Problems of acoustic safety in power engineering

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Abstract. Environmental safety issues are becoming increasingly important in the life of society. Among environmental safety issues in power engineering, acoustic safety occupies a special place. The problem of acoustic safety is associated with the fact that the regular operation of power equipment leads to an increased noise level, and power facilities are located in close proximity to residential areas. In this work, acoustic calculations were performed to determine the sanitary protection zone for gas turbines units (GTU) and combined cycle gas turbine units (CCGT) of various capacities. A formula was obtained for calculating the width of the sanitary protection zone depending on the capacity of gas turbine units and combined cycle plants and their number. It is shown that the sanitary protection zone (SPZ) of a power unit of high capacity is smaller than the sanitary protection zone of several power units of the same capacity. It is found that the noise levels from individual groups of equipment can determine the noise level at the entire border of the sanitary protection zone or in its individual sections. At the same time, noise suppression measures should be taken for all sources that generate noise levels in excess of standards. It is necessary to start noise suppression measures from those sources that generate excess noise in a larger section of the sanitary protection zone.

1. Introduction

Environmental safety issues are now becoming increasingly important in the life of society. Among environmental safety issues in power engineering, acoustic safety occupies a special place. The problem of acoustic environmental safety is associated with the fact that the regular operation of power equipment produces increased noise, and power facilities are located in close proximity to residential areas.

New requirements SanPiN 1.2.3685-21 "Hygienic standards and requirements for ensuring the safety and (or) harmlessness of environmental factors for humans” [1], introduced in March 2021, limit permissible noise values at the border of sanitary protection zones to 55 dBA during daytime and 45 dBA at nighttime. For power facilities, the boundaries of sanitary protection zones can be located at 300, 500, and 1000 m [2].

A feature of a power facility is a large number of sources of constant noise, their continuous operation, close proximity to residential areas, especially in large cities. Sources of continuous noise vary greatly depending on the type of equipment used. Strong sources of noise for the surrounding area are the air intakes of the blower fans and compressors of gas turbine units, the nozzles of gas ducts of smoke exhausters and pipes of gas turbine and combined cycle power plants, transformers, gas distribution points, cooling towers, coal-grinding equipment, the bodies of draft machines, and
noise penetrating from noisy premises, etc. [3]. Axial draft machines are much more noisy than centrifugal ones. A classification of noise sources in turbine power plants (TPPs) is given in [3–4]. The most significant source of noise is the release of steam into the atmosphere. A large number of papers are devoted to the issues of noise from equipment and the creation of sanitary protection zones of power facilities [5–12]. Noise levels at the border of sanitary protection zones depend on the capacity and type of equipment used [11–12]. A comparison of noise levels from steam power equipment with CCGT equipment is made in [12].

This paper presents calculations for both individual TPPs and individual groups of equipment. The width of sanitary protection zones of thermal power plants with advanced equipment for both gas turbine and CCGT units is discussed with regard to their capacity. In addition, the impact of equipment such as fan cooling towers and transformers is considered.

2. Results of calculations of SPZ around GTU and CCGT

The calculations were carried out for GTU and CCGT units of various capacities: GTU-78 MW and CCGT units with a capacity of 114 MW and 450 MW.

Acoustic calculations were performed in accordance with ISO 9613–2: 1996 [13]. In this case, the individual sound power levels of each piece of equipment, noise propagation conditions, and climatic and terrain features are taken into account. Such complex calculations are performed using specialized software products. The calculation is carried out according to the formula [13]:

$$L = L_W + D_C - A,$$  \(1\)

where 

- \(L_W\) is the octave-band sound power level in decibels produced by the point sound source relative to a reference sound power of 1 picowatt (1 pW);
- \(D_C\) is the directivity correction in decibels that describes the extent to which the equivalent continuous sound pressure level from the point sound source deviates in a specified direction from the level of an omnidirectional point sound source producing sound power level \(L_W\);
- \(A\) is the octave-band attenuation in decibels that occurs during propagation from the point sound source to the receiver.

The octave-band attenuation calculating by the formula

$$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc},$$  \(2\)

where

- \(A_{div}\) is the attenuation due to the geometrical divergence (the energy divergence upon emission into free space);
- \(A_{atm}\) is the attenuation due to atmospheric absorption;
- \(A_{gr}\) is the attenuation due to the ground effect;
- \(A_{bar}\) is the attenuation due to a barrier;
- \(A_{misc}\) is the attenuation due to miscellaneous other effects.

The use of a specialized program for acoustic calculations makes it possible to simulate the location of TPP buildings with their overall dimensions with the main sources of noise. In the calculations, the shielding effect from buildings and structures of TPPs is taken into account. Acoustic calculations using a specialized program allow one to determine the noise level both from the main sources of noise and from individual sources or groups of sources at a distance from the TPP taking into account the relative position of sources in the area of the station and their height above the ground. The latter is especially important since artificial and natural barriers do not have a shielding effect on the radiation from a high-altitude source.

To determine the noise levels at the border of the sanitary protection zones, mathematical modeling of TPP with gas turbine equipment and CCGT was performed. At the same time, dry fan cooling towers are used at some stations, and natural draft counterflow cooling towers are installed at other TPPs.

Figure 1 shows the results of calculations of the sanitary protection zone for operation of a 78 MW GTU and a 114 MW CCGT and a 450 MW CCGT units. The number of operating units was varied from 1 to 4. Acoustic calculations were performed for the entire set of equipment operating with the specified gas turbine and CCGT units in the factory configuration without additional measures for noise suppression. In all cases, natural draft counterflow cooling towers are used. The operation of the
GTU and CCGT units requires the establishment of sanitary protection zones significantly exceeding the regulatory limits.

The calculation results in Figure 1 can be approximated by the formula for calculating the size of the sanitary protection zone $R$, m, from the electric power of the station $N$, MW:

$$ R(N) = A \ln(N) - C, \quad (1) $$

where $N$ is the electric power of the station, MW; $A$ and $C$ are empirical coefficients, which are presented in Table 1. The confidence level $R^2$ for the obtained values according to formula (1) is about 0.99.

![Figure 1](image_url)

**Figure 1.** Width of the sanitary protection zone in a residential area versus the power of the station and the type of units to comply with the limit of 45 dBA for the boundaries of sanitary protection zones: 1 – GTU 78; 2 – CCGT 114; 3 – CCGT 450

Figure 1 shows that with the commissioning of a second unit, the sanitary protection zone increases by 535 m for a 78 MW GTU, by 263 m for a 114 MW CCGT unit, and by 226 m for a 450 MW CCGT. For a TPP with a capacity of approximately 450 MW, the sanitary protection zone with the installation of one 450 MW CCGT unit is 674 m, with the installation of four 114 MW CCGT units, it is 870 m, and with the installation of five 78 MW GTU units, 2314 m. The plant with five 78 MW GTU units, should have a sanitary protection zone 3.4 times larger than the TPP with one 450 MW CCGT unit. Thus, when choosing the composition of the equipment, one should give preference to equipment with a larger unit capacity.

The acoustic calculations performed make it possible to determine the main sources of noise responsible for the exceedance of the sanitary limits in the area surrounding the sanitary protection zone. For example, for supercritical pressure units, this is the noise from exit nozzles of axial smoke exhausters [3–4]; for TPPs with gas turbine units, this in some cases may be the noise from dry fan cooling towers [14].
Table 1. Empirical coefficients characterizing the dependence of the size of the SPZ on the electrical power for different types of units

| Units     | Coefficient A | Coefficient C | Confidence R² |
|-----------|---------------|---------------|---------------|
| GTU 78    | 767.79        | 2406.2        | 0.99          |
| CCGT 114  | 379.97        | 1440.9        | 0.99          |
| CCGT 450  | 326.22        | 1334.6        | 0.99          |

3. The results of calculations for individual groups of power equipment

The results of calculations for the main sources of noise for various sections of the sanitary protection zone are given below. For example, the section of the sanitary protection zone may be large for dry fan cooling towers and small for transformers.

Consider the noise from fan cooling towers. It has been shown [14] that fan cooling towers are always noisier than natural draft counterflow cooling towers for cooling the same amount of water from condensers. Therefore, the use of high-capacity dry fan cooling towers at TPPs instead of natural draft counterflow cooling towers increases the noise level in the surrounding area.

![Figure 2](image1.png)

**Figure 2.** Sound pressure levels at the design point on the border of the sanitary protection zone during operation of natural draft cooling towers and fan cooling towers of a 78 MW GTU: 1—dry fan cooling towers; 2—natural draft counterflow cooling towers; 3—sanitary standards at 45 dBA

Figure 2 shows the maximum sound pressure levels at the design point at the border of the sanitary protection zone during operation of natural draft counterflow cooling and dry fan cooling towers required for the operation of a 78 MW GTU. The sound pressure levels during operation of dry fan cooling towers will be higher than sound pressure levels during operation of natural draft counterflow cooling towers for low- and medium-octave band frequencies. For example, the difference in sound pressure levels between a natural draft counterflow cooling tower and a dry fan cooling tower will be about 40 dB for octave band frequencies of 31.5, 63, and 125 Hz. During the operation of fan cooling towers, the sanitary limits will be exceeded at the control point at the boundary of the sanitary protection zone for octave band frequencies from 31.5 to 1000 Hz.

Figure 3 shows the maximum sound pressure levels at the design point on the border of the sanitary protection zone during the operation of transformers at thermal power plants with a capacity of 200 MW. For example, the maximum sound pressure levels during operation of transformers at TPPs will be 106 dB and 104 dB, respectively, for low- and medium-octave band frequencies.
900 MW. For octave band frequencies of 1000 and 2000 Hz, the noise from the transformers is the main one. For other points shielded by buildings, the sound pressure level from the transformers does not exceed the norm.

![Figure 3](image-url)

**Figure 3.** Sound pressure levels at the design point on the border of the sanitary protection zone during TPP operation: 1 – from all sources; 2 – from transformers; 3 – sanitary standards at 45 dBA

Individual groups of sources can affect noise levels in the entire surrounding area. These sources include steam emissions from the nozzles of gas ducts of smoke exhausters and pipes of GTU and CCGT. Most of the boundary of the sanitary protection zone is influenced by sources such as fan cooling towers and air intakes of blower fans. Some parts of the sanitary protection zone are affected by noise from transformers and hydraulic fracturing.

In any case, if the sanitary standards are exceeded, it is necessary to take measures to suppress noise. Possible measures to reduce the power of equipment are given in [15–17].

When developing measures to reduce the power and suppress the noise of power equipment, it is necessary to consider the regional climate factor [18–20].

4. Conclusion

- The noise from energy facilities depends on both the type and power of the energy units of which it is composed. Increasing the capacity of an energy facility leads to an increase in the sanitary protection zone. At the same time, the noise level at the SPZ border is often determined by a separate group of sources.
- Formula (1) was obtained for calculating the width of a sanitary protection zone depending on the capacity of GTU and CCGT units and their number. It is shown that the sanitary protection zone of a power unit of high capacity is smaller than the sanitary protection zone of several units of the same capacity.
- It is shown that the noise levels from individual groups of equipment can determine the noise at the entire border of the sanitary protection zone or at its individual sections. At the same time, noise suppression measures should be carried out for all sources that generate noise in excess of standards. It is necessary to start noise suppression measures from those sources that generate excess noise in a larger section of the sanitary protection zone.

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