBA limit for nighttime use, while the step-up transformers only need to be located approximately 8 feet away.

Figure 2 - Two Inverters and a Step-up Transformer (2021) https://www.fimer.com

Applicable Standards and Guidelines

NEMA TR-1: This standard specifies the maximum allowable noise level for different types and sizes of transformers. According to Kalinski (2020), "While NEMA TR-1 represents the maximum sound pressure level, transformer noise can be mitigated at the source. This is especially true with "low-loss" transformers, which are often about 10 dB below the NEMA TR-1 levels." Audible sound levels measured for compliance with NEMA TR-1 are performed in accordance with IEEE Std. C57.12.90, which specifies that the measurements shall be performed at a distance of 0.3 m. This is different from other standards for other types of industrial equipment, for which the sound measurements are taken at a distance of 1 meter, and different from what the manufacturer may report on their spec sheet, which may be given for distances of 15 m to 25 m. As a result, it is very important to identify the distance used when comparing dBA ratings. The table below is from NEMA TR-1, showing allowable audible sound levels for liquid-immersed step-up transformers of the type commonly used in solar power generation facilities. A given project may have many of these step-up transformers distributed throughout the site to step up the relatively low inverter output voltage to a medium voltage for distribution within the solar plant, and potentially along a short distribution line, to the substation transformer.

Table 2
Audible Sound Levels for Liquid-Immersed Network Transformers and Step-Voltage Regulators

Equivalent Two-Winding kVA	Average Sound Level Decibels
0-50	48
51-100	51
101-300	55
301-500	56
501-750	57
751-1000	58
1001-1500	60
1501-2000	61
2001-2500	62
2501-3000	63

It is not uncommon for a large solar project to have a substation that connects the solar project to the transmission grid, and that substation will have a large transformer that can also produce noise. The noise rating for substation transformers is higher than step-up transformers, depending on the voltage rating, with sound ratings ranging from 57 dBA for 350 kV transformers up to 91 dBA for 1300 kV and higher.

ISO 9613-2: This standard provides a method to calculate the attenuation of sound propagation outdoors. It is designed to predict long-term average A-weighted sound pressure levels under meteorological conditions favorable to sound propagation. Computing the noise levels at some distance from a sound source is a function of topography, groundcover type, and intervening structures, which can become quite complicated. As a result, the calculations are often performed with sophisticated computer programs that implement the ISO 9613-2 standard. Examples of such computer programs include Cadna/A, SoundPLAN, and Nord2000.

EPA 550/9-74-004: Provides information on environmental sound levels that are allowable to protect public health and safety with an adequate margin of safety. To avoid hearing loss, the EPA recommends Leq(24) ≤ 70 dBA, where Leq represents the sound energy averaged over a 24 hour period. In order to avoid interference with other activities or prolonged periods of annoyance, another measure is used, Ldn, which is the day-night average where the Leq is given a 10 dBA weighting, or penalty, during nighttime hours. For outdoors in residential areas and farms, Ldn ≤ 55 dBA is recommended. Because of the 10 dBA penalty during nighttime hours, this effectively limits the average outdoor sound level at night to be less than or equal to 45 dBA while during the daytime hours 55 dBA would be acceptable.

World Health Organization Guidelines for Community Noise: This guideline recommends daytime exposer levels of 50 dBA to prevent the majority of people from being moderately annoyed, and nighttime levels of 45 dBA, which when assuming a 15 dB attenuation of noise levels from inside to outside of a building, allows a 30 dBA environment that is conducive to sleeping with minimal disturbance even with the windows open.

