Anatomy of a Quiet Power Plant

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Details of noise control design are presented for a recent power plant expansion project that involved adding heat-recovery steam generation to a gas-fired power plant in the U.S. The project, including its expansion, was subject to a 45-dBA nighttime property boundary sound level limit. The development and coordination of noise control design for large and small equipment packages, some of which would be located within several meters of the property boundary, are discussed in detail. Sound level measurements are presented and discussed, particularly with regard to the challenges involved with conducting sound level measurements in the presence of ambient sound levels that often approached the allowable noise limit.

A recent power plant expansion involved adding heat-recovery steam generators (HRSGs) to two simple-cycle combustion turbines at an existing power plant facility in the United States. The expansion included adding HRSG units to each combustion turbine, an indoor steam turbine generator (STG) unit, an air-cooled condenser (ACC) unit, and various supporting equipment packages (pumps, blowers, control valves, transformers, etc.). The existing facility was subject to a property boundary sound level limit of 55 dBA during daytime hours and 45 dBA during nighttime hours in accordance with state noise limits for a residential boundary. Some existing equipment was situated within 15 meters (50 feet) of the north property boundary. The expansion equipment would be situated similarly, and the entire expanded facility would be subject to the same property boundary sound level limits.

Background

The two simple-cycle combustion turbines that would be expanded to combined-cycle operation are shown on Figure 1 relative to the facility property boundary. The combined-cycle equipment, installed in 2008 and 2009, is also shown. In accordance with the state noise regulations, the facility is subject to residential noise limits at the facility property boundary, specifically, 55 dBA during the day (7 a.m.-10 p.m.) and 45 dBA during the night (10 p.m. -7 a.m.). Due to the arrangement of the site for both the original simple-cycle and the retrofitted combined-cycle equipment, sound level measurements and noise mitigation design focused on the portion of the northwest, north, and northeast property boundaries shown on Figure 1. To support combined-cycle facility acoustical design, property boundary sound levels were examined along the entire portion of the boundary shown on Figure 1 and at specific locations as necessary.

Simple-Cycle Sound Levels. Measurements by the author and by other consultants confirmed the noise contribution of the simple-cycle facility. Sound levels were generally compliant with the daytime and nighttime limits for most of the property boundary. At 11 locations along the portion of the north property boundary shown on Figure 1, the author measured an average nighttime sound level of 43 dBA during simple-cycle operation.

Background Sound Levels. The facility is located approximately 1500 meters (1 mile) from a major airport and approximately 122 meters (400 feet) from a major local highway, both of which are significant sources of daytime background noise. Daytime sound level measurements of facility noise were not practicable because of the airport activity and highway traffic. Since the facility was being designed to meet the nighttime sound level limit of 45 dBA, the plant was generally inaudible along most of the property boundary during the day. For reference, typical daytime sound levels along the west boundary, closest to the highway and airport were generally 50 to 55 dBA. With an average simple-cycle facility sound level of 43 dBA, daytime background sound levels were typically at least 7 dBA above the facility noise.

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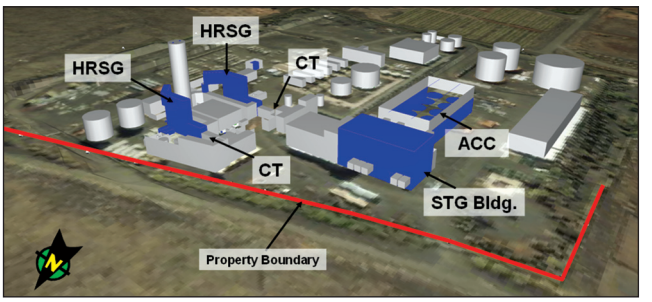

Figure 1. Facility setup relative to property boundary.

Airport activity was generally lower during the nighttime hours, which provided a good window of opportunity for measuring facility sound levels. However, care was still exercised because of wind conditions. The facility property boundary has significant areas of heavy vegetation. With no breeze, the average background sound level at the property boundary (without the facility in operation) was approximately 34 dBA. Even a slight (less than 3 m/s) breeze would raise the average background sound level along the property boundary to approximately 42 dBA. Therefore, careful data analysis was required to ensure that the operational sound level measurements were being conducted under similar wind conditions to the background sound level measurements at the same locations. To properly quantify the operational sound levels in some cases, different background sound level corrections at different locations were required because of the different prevailing wind conditions.

Combined-Cycle Acoustical Design

As noted above, the combined-cycle expansion required adding two HRSG units, an indoor STG unit, an ACC, and various ancillary supporting equipment packages. To ensure the nighttime sound level limit would be met during combined-cycle operation, noise mitigation measures were developed for major and ancillary equipment packages.

