Noise Measurement and Analysis Results

for the

Luning Solar Energy Center

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1. Introduction

This report provides a description of the results of the noise measurements and analyses conducted at the Luning Solar Energy Center (Facility). The purpose of these measurements and analyses is to provide information to support the analysis of predicted noise levels from future solar energy projects. There have not been any noise complaints or regulatory noise concerns regarding this Facility. The Facility is a solar photovoltaic electric generation facility and has an installed capacity of up to 55 MW. It is located in west-central Nevada, about 110 miles southeast of Reno, Nevada near Luning, Nevada, as shown in Figure 1-1.

The first set of noise measurements was conducted close to a representative inverter, the Facility's step-up transformer, and a tracking motor to define the level and frequency characteristics of the noise emissions from each of these sources. This measurement data was used to calculate the sound power levels of each source. The second set of noise measurements consisted of two noise monitors continuously logging noise levels at the fence line of the Facility for approximately two weeks in order to determine noise emissions from the Facility as a whole. Finally, an acoustic model of the Facility was created using the sound power levels. The model was used to predict Facility noise levels at the monitoring locations, and the results of this were used to adjust the model so that predicted and measured noise levels were in agreement.

The following sections provide a description of the Facility's primary noise sources and their locations, the results of the noise measurements, the results of the noise model validation, and a summary of the findings from the noise analyses.

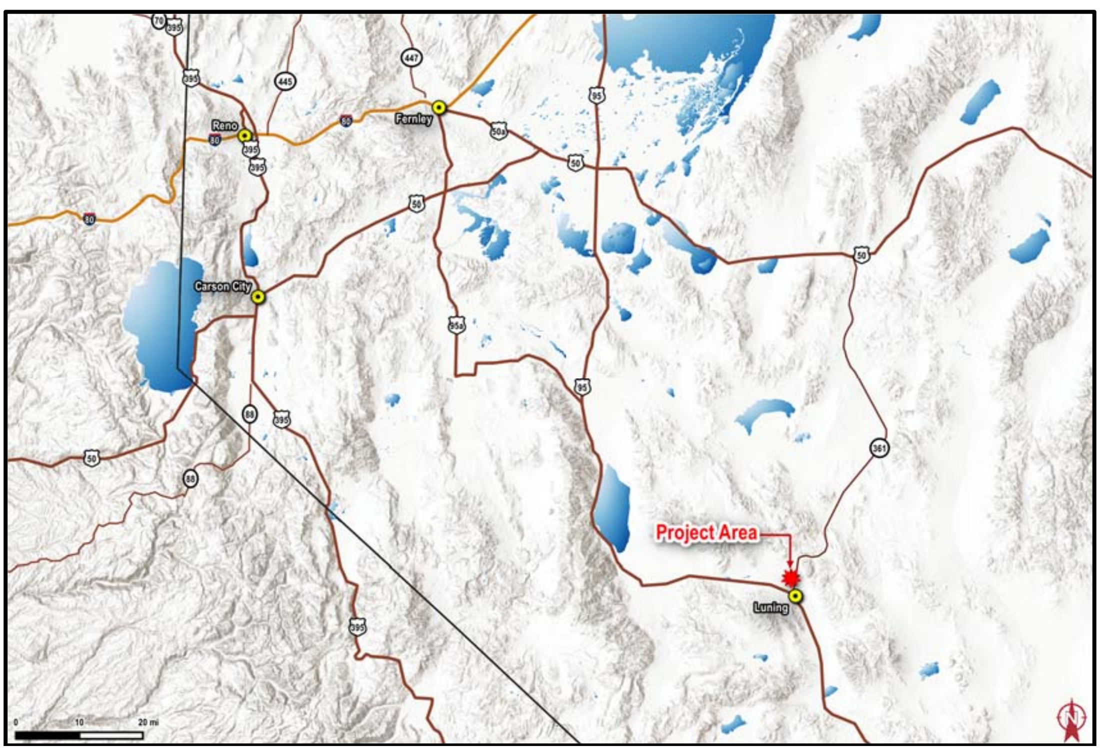

Figure 1-1. General Location of the Project

2. Description of Noise Sources

The primary sources of noise from the Facility include the solar inverters and the Facility's step-up transformer located at the substation. A secondary source of noise is the solar tracking motors. The following provides a description of each.

Solar Inverters

This Facility uses 22 SMA Sunny Central 2500-EV model solar inverters that convert the variable direct current (DC) output of the solar panels into alternating current (AC) for transmission to the grid. These inverters are spread throughout the site, but are generally located in the middle of the Facility and not near the property line. At this Facility, most of the inverters are arranged in adjacent pairs. Each inverter is connected to its own transformer. The primary sources of noise from the inverter are the cooling system and internal switching circuitry. More specifically, a majority of the noise emanates from the intake vent located about six feet above the ground on one of the long sides and the exhaust vent located about two feet above the ground on one of the short sides. When operational, the inverter emits a constant high-pitch tone, as well as fan noise from the cooling system (which cycles on and off depending on temperature). Figure 2-1 provides photographs of one of the inverters with the sources of noise identified.

Figure 2-1. Photographs of Solar Inverter

Solar Tracking Motors

At the Facility, solar tracking is accomplished using a combination of motors and long linkages that allow one motor to rotate several rows of panels. Each of the motors (SunLink ViaSol Single-Axis Tracker using Baldor 3 HP units) are enclosed inside a metal housing that sits about three feet off the ground. Figure 2-2 provides photographs of the motor housing and one of the motors inside the housing. The motors slowly rotate the panels approximately two degrees every five minutes with each rotation taking less than ten seconds to complete. The enclosed motor is not a significant noise source, particularly at off-site receivers. There is also some noise generated by friction within the metal linkages, but this too is not significant off-site.

Figure 2-2. Photographs of a Solar Tracking Motor

Substation

This Facility connects to the existing Table Mountain Substation located southeast of the site via a 120 kilovolt power line. The only significant source of noise is the 55 megavolt-ampere step-up transformer that increases the voltage from that produced by the Facility to that required by the grid. Noise from the transformer consists of a constant hum, with a primary frequency of 120 Hertz. Also audible is noise from cooling fans, which cycle on and off with temperature. Figure 2-3 provides a photograph of the substation from one of the noise measurement positions.

Figure 2-3. Photograph of the Table Mountain Substation

3. Noise Measurement Results

This section describes the noise level measurement results. In April 2019, noise levels were measured close to each source within the Facility, as well as at the fence line.

Solar Inverters

Noise measurements were conducted around Inverter 22, which was isolated by itself whereas most other inverters were installed as pairs in close proximity to each other. Each inverter is connected to a transformer, which was found to be largely silent. A majority of the noise emitted by the inverter is generated by the internal switching circuitry and cooling fans. This noise emanates through the exhaust and intake vents located on different sides of the inverter. Note, up close to the unit (within ~100 feet), a constant tonal noise from the internal switching components and cooling fans is audible. However, this tonal noise is not discernable at the fence line (or beyond), located more than 500 feet from the unit.

Figure 3-1. Schematic of an Inverter and Transformer (top view)

Noise measurements were conducted around all four sides (intake, exhaust, solid panel, and transformer - see Figure 3-1). Noise levels were measured at distances from the unit ranging from a few feet to 108 feet away. Figure 3-2 shows the measured one-third octave band sound pressure levels measured at a distance of 50 feet from different sides of the inverter/transformer. The measurements at 50 feet clearly show the spectral content of the noise emissions. As can be seen, the exhaust and intake sides are the loudest. Noise levels on the solid panel and transformer sides are roughly 10 dBA quieter. All results shown are with the cooling fans on. When the fans are off noise levels drop by approximately 20 dBA along the intake side, 13 dBA along the exhaust side, and 11 dBA along the solid panel and transformer sides.

Table 3-1 lists the sound pressure levels measured 108 feet from the exhaust and intake sides of the unit. The measurement data taken at 108 feet were used in this analysis because they are most indicative of the amount of noise propagating away from the inverter, which is the purpose of this study.