Literature Review

The Massachusetts Clean Energy Center (2012) commissioned a "Study of Acoustic and EMF Levels from Solar Photovoltaic Projects," which studies four different solar generation facilities and found that sound levels were at ambient conditions at the fence line of the project. Malén (2013) performed an "Analysis of noise emissions of solar inverters," and identified the various components of the inverter that contributed to the overall noise of the inverter. Although these early studies were valuable, they only analyzed relatively small string inverters of an earlier design. Modern inverters for utility-scale projects are significantly different in terms of size and design. A more recent study by Kalinski et. al (2020) studied the types of equipment used in utility-scale proejcts that emit sound, including transformers, inverters, storage devices, and tracking motors, and gave typical values for sound emissions from each component. They also gave guidance on how to perform an acoustic assessment of a solar project, including the modeling assumptions that are appropriate for that task. Hankford Environmental, Inc, (2019) measured noise levels from solar tracking motors while in operation and noted that while the maximum sound output is 68 dBA at 3 feet, the tracker motor only operates for several seconds every five minutes and thus does not become a significant source of sound from a solar power plant. Bošnjakovic et. al (2023) discuss noise emissions as part of the larger environmental impact of photovoltaic power systems, concluding that noise emissions from a PV power plant "does not represent a significant problem." Similarly, Tawalbeh et. al (2021) concluded, "the noise pollution of PV is minor." Although these conclusions are no doubt true in the general case, individual solar projects could potentially present noise problems for neighboring properties, depending on the placement of the important pieces of equipment, so the issue is best considered on a case-by-case basis.

There are numerous published examples of acoustic impact studies that were performed for specific proposed solar projects, and examples are listed in the reference section. Most of these studies use modern computer acoustic analysis software, such as SoundPLAN, Nord2000, or Cadna/A, and take as inputs the locations of specific pieces of equipment, as well as the topography of the site and any obstructions to compute sound levels at the boundaries of individual neighboring properties. Those studies generate noise contour maps like Figure 1 below, that show sound levels throughout the solar project and on the perimeters.

Figure 3 – Sound Contours for a Proposed Solar Project (Kimley and Horn, 2021)

Because sound ordinances are usually enacted at the local level it is difficult to draw generalized conclusions, but after reviewing many engineering studies for specific proposed solar projects, none were found to violate local sound ordinances. However, if a problem is found during the project development and permitting stage, design choices can be made to mitigate any potential noise issues by either locating particular pieces of equipment farther away from neighboring properties or installing noise barriers.

Simplified Model of Sound Propagation Outdoors

The simplified model of sound propagation outdoors shown below can be used to calculate the sound levels at the boundaries of the solar project. The model below was given by Solli Engineering in their report on a proposed solar project in Connecticut.

$$L_b = L_a - 20 \times log_{10}(\frac{D_b}{D_a})$$

Where:
L_b = Noise level at new distance (dBA)
L_a = Noise level at original distance (dBA)
D_b = New distance from source of noise (meters)
D_a = Original distance from source of noise (meters)

To add multiple sound levels of different strength, the following equation was used:

$$L_t = 10log_{10}(\sum 10^{\frac{L_b}{10}})$$

Using this model results in a 6 dBA decrease in sound levels each time the distance doubles.

For the purposes of this study, the noise level of the largest step-up transformer listed in the NEMA TR-1 was taken to be 63 dBA at 0.3 m, which corresponds to 52.5 dBA at 1 m. The substation transformer was assumed to have the largest noise level of those listed in NEMA TR-1, which is 91 dBA at 0.3 m, which would be equivalent to 80.5 dBA at 1 m. These estimates are very conservative, since actual transformers often operate about 10 dB below the NEMA TR-1 limits and the worst case is considered. It was assumed that the central inverters for the project would be similar in kind to the SMA 4 MW inverter, which has a sound rating of 65 dBA at 10 m, which is equivalent to 85 dBA at 1 m, or the ABB 3.3 MW inverter, which has a rating of 88 dBA at 1 m, according to their respective spec sheets. The higher value of 88 dBA was used for the calculations of minimum distance to the property line. Because the central inverters will be scattered around the property, and since combined sounds from multiple sources do not increase the overall sound levels by a large amount, a further simplifying assumption was made to consider only the one central inverter closest to a property line. Based on those assumptions, the following chart was generated.