Heat Recovery Steam Generation Equipment. Each HRSG unit was rated to meet a sound level of 33 to 39 dBA at a distance of 30 meters (100 feet), which was in accordance with the project requirements. Additional equipment provided by the HRSG supplier included ammonia blower packages (one for each HRSG unit), as well as some control valves and the boiler feed pumps. Noise mitigation for some HRSG components was accomplished by choosing locations where the noise contribution at the property boundary would be minimal. In addition, some noisier components were placed indoors when possible. For example, the HRSG blowdown tank, often a significant source of noise during plant startup, was erected inside the STG building as opposed to its more typical outdoor location directly beside the HRSGs. The ammonia blower packages were situated outdoors, relatively close to the HRSG units. For the north HRSG, the ammonia blower package was situated approximately 20 meters (65 feet) from the north boundary. To minimize its noise contribution at the northern property boundary, a partial enclosure was erected around the ammonia blower package, as shown on Figure 2. The entire package, including the enclosure, was rated to meet a sound level of 48 dBA at a distance of 1 meter (3 feet) from the sides of the enclosure.

Indoor Steam Turbine Generator. Since the STG was to be located indoors, no special noise mitigation measures were required. Instead, noise emissions from the STG would be controlled within the building. The STG was rated to meet a sound level of 88 dBA at a distance of 1 meter (3 feet). Since the STG building would be 20 meters (65 feet) from the north boundary, both the building wall, roof panels and the ventilation system required substantial noise mitigation. The wall and roof panels were provided with an STC-54 rating. The building doors were provided with an STC-38 rating.

Figure 2. Ammonia blower skid acoustical enclosure.

Figure 3. STG building ventilation acoustical hoods.

Figure 4. Air-cooled condenser inlet acoustical baffles.

The building ventilation system consisted of building wall fan openings to provide inlet air and exhaust louvers. The building wall fans were provided with a sound power level rating of 99 dBA. As a result, the wall fan noise emissions and the STG emissions from inside the building needed to be attenuated prior to exiting the STG building via openings in the north and south walls. Acoustical hoods were provided for each opening, as shown on Figure 3. Each hood consisted of a dynamic silencer and an acoustically lined elbow and was rated to provide 20 to 45 dB of dynamic insertion loss (DIL) in octave bands from 63 to 8,000 Hz.

Air-Cooled Condenser. The ACC was the largest combined-cycle equipment package and located outdoors south of the STG building. The primary sources of noise from the ACC were fans, motors, and gearboxes. Although some shielding was provided by the STG building, ACC noise was still a concern along the west property boundary, which is approximately 51 meters (166 feet) from the ACC. The ACC was rated to meet a sound level of 41 dBA at 51 meters (166 feet). Noise mitigation for the ACC was accomplished by using large sound-attenuating baffles for the inlet and discharge of the ACC. Figure 4 shows the inlet (vertical) baffles placed from grade up to the ACC wind wall. A similar baffle arrangement was used horizontally along the top (discharge) of the unit.

Other Noise Sources. Other noise sources, which are often considered "secondary" or even "tertiary" power plant noise sources for typical projects, were found to require noise mitigation to ensure

Figure 5. Various facility noise mitigation measures: (a) lube oil cooler acoustical barrier; (b) steam bypass silencer.

that the nighttime property boundary limit would be met. These sources included steam turbine lube oil coolers (LOCs), boiler feed pumps (BFPs), the generator step-up transformer (GSUT), and various pumps, blowers, valves, and vents. The LOCs, BFPs, and GSUT noise emissions were controlled with enclosures and/or barrier walls, some examples of which are shown on Figure 5. Valves and vents were specified to be inherently quiet or otherwise fitted with silencers. For example, the large steam-bypass silencer shown in Figure 5b.

Combined-Cycle Sound Levels. Following combined-cycle commercial operation, which was achieved in 2009, property boundary sound level measurements were conducted to verify the acoustical design. The property boundary sound levels during combined-cycle operation were found to be generally consistent with the 45-dBA nighttime limit.

Conclusions

It was challenging to design the expansion so that the entire completed facility met the nighttime property boundary sound level limits. Considering the short distances involved, the simple-cycle sound levels along the north boundary approached the nighttime limit at a number of locations. Therefore, very little "acoustical budget" for the combined-cycle equipment noise emissions was available at some locations. Finally, major equipment packages, such as the HRSGs and the ACC, had to be provided with very low noise emissions ratings – much lower than is typical for a combined-cycle power plant. For example, a typical, unmitigated ACC for a plant this size might have a rated sound level of 55 dBA at 122 meters (400 feet), which would have been approximately 20 dB too high for this project. Considering the typical noise emissions from these types of power plants, this particular combined-cycle facility is impressively quiet. SV

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