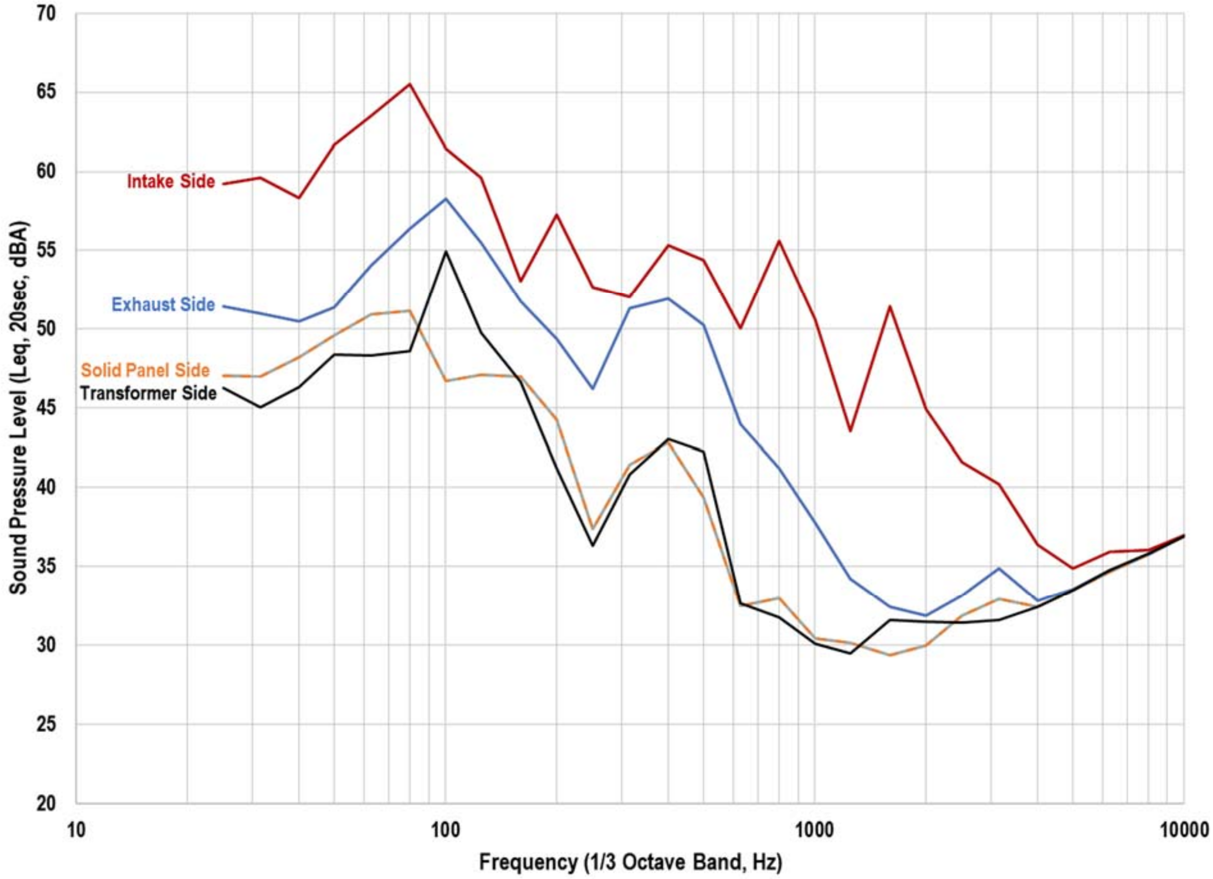

Figure 3-2. Noise Levels Measured 50 feet from Solar Inverter

Table 3-1 – Measured Sound Pressure Levels of Equipment

Equipment	Distance (feet)	Octave Band Center Frequency (dB)									Overall (dBA)
		31.5	63	125	250	500	1000	2000	4000	8000	
Inverter Intake	108	58	62	58	54	58	47	43	39	41	56
Inverter Exhaust	108	56	59	61	54	55	43	37	39	41	53
Solar Tracking Motor	3	56	41	43	45	45	44	44	37	37	68
55 MVA Step-Up Transformer	300	45	44	42	37	37	35	31	34	37	42

Tracking Motor

Noise levels were measured three feet from a solar tracking motor while in operation. The solar tracker operates for approximately seven seconds every five minutes. A plot of the noise levels measured at a distance of three feet over the course of one operational cycle is shown in Figure 3-3. The maximum noise level is 68 dBA. The spectral content of this measurement is listed in Table 3-1. In general, tracking motors are not a prominent source of noise from solar facilities. The maximum measured noise level of 68 dBA at a distance of 3 feet translates into a level of about 20 dBA at a distance of 500 feet (approximate distance to the fence line of this or likely any solar facility). This would be inaudible. Furthermore, the level of 68 dBA only occurs for several seconds every five minutes. Even when one accounts for the fact that there are many such motors in a typical solar facility, there are only a limited number of them near any one receptor (e.g. a residence). Thus, we recommend not including tracking motor noise in future solar facility noise analyses. This will simplify the analyses and have no bearing on the results.