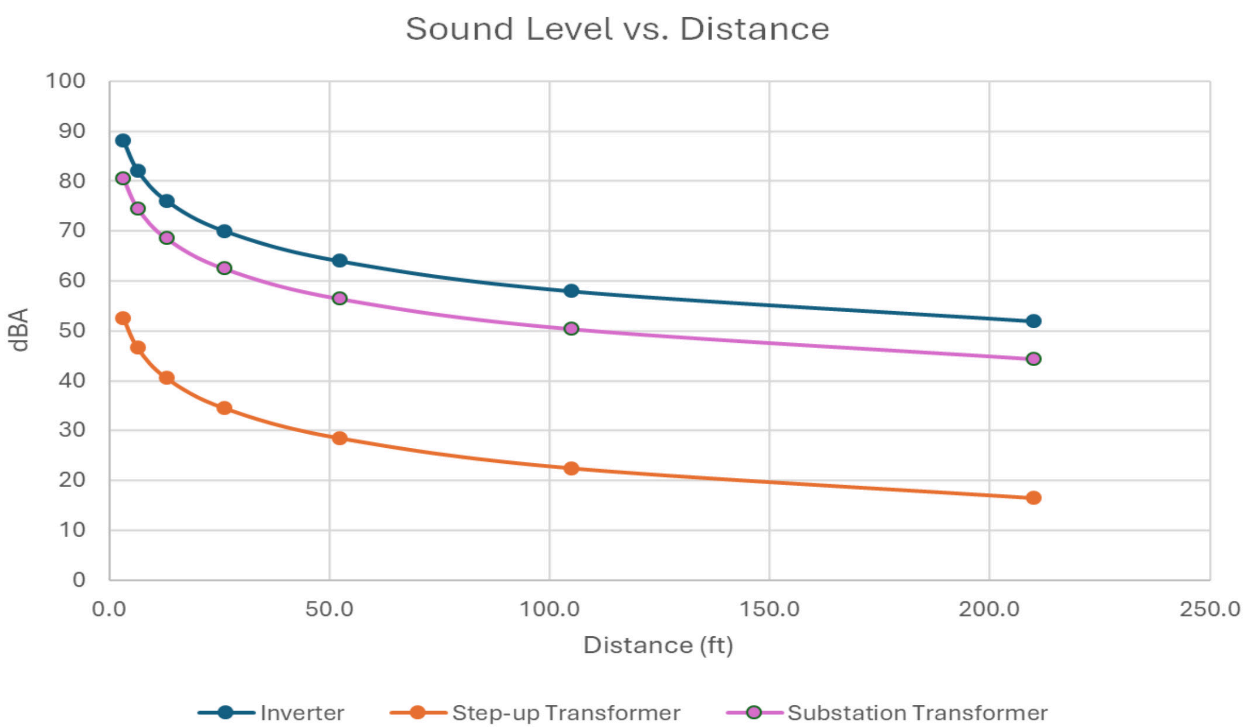

Figure 4 – Sound Level vs. Distance for Solar Equipment

Based on those calculations, it was found that the central inverter would need to be located no less than 147 feet from neighboring properties to remain below the 55 dBA daytime limit. The substation transformer should be located at least 196 feet from neighboring properties to remain below the 45 dBA limit for nighttime use, while the step-up transformers only need to be located approximately 8 feet away. These distances would almost certainly vary depending on the specific solar project being considered, but since the highest noise rating for each type of equpment was assumed, and since the fairly conservative EPA noise guidance was used, the distances generated should also be considered fairly conservative, meaning that the distances could be less for a particular solar project.

Summary and Conclusion

In general, noise from solar power generation facilities is not a significant problem, but it is one of several environmental impact factors that should be considered when designing and permitting a solar project. The primary sources of noise in a solar power generation facility are the inverters and the transformers. The step-up transformers located within the solar facility are so quiet that they will not normally be an issue compared to the central inverters and substation transformers. Based on a simplified analysis using conservative noise ratings for solar equipment and the EPA guidance, central inverters should be located at least 147 feet away from neighboring properties to remain below 55 dBA during the day, while substation transformers should be located at least 196 feet away to remain below 45 dBA at night. If the layout of a particular project prevents these distances from being observed, other sound mitigation measures, such as sound barriers can be employed.

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