Noise radiated from wind turbine generator systems

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Abstract
The power consumption in Japan increases year by year and it is said that the twice as many amount of electric power generation as the current will be needed 30 years later.

In Japan we depend for 60 percents of energy resources on fossil fuels, such as oil, natural gas, and coal. Therefore, response to the shortage and drain of fossil fuels in the future and global-scale environmental conservation by controlling carbon dioxide emission as a big factor for global warming are the questions of glowing concern. For this reason, great expectations have been put on the power generation system using wind force. Wind turbine generator is natural motive power which is not exhausted, and is always clean energy without output.

On the other hands, however, there are also regions which have caused a new environmental issue on noise emitted from large-sized rotor blades or dynamo mechanism of wind turbine generators. Here, the actual condition in Japan is introduced about the noise emitted from a wind turbine generator facility.

1. Wind turbine generators in Japan

Power generation in Japan is mainly handled by the Electric Power Development Co., Ltd., now operating under the name J-POWER. According to figures published by J-POWER, thermal power generation has the biggest share of power generation methods, and its lead over hydroelectricity is increasing year by year (see Fig. 1, Table 1, "Yearly trends in power generation").
Although J-POWER is actively promoting the adoption of wind turbine generator systems, the share of wind power generation still lags far behind the thermal and hydraulic methods. Table 2 lists wind turbine generator systems that are currently in operation in Japan.
Locations where wind turbine generators are to be installed must have good wind exposure all year round. The large size of the turbine rotors further limits the number of suitable sites. A wind turbine begins to produce power already at low wind speeds of about 3 m/s, with optimal values being reached at 6 - 7 m/s. The most commonly used types are computer-controlled high-efficiency turbines rated at 750 and 1500 kilowatts. Because the noise generated by such wind turbine generators can be a problem, various countermeasures such as low-noise gear construction and reduced blade speed are being implemented. The turbines are designed to stop in the event of extremely high winds, such as encountered during typhoons. This is achieved by specially designed safety devices which stop blade rotation at wind speeds of 25 m/s and above.

2. Noise measurements at wind turbine generator installations

Normally, wind turbine generators are installed in remote areas, removed from residential neighborhoods. However, since ambient noise levels in such areas are usually low, the noise produced by the wind turbines is more noticeable, which can be perceived as a problem. Also, the type of noise is unfamiliar, because such installations have only come into existence recently. This also can give rise to complaints.

There is a scarcity of data regarding the noise produced by wind turbine generators. Measurements of this type of noise are fairly complex and require technical expertise, because the influence of the wind itself must be excluded. For this purpose, a windscreen must be used on the microphone. This is particularly important when carrying out noise surveys on wind power installations. Another aspect to consider is that of low-frequency noise. The rotor blades used in wind turbines emit a noise component (aerial vibration) whose frequency is lower than the audible frequency range. Because of their long wavelength, these low-frequency waves are not significantly attenuated by terrain features and can travel long distances. "Rattling of doors and fixtures" is a complaint often associated with such noise components.

3. Actual examples of wind turbine generator noise measurements

At the end of last year, a noise survey was carried out at the wind turbine generator installation “A”. The results are reported below. This installation is located on a livestock pasture.

3.1 Locations of wind turbine generators and investigation points (microphones):

Figure 2 shows the relative locations of the wind turbine generators in the wind turbine generator installation “A “ and investigation points where microphones are installed..

3.2 Low-frequency noise radiated by rotor blades (1 - 80 Hz):

Figure 3 shows the relationship between the noise level (audible noise and low-frequency noise) and wind speed.

3.3 Frequency analysis of noise radiated by rotor blades:

Figure 4 for “Frequency analysis of audible range” and Figure 5 for “Frequency analysis of low-frequency range” show examples of analysis results.

3.4 Sound pressure level and wind speed on long term observation results:

Figure 6 for “Sound pressure level and wind speed long term observation results” shows an example of measurement results.

4. Discussion of noise and low-frequency noise measurements

Minute changes in pressure occurring in the atmosphere are picked up by the human ear and perceived as sound. This is called auditory perception. There are various causes for these changes in pressure, which are transmitted in the atmosphere.

In so far as vibrations are being transmitted in the atmosphere, low-frequency noise is no different from other kinds of noise. But the fact that the frequency of such noise is extremely low makes for some peculiarities. Low-frequency noise as an environmental problem usually has two aspects. One is direct auditory perception of the vibrations as noise, and the other is indirect perception, such as by rattling windows, doors, and other fixtures.

The wind turbine generator installation “A” is a large-scale facility with many big rotors. It can be assumed to be producing low-frequency noise which is transmitted to adjacent residential areas and has led to complaints. The current survey was aimed at examining the circumstances under which noise including ordinary noise and low-frequency noise is produced.

The noise measurement results obtained at the microphone installation location, as included in this report, did not show extremely high levels either for the audible or the low-frequency range. Viewed in a general context, these levels did not seem high enough to allow drawing a definite conclusion about a negative impact on the living environment. However, because the survey dealt with sound pressure level only as a physical quantity, these results do not mean that the subjective impressions of residents regarding the sensory impact of low-frequency noise are necessarily invalid.

The impact of low-frequency noise on the living environment is currently the object of intensive studies by researchers in various fields, but a definite conclusion has yet to be reached, also at the Ministry for the Environment. The sound pressure level for rattling of fixtures and sensation of pressure observed during the current survey in the region are much lower than the levels dealt with in other studies.

However, the residents in the current case do experience sound that seems to originate at the wind turbine generator installation “A”, and it is a fact that rattling of fixtures does form a part of some claims. The results of the current survey alone do not seem to be sufficient in order to gain a full understanding of the situation. A problem that remains to be considered is the fact that naturally occurring wind also produces low-frequency vibrations and the topological features of the area commonly give rise to windy conditions. Furthermore, it has been noted that there is a difficulty of distinguishing between measurement results produced by wind-induced pressure changes and low-frequency noise.

It is important to determine whether the rattling of fixtures is caused by the wind or by low-frequency noise. One way of doing this would be to mount vibration sensors on the fixtures to assess their behavior in detail, while simultaneously measuring sound pressure level changes over time, using microphones at multiple locations. By examining the way low-frequency vibrations are transmitted within dwellings, