Sound Assessment Study

Eversource

Barbour Hill Substation
Project No. 90026

October 14, 2016

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prepared for

Eversource
Barbour Hill Substation
South Windsor, Connecticut

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October 14, 2016

prepared by

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LIST OF ABBREVIATIONS

Abbreviation	**Term/Phrase/Name**
ANSI	American National Standards Institute
Burns & McDonnell	Burns & McDonnell Engineering Company, Inc.
CSC	Connecticut Siting Council
dB	decibels
dBA	A-weighted decibels
Eversource	Eversource Energy
Hz	hertz
IEEE	Institute of Electrical and Electronics Engineers
kV	kilovolt
MVA	mega-volt amperes
Substation	Barbour Hill Substation

1.0 EXECUTIVE SUMMARY

In February, 2015, Eversource filed a Petition with the Connecticut Siting Council (CSC) to, among other things, add an additional transformer bank comprised of three, single-phase 345-kilovolt (kV) to 115-kV autotransformers. In April, 2015, the CSC approved the Petition. Construction began in May, 2015.

The Barbour Hill Substation now consists of two sets of three, single-phase autotransformers (1x and 2x units); four smaller, three-phase distribution transformers; circuit breakers; and switchyard equipment (Substation). In support of the additional autotransformer Eversource commissioned Burns & McDonnell Engineering Company, Inc. (Burns & McDonnell) to conduct an environmental sound assessment study for the Barbour Hill Substation.

The objective of the Burns & McDonnell work has been two fold – to prepare a sound study to be used in support of the CSC filing as well as to measure operational noise levels in and around the Substation once the autotransformers were installed to determine if the Substation exceeds the State or local noise regulations.

Both the State of Connecticut and the Town of South Windsor have regulations which define and govern permissible sound levels. The Town of South Windsor's regulations are similar to those defined by the State of Connecticut in Control of Noise Section 22a-69-3. Meeting the limits defined by the State of Connecticut will also satisfy the Town of South Windsor regulation.

Pursuant to the Burns and McDonnell environmental sound assessment, continuous sound monitoring was conducted during multiple time periods for a total of 125 days under various operating conditions. The Sound monitoring that took place from January 26 to February 16, 2016, measured sound with both the 1x and the 2x autotransformers in service but without the anti-vibration pads having been installed under the 1x autotransformer. The sound monitoring that took place from May 10 to June 21, 2016, measured the sound of the 2x while the 1x was out of service to accommodate the installation of the anti-vibration pads. The final round of sound monitoring took place from June 21 to August 22, 2016, and measured both the 1x and 2x during what is typically the peak demand for electrical use. Sound levels collected at the property line measured dominant frequencies that were typical of those near an operational substation. The amount of data collected provides confidence that the generally loudest property line sound levels were captured during this study.

Measurements showed the sound levels of the single-phase autotransformers can vary significantly over time. The sound levels measured at different locations varied based on distance to the Substation, time of day, and amount of local roadway traffic. The Substation is audible at offsite locations during times of low background sound. When the autotransformers were operating normally, at their specified sound levels, the Substation was well below the applicable noise limits. However, during the autotransformer's short-duration peak sound levels, the Substation exceeded the State sound level limits on several occasions.

As a result of this occasional exceedance, various mitigation installations have been explored to determine ways to achieve compliance with the regulations at all times. A preliminary review of the available and feasible mitigation options shows full enclosures of the autotransformers may be the optimum solution to bring the Substation into full compliance with the applicable noise regulations. The following chapters provide background information and describe the study in further detail.

2.0 ACOUSTICAL TERMINOLOGY

The term “sound level” is often used to describe two different sound characteristics: sound power and sound pressure. Every source that produces sound has a sound power level. The sound power level is the acoustical energy emitted by a sound source and is an absolute number that is not affected by the surrounding environment. The acoustical energy produced by a source propagates through media as pressure fluctuations. These pressure fluctuations, also called sound pressure, are what human ears hear and microphones measure.

Sound is physically characterized by amplitude and frequency. The amplitude of sound is measured in decibels (dB) as the logarithmic ratio of a sound pressure to a reference sound pressure (20 microPascals). Sound waves can occur at many different wavelengths, also known as the frequency. Frequency is measured in hertz (Hz), and is the number of wave cycles per second that occur. The typical human ear can hear frequencies ranging from approximately 20 to 20,000 Hz. The A-weighting scale was developed to simulate the frequency response of the human ear to sounds at typical environmental levels.

Some sounds contain many frequencies while others contain a singular frequency, or groupings of frequencies, that stand out from adjacent frequencies. Those sounds that contain a singular frequency that is louder than the adjacent frequency bands are sometimes called prominent discrete tones or pure tones.

Sound can be analyzed for frequency components. These frequency components are described in the American National Standards Institute (ANSI) S1.11 and are commonly referred to as the octave band center frequency and the 1/3 octave band. The octave band is a set of frequencies used to describe a sound by lumping the entire spectrum of frequencies measured into specific frequency groups. These groups include any sound measured in any frequency, but the sound meter combines the discrete, adjacent frequencies together, as defined by ANSI.

A more detailed explanation of acoustical terminology, which is appropriate to this study, can be found in Appendix A.

3.0 APPLICABLE REGULATIONS

The regulation of noise falls within the responsibilities of the Connecticut Department of Environmental Protection and the Town of South Windsor. Both entities have applicable noise ordinances, as described below.

3.1 State of Connecticut Noise Regulations

The Connecticut regulation for the Control of Noise Section 22a-69-3 defines the allowable noise levels for the State of Connecticut. The regulation defines land that is generally industrial as a Class C noise zone, and land that is generally residential as a Class A noise zone. This regulation defines excessive noise from a Class C noise zone to a receiving Class A noise zone as sound levels in excess of 61 dBA during the day and 51 dBA at night, measured at the property line of the receiving property. The regulation defines nighttime as the hours between 10:00 P.M. and 7:00 A.M.

This regulation also includes a penalty for sources that emit prominent discrete tones. Prominent discrete tones are defined as the presence of acoustic energy concentrated in a narrow frequency range. Excessive noise is identified as any tone that, first, produces a 1/3 octave band sound-pressure level greater than that of either adjacent 1/3 octave band and, second, exceeds the arithmetic average of the two adjacent 1/3 octave-band levels by an amount greater than those listed in Section 22a-69-1.2(r). When prominent discrete tones are present, the daytime and nighttime sound level limits are reduced by 5 dBA. This changes the overall daytime and nighttime sound level limits for the Substation to 56 dBA and 46 dBA, respectively. Discrete tones at points with sound levels below these limits are not considered excessive noise under this regulation.

3.2 Town of South Windsor Noise Regulations

The Town of South Windsor Code of Ordinances, Chapter 50, Article III provides sound level limits for industrial properties adjacent to residential properties. The regulation states that noise emitted from an industrial zone beyond the boundary of the lot or parcel onto a residential zoned property shall not exceed a daytime limit of 61 dBA and a nighttime limit of 51 dBA. The regulation defines daytime hours as between 7:00 A.M. and 8:00 P.M. on every day but Sunday and the hours of 9:00 A.M. and 8:00 P.M. on Sundays. Nighttime hours are defined as between 8:00 PM and 7:00 AM each day from Sunday evening through Saturday morning and between 8:00 P.M. Saturday and 9:00 A.M. Sunday. The Town of South Windsor noise regulation does not address prominent discrete tones with a penalty as the Connecticut noise regulation does. Meeting the Connecticut noise regulation during nighttime hours will satisfy the Town of South Windsor noise ordinance.

4.0 FIELD MEASUREMENTS

Field measurements were taken to quantify sound levels in the area surrounding the Substation. The neighboring residents communicated that noise generated by the Substation reaches their houses and causes discomfort. In an effort to determine how sound generated at the Substation affects the neighboring properties, both near-field and far-field measurements were taken.

Near-field measurements are those taken close to the autotransformers. Near-field measurements reduce the influence of extraneous background sounds. Since the Substation is not operating in a controlled environment, it is nearly impossible to measure only the autotransformers' sound levels without significant isolation techniques that would potentially be unsafe for testing personnel. However, the near-field sound levels are considered generally representative of each piece of equipment's operational sound levels, as most background sounds have little influence this close to the autotransformers.

Far-field measurements are those taken outside the Substation fenceline. Far-field measurements are affected more by extraneous sources of sound than are near-field measurements, but they provide information on how sound potentially propagates outward from the Substation.

Five continuous, long-term sound monitors were installed at various locations in and around the substation to monitor sound during three multi-week time periods. One meter was placed 15 feet from the northern edge of the operational 1x autotransformer (Meter 1). This meter acted as a "control meter" for the 1x autotransformer since it was unlikely to be significantly affected by extraneous sounds. A second control meter was installed 15 feet from the northern edge of the 2x autotransformer (Meter 2). This meter acted as a control meter for the 2x autotransformer. Sound levels at the control meters were used as the basis for comparison to the offsite meters. Three other sound meters (Meter 3, Meter 4, and Meter 5) were installed at various locations along the Substation property line in the directions of the closest neighboring residences. Figure 4-1 shows the locations of the sound meters used for the study.

Figure 4-1: Continuous Monitoring Points

4.1 Noise Monitoring Summary

According to the Institute of Electrical and Electronics Engineers (IEEE) Standards C57.12.90 and C57.136, the principal sources of sound in transformers and autotransformers are the core sound and sound from cooling equipment. The core sound is caused by magnetostriction effects and inter-laminar magnetic forces. It is influenced by the flux density, core material, core geometry, and excitation voltage waveform. The sound from cooling equipment is generally caused by the cooling fans. The fan noise is influenced by the blade-tip speed, blade design, and number of fans. Pump noise is typically insignificant when fans are running. According to the autotransformer manufacturer sound level guarantee, the autotransformers are guaranteed to 62 dBA at 120 mega-volt amperes (MVA), 64 dBA at 160 MVA, and 65 dBA at 200 MVA. Therefore, the units should meet a spatially averaged sound level of 65 dBA at 3 feet at any load. This sound level includes the effects of both the core and the cooling equipment.

The autotransformers are rated to a maximum sound level of 65 dBA at 3 feet, but the sound measurements demonstrate that the units are capable of operating well above that level. At times, the sound meters located 15 feet from the units measured autotransformer-generated sound up to 80 dBA in short sound excursions. These increases were also measurable at the property line.

The autotransformers vary in loudness throughout the day and night. Control Meter 1 measured sound levels between 43 and 74 dBA, and Control Meter 2 measured sound levels between 48 and 80 dBA. The control meter locations are close enough to the units that common extraneous sounds would not have a significant effect on measured sound levels.

The autotransformers' sound levels were generally dominant in the 125- and 400-Hz 1/3 octave band frequencies. At times throughout the measurements, autotransformer sound levels spiked by as much as 25 dBA. The sound level spikes remained elevated for various amounts of time before eventually falling back to normal levels, which are generally between 55 and 65 dBA at the control meters. Some of the spikes in sound lasted for extended periods of time. The average control meter sound levels measured during the study are shown below in Table 4-1.

Table 4-1: Control Meter Average Sound Levels

Measurement Period	Average Meter 1 (1x)	Average Meter 2 (2x)
Winter 2016	56.5 dBA	61.6 dBA
Summer 2016	56.4 dBA	58.4 dBA

The control meters measured sound levels that fluctuated from day to day. The data shows the autotransformers can ramp up and down in sound over 15- to 30-minute periods. The Substation is audible offsite when background sounds subside and at times when the autotransformer sound levels ramp up. Substation sound is periodically measureable as a pure tone at the property line. Based on the far-field data collected, the Substation periodically exceeds the State of Connecticut noise regulations.

The property line meters fluctuated constantly due to extraneous sources. There were time periods where background sounds were low and the property line meters appeared to clearly follow changes in Substation sound measured at the control meters. Peak contribution to sound levels from the 125- and 400-Hz octave bands were measured during these times as well, consistent with Substation operation.

One instance of nighttime substation sound levels exceeding the State of Connecticut noise regulation was measured on July 12, 2016, at 12:24 AM. This was not a time when the loudest control meter sound levels were measured, but it was an instance where sound levels at the property line were clearly influenced by autotransformer sound and were in excess of the limits. During this time period, background sounds were minimal and winds were likely calm. Calm wind conditions are favorable for sound propagation from the Substation to neighboring residences. Favorable sound propagation, in combination with low background sound levels, generated prominent discrete tones measured at the property line. Under prominent discrete tone conditions, the State sound level limits are reduced by 5 dBA. At night the limit is reduced from 51 dBA to 46 dBA. The property line meters measured prominent discrete tones in the 400-Hz octave band during this time period, consistent with Substation operation. Table 4-2 provides the measured time period compared to State nighttime sound level limits.

Table 4-2: Sound Levels on July 12, 2016, at 12:24 AM

Meter	Date	Time	1-Min Leq (dBA)	Hourly Leq[a] (dBA)
Meter 1 Control meter (1x Auto)	7/12/2016	12:24 AM	70.2	66.8
Meter 2 Control meter (2x Auto)	7/12/2016	12:24 AM	76.9	74.2
Meter 3 South at Property Line	7/12/2016	12:24 AM	52.2	45.9 (limit 46 dBA)
Meter 4 Northwest at Property Line	7/12/2016	12:24 AM	56.0	50.0 (limit 46 dBA)
Meter 5 North at Property Line	7/12/2016	12:24 AM	56.4	52.3 (limit 46 dBA)

(a) Hourly sound level measured from 11:54 AM to 12:54 AM

These exceedances happen at irregular intervals. When the autotransformers are operating at their specified levels, the Substation is well below the State limits. However, there appears to be something causing the autotransformers to ramp up in sound for short periods of time. During these short-lived sound excursions, State sound level limits have been exceeded.

A more detailed explanation of sound monitoring study completed for the Barbour Hill Substation is included as Appendix B.

5.0 POTENTIAL MITIGATION OPTIONS

Various mitigation techniques could reduce sound impacts to the surrounding areas. The first consideration in reducing sound levels from the Substation is to address the autotransformers themselves. The autotransformers, when purchased, were specified to the low-sound option. Subsequently, anti-vibration pads were installed on both the 1x and 2x autotransformers to help reduce vibrations. Having addressed the physical autotransformer installations, there are multiple options that could be pursued, as detailed below.

5.1 Sound Walls

Sound walls can be effective at reducing sound levels experienced near a source and are fairly easy to install when compared to other options. Acoustic wall systems can be made of a variety of materials which may be chosen to address specific sound emission concerns. Burns & McDonnell has recently installed removable systems that use metal panels at substations.

This type of wall panel system is typically supported by steel, wide-flanged posts installed at approximately 15-foot spacing. The posts are usually supported by concrete foundations; however, a support framing system can be installed on existing firewalls or other existing structural framing to support the post and panel assembly. The panels are inserted between adjacent posts to create the wall. Systems of this type permit removal of panels and posts should equipment replacement or major work be necessary and require unrestricted personnel access for such operations.

Smaller, less intrusive barriers, generally 7 to 10 feet tall, could also be installed along the fenceline of the Substation. These barriers would not be as effective as barriers placed adjacent to the autotransformers, but they could help reduce some of the sound experienced at neighboring properties.

5.2 Autotransformer Enclosures

Enclosing the autotransformers would be similar to building sound walls adjacent to the autotransformer and then closing the top. Enclosing the top of the autotransformers would provide the maximum reduction in sound emissions, as the sound would not be able to escape over a wall. However, it also has significant construction implications. The enclosure may be an attenuating concrete block building with membrane roof, or a manufactured-panel system. To allow for the air flow needed to maintain the equipment’s ratings and cooling capacity, either a ventilation system would need to be installed or louvers would need to be placed at the top and bottom of the enclosure. An enclosure with a ventilation system would reduce sound from the transformer in all directions, as well as not allowing sound to escape over the walls. Wall sections with louvers would not reduce sound as well as solid sections.

5.3 Autotransformer Cladding

Attaching sound suppression cladding to the autotransformer themselves would be similar to building an enclosure very close to the units. The cladding would provide a reduction in sound emissions, as the sound would be suppressed in every direction. The cladding would be a manufactured-panel system that would be attached directly to the autotransformers themselves. The system would be engineered and designed by the cladding manufacturer. It would be comprised of removable noise suppression cladding sections to be fitted to the exterior of the autotransformer tanks. The direct cladding can be designed such that outlets for oil circulation pipes to the radiators and the conservator tank would remain external to the enclosure and would not be relocated. Access hatches can also be constructed as a part of the enclosure to allow for access to autotransformer gages or other components.

6.0 CONCLUSION

A sound assessment study for the Barbour Hill Substation, including near-field and far-field short-term measurements sound monitoring was completed to determine operational sound levels for the Substation. The Substation must meet the Connecticut regulation for the Control of Noise Section 22a-69-3 and the Town of South Windsor noise control regulations to maintain compliance with State and local codes.

Continuous sound monitoring was conducted during multiple time periods for a total of 125 days. Sound levels were monitored during winter, spring and summer months from January 26 to February 16, 2016; May 10 to June 21, 2016; and June 21 to August 22, 2016, under different operating conditions. Near-field data was collected approximately 15 feet from the autotransformers; the near-field noise meter locations are close enough to the autotransformers that common extraneous sounds would not have a significant effect on measured sound levels.

Measurements showed the sound levels of the single-phase autotransformers can vary significantly over time. The near-field measurements showed the autotransformers can vary in loudness and produce short-term excursions in sound. The sound levels measured at different locations varied based on distance to the Substation, time of day, and amount of local roadway traffic.

The Substation is audible at offsite locations during times of low background sound. When the autotransformers are operating normally, at their specified sound levels, the Substation is well below the applicable noise limits. However, during the autotransformer’s short-duration peak sound levels, the Substation can be in excess of the State sound level limits. These exceedances happen at irregular intervals. There appears to be something acting on the electrical system that is causing the autotransformers to ramp up sound levels for short periods of time. State sound level limits have been exceeded during these short-lived sound excursions.

Since the Substation is exceeding the permissible property line sound level limits at times, sound mitigation is required. The sound mitigation will need to be sufficient to keep Substation sound levels below the State sound level limits during the autotransformer sound excursions measured during this study. There are various types of mitigation that could be used to reduce Substation sound levels. A preliminary review of the available and feasible mitigation options shows full enclosures of the autotransformers will likely be the optimum solution to bring the Substation into compliance with the applicable noise regulations. Enclosures can be designed to reduce sound levels from the units, but consideration would need to be made for the autotransformers cooling apparatus as well as other substation equipment. Further detailed engineering will be completed to provide a final solution.

APPENDIX A – ACOUSTICAL TERMINOLOGY

APPENDIX B – SOUND MONITORING STUDY

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