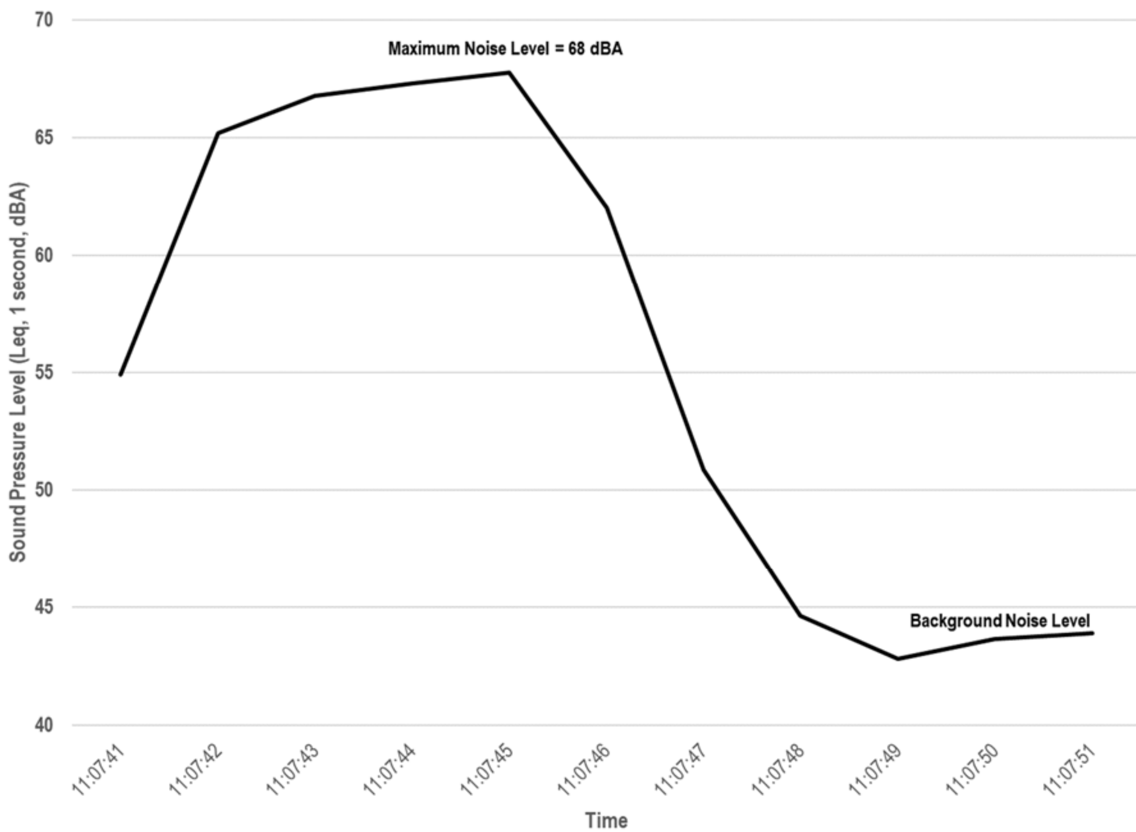

Figure 3-3. Noise Levels Three Feet from a Solar Tracking Motor

Step-up Transformer (Substation)

Noise from the operation of a 55 MVA step-up transformer and its associated cooling fans was measured in multiple directions and distances. The noise levels measured at the south side of the step-up transformer were almost 10 dB louder than those measured at the other sides, and are the only levels discussed herein (to provide for a worst-case analysis). Table 3-1 provides the sound pressure levels measured at a point 300 feet south of the step-up transformer. Figure 3-4 shows the one-third octave band sound pressure levels measured at a distance of 50 feet from the step-up transformer for both fans on and fans off.

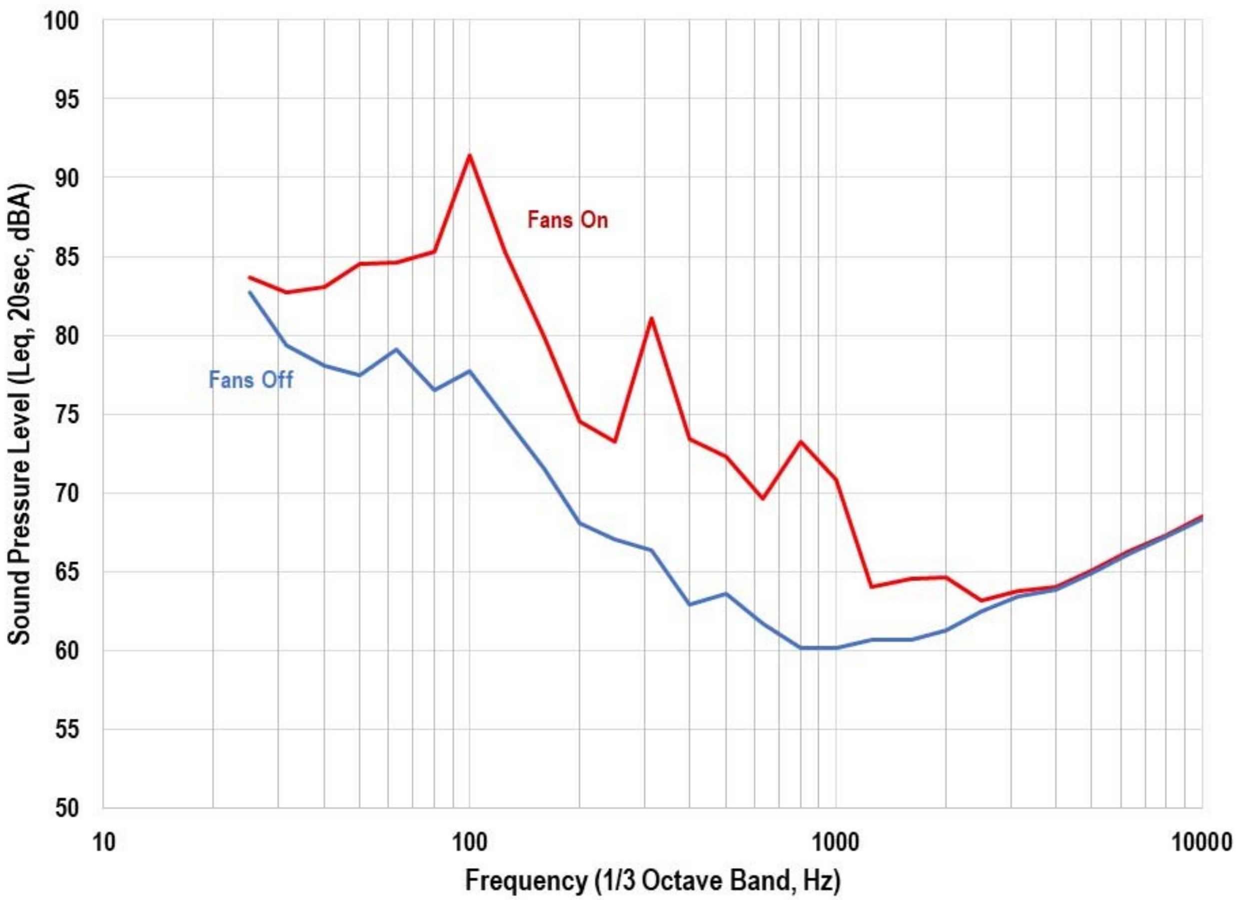

Figure 3-4. Noise Levels 50 Feet from the Step-up Transformer at the Substation

Fence Line Monitoring

Two noise monitors (M1 and M2) were placed along the fence line directly across from the nearest pair of inverters. M1 was located 635 feet from the nearest inverter intake. M2 was located 576 feet from the nearest inverter exhaust. There was a direct line of sight between each microphone and its nearest inverter. Photographs from each measurement position looking toward the nearest inverter are shown in Figure 3-5. The monitors were left to continuously measure noise levels for two weeks. In addition, the operational status of the Facility and onsite meteorological data were obtained from the Facility staff. Plots of the measured noise levels at M1 and M2 are shown in Figures 3-6 and 3-7, respectively. Shown are the 10-minute L_{90} noise levels (dBA). The L_{90} is the noise level that is exceeded 90% of the time and is representative of the constant noise in an environment. Thus, it is representative of the constant noise of the facility, while rejecting intermittent noise such as that from wind gusts, aircraft overflights, and vehicle pass bys.

Also shown in Figures 3-6 and 3-7 are the times when the two nearest inverters were fully operational and wind speeds were below 5 miles per hour (green shading). It is during these times that the measured noise level will be representative of noise from the facility only. Based on this data, it was found that the maximum measured noise levels from the Facility is 35 dBA at M1. At M2, it was found that the Facility produces 39 dBA for anywhere from only a few minutes to as long as two hours in the morning, the level decreases to the low 30's (dBA) during most of the day, and then there is another brief increase in the evening. The periods of louder levels may be due to the inverter itself (e.g. closing-in of the contactors during low sunlight conditions at the beginning and end of the day), differences in sound propagation and reflections with the changing positions of the panels throughout the day, or some other unknown phenomenon. Regardless, as discussed in the next section, this analysis used the loudest measured levels to produce a "worst-case" assessment.

Figure 3-5. Photographs from the Fence Line Measurement Locations

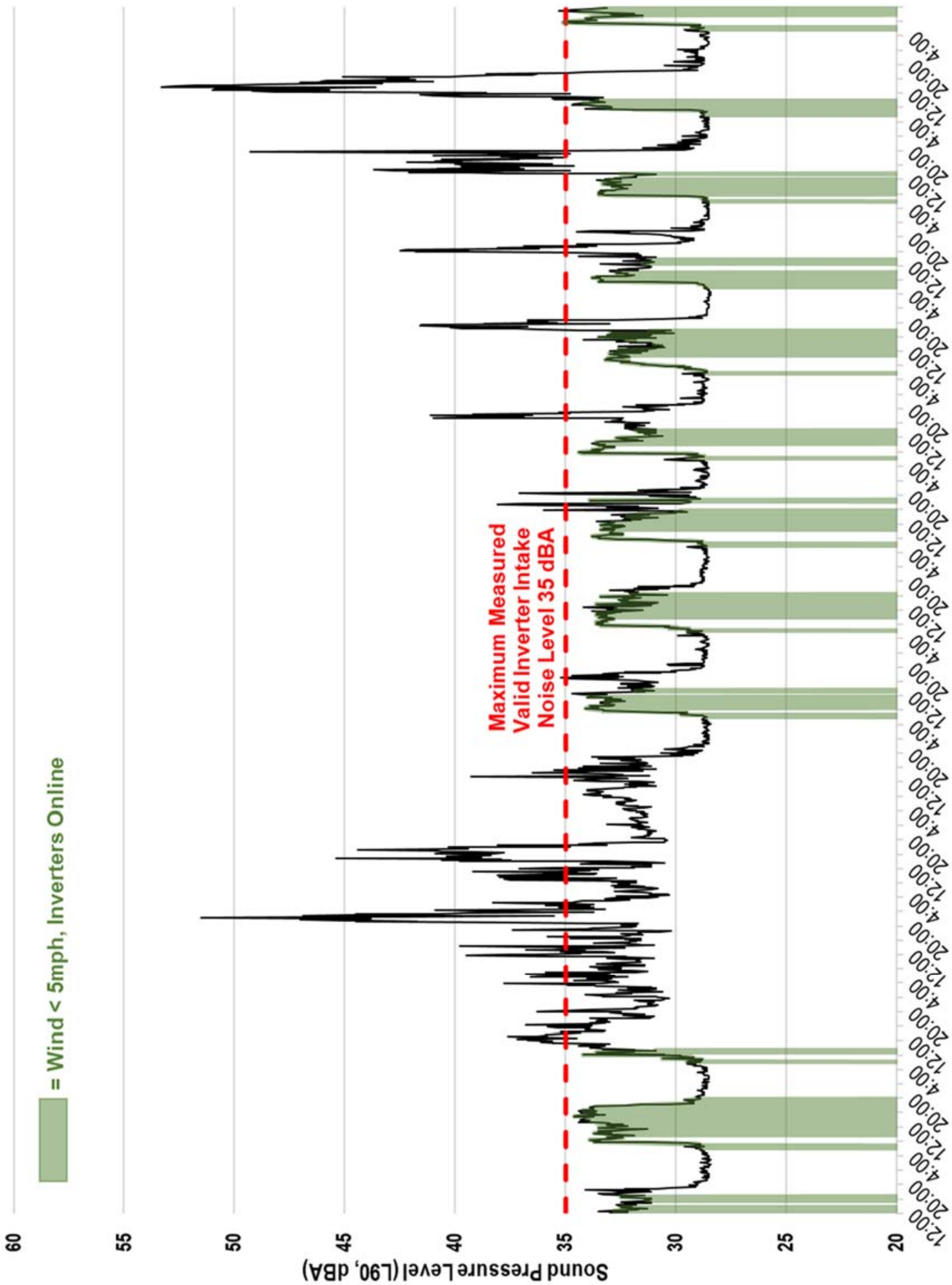

Figure 3-6. Measured Noise Level at M1 at 635 feet from Inverter Intake

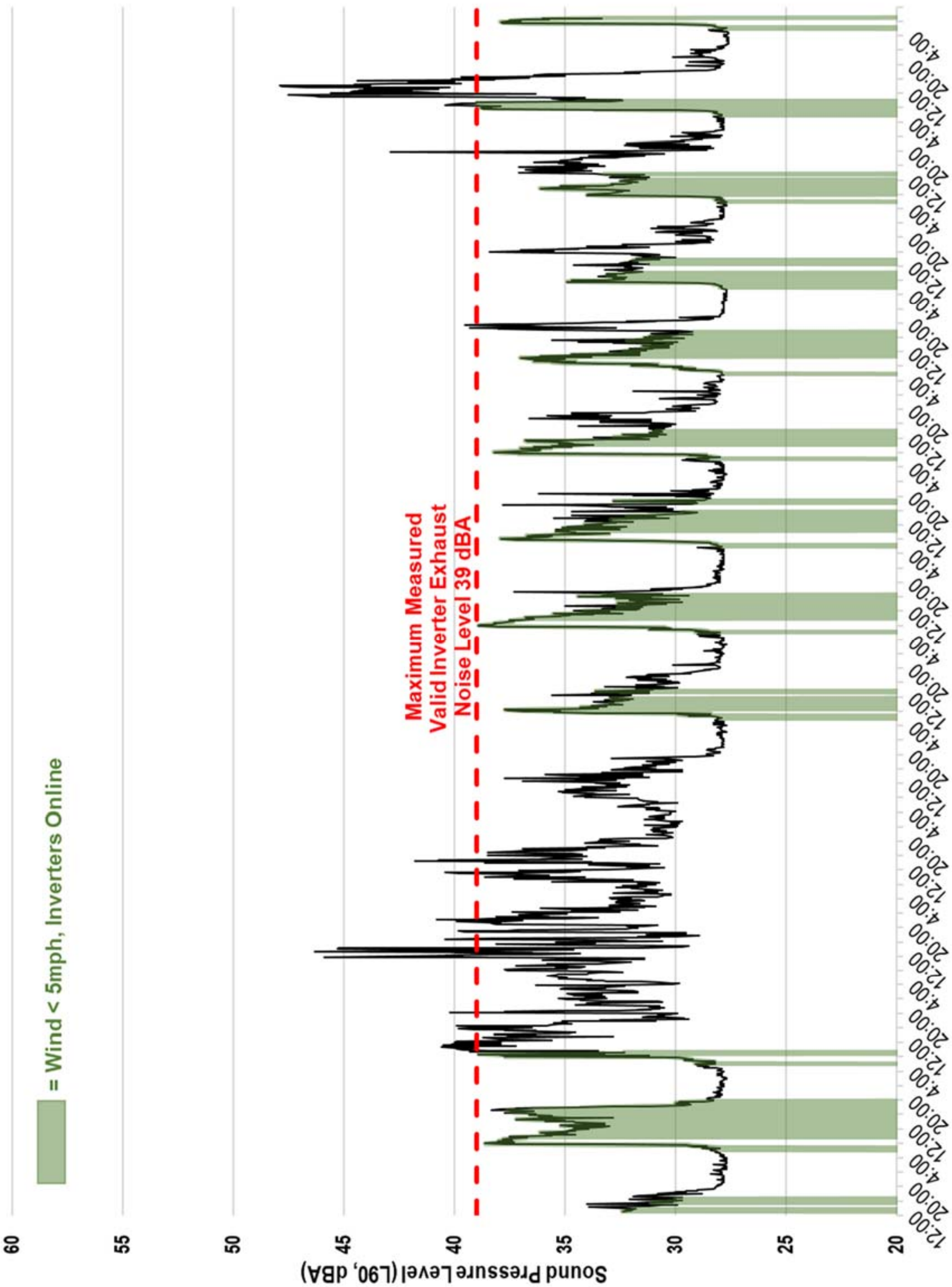

Figure 3-7. Measured Noise Level at M2 at 576 feet from Inverter Exhaust

4. Noise Model Validation Results

Noise levels from the Facility were predicted using the International Organization for Standardization (ISO) Standard 9613-2:1996, *Attenuation of Sound During Propagation Outdoors - Part 2: General method of calculation*, for comparison to measured levels. The calculations were implemented using the SoundPLAN v8.1 acoustical modeling software program. Described below are the input data and assumptions used in the model. The ISO method assumes optimal acoustic propagation in all directions, specifically that a "well-developed, moderate ground-based temperature inversion" is present or, equivalently, that all receptors are downwind of all noise sources at all times.

Noise Model Settings

Figure 4-1 provides a plan view of the SoundPLAN model for this Facility, which includes all 22 solar inverters and the step-up transformer. Each source was represented by a "point source" in the model. The inverters were located 6.6 feet above the ground and the step-up transformer was located 9.8 feet above the ground. Ground elevations were taken from the Digital Elevation Model from the U.S. Geological Survey National Elevation Dataset. The source power levels for each piece of equipment are listed in Table 4-1, which were calculated using the noise levels measured close to each source (from Table 3-1). No solar tracking motors were included in the noise prediction model, as their influence on fence line noise levels is insignificant. No barriers were modeled, even though some of the solar panels act as such in the direction of the prediction points. The modeling of barriers would add unnecessary complexity to this and any future noise models.

The ground factor was set to 0.5, which represents partially absorptive ground. The air temperature, relative humidity, and atmospheric pressure were set to standard-day conditions of 10°C, 70%, and 1 atmosphere, respectively. Per ISO 9613-2:1996, these values may not match local conditions, but more importantly, they result in the least amount of atmospheric sound absorption and the highest levels of sound reaching the receivers. Prediction points (receptors) were located at the two measurement locations near the solar array (M1 and M2) and 300 feet from the substation (M3), as shown in Figure 4-1. In accordance with ISO 9613-2:1996, the height above the ground for each receptor was set to 5 feet, consistent with the actual measurement height.

Table 4-1 – Sound Power Levels Based on Near-Field Measurements

Equipment	Octave Band Noise Levels (dB)									Overall (dBA)
	31.5	63	125	250	500	1000	2000	4000	8000	
Inverter Intake	96	100	96	92	96	85	81	77	79	94
Inverter Exhaust	93	96	98	91	92	80	74	76	78	92
Solar Tracking Motor	63	48	50	52	52	51	51	44	44	75
55 MVA Step-Up Transformer	92	90	88	83	84	81	78	81	84	89

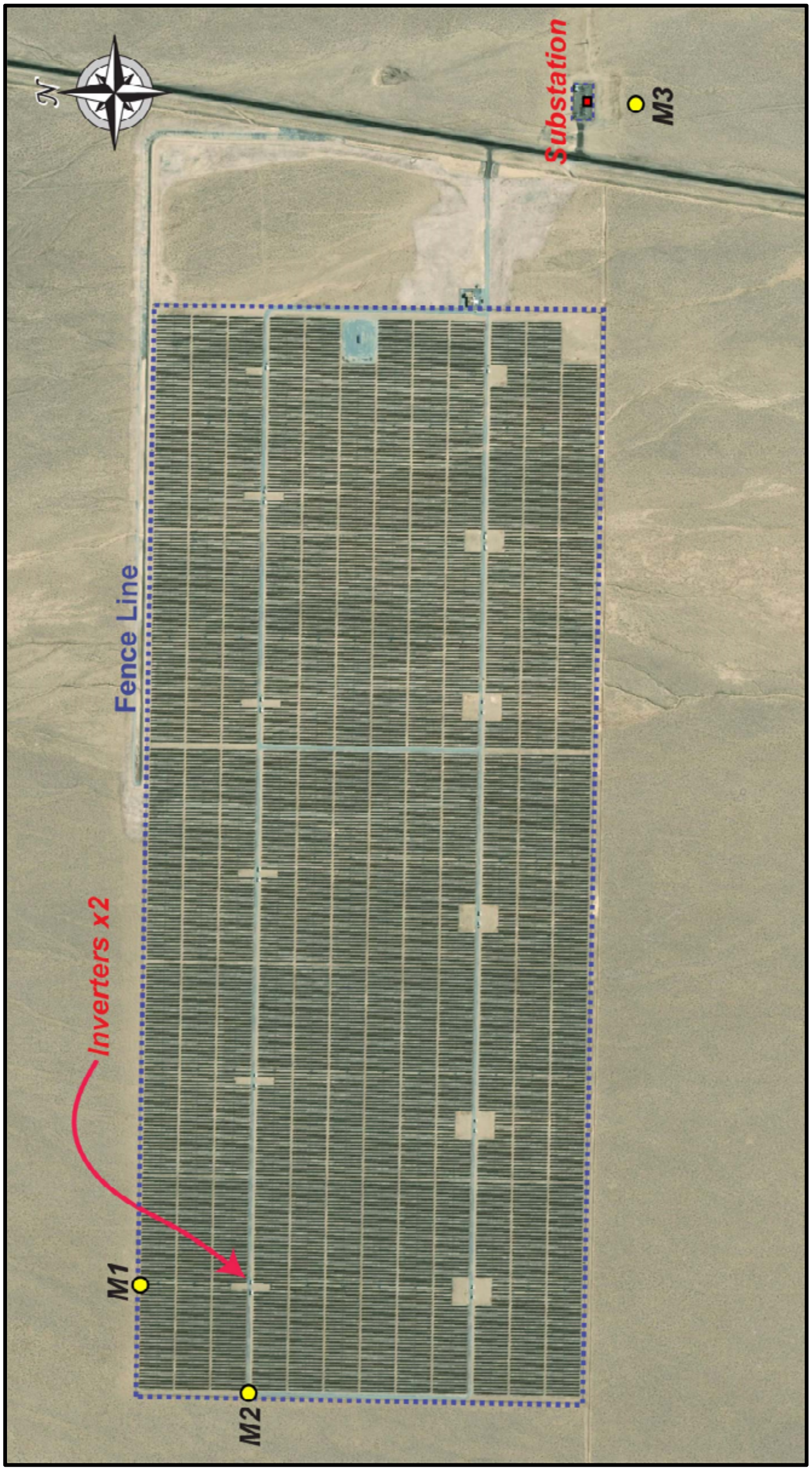

Figure 4-1. SoundPLAN Noise Model Validation Layout

Results

Table 4-2 shows the results of the predictions and a comparison of predicted and measured noise levels. As shown, at M1 (intake) the model is overpredicting by 4 dBA, at M2 (exhaust) the model is underpredicting by 1 dBA, and at M3 (step-up transformer) the model is underpredicting by 4 dBA. Based on these results, we recommend adjusting the sound power levels of the equipment for use in future modeling using this inverter. That is, we recommend that the intake sound power levels be adjusted downward by 4 dB and the solar inverter exhaust levels be adjusted upward by 1 dB. The resulting inverter sound power levels recommended for use in future modeling are shown in Table 4-3. Given the conservative nature of this analysis (worst-case), we recommend using the intake sound power levels for permitting. These will provide a reasonable estimate of expected noise levels. We recommend using the exhaust sound power levels for design purposes. In doing so a 3 dB "design margin" is provided.

With regard to the transformer, on this project the transformer sound power levels need to be adjusted upward by 4 dB to match the 300-foot measurement results. The resulting sound power levels are listed in Table 4-3. However, this is just one measurement at one site. For modeling of transformer noise on future projects, we recommend the continued use of the prediction method specified by the Edison Electric Institute report *Electric Power Plant Environmental Noise Guide* (1984). That method uses the megavolt-ampere (MVA) rating of the transformer and its physical size.

Table 4-2 – Comparison of Measured Worst-Case Noise Levels with Predicted Noise Levels

Location	Measured Noise Level (dBA)	Predicted Noise Level (dBA)	Predicted minus Measured (dBA)
M1 (Intake Source)	35	39	+4
M2 (Exhaust Source)	39	38	-1
M3 (55 MVA Step-up Transformer)	42	38	-4

Table 4-3 – Sound Power Levels Validated Based on Fence Line Measurements

Equipment	Octave Band Noise Level (dB)									Overall (dBA)
	31.5	63	125	250	500	1000	2000	4000	8000	
SMA 2500 EV Inverter (Intake)	92	96	92	88	92	81	77	73	75	90
SMA 2500 EV Inverter (Exhaust)	94	97	99	92	93	81	75	77	79	93
55 MVA Step-Up Transformer	96	94	92	87	88	85	82	85	88	93

5. Conclusions

Noise emissions from the Facility, which primarily include that from SMA Sunny Central 2500-EV model solar inverters, are very low. Noise levels do not exceed 40 dBA at the fence-line. Noise emissions are generated by the cooling fans and by the electronic switching equipment located inside the inverter unit, with the latter being somewhat tonal. Noise emissions are greatest on the sides of the unit containing the intake and exhaust air vents. Approximately 7 dB of additional noise was measured along the fence line in the early morning and late evening hours for reasons not fully understood, but possibly related to closing-in of the contactors in low light conditions or differences in sound propagation and reflection due to the changing position of the solar panels.

Noise from tracking motors, which operate only occasionally, was measured and found to be insignificant. Tracking motor noise levels had to be measured at a close distance (3 feet), because at further distances they were inaudible in the presence of noise from the inverters and from other background sources. Noise levels from the step-up transformer located at the Facility's substation were measured and found to be very consistent with those measured on other projects.

A software model of noise from the Facility's sources was generated. The model initially used sound power levels based on the field measurements conducted close to each source. The model was used to predict Facility noise levels at the fence-line measurement locations. It was found that the model over-predicted at one long-term measurement location and under-predicted at the other, when compared to measured maximum Facility noise levels. Based on this, the sound power levels were adjusted such that there was perfect agreement between predicted and measured Facility noise levels. The result of this analysis is a set of sound power levels, which when used with a relatively simple ISO 9613-2:1996 model of the Facility, accurately predict the loudest noise levels the Facility will generate. There is no need to model the effect of solar panels acting as barriers, and no need to include tracking motor noise. These effects have been taken into account in the validation of the model where predicted noise levels were compared to measured noise levels which included the effect of barriers and tracking motors. Also, the model should use a ground factor of 0.5.

This model can be used to predict noise levels at future solar energy projects. We recommend the use of the inverter intake sound power level when modeling during pre-construction for the purpose of permitting. However, in order to provide a design margin, we recommend that the louder inverter exhaust sound power level be used internally. With regard to primary step-up transformers, we recommend the continued use of the prediction method specified by the Edison Electric Institute report *Electric Power Plant Environmental Noise Guide* (1984). That method uses the megavolt-ampere (MVA) rating of the transformer and its physical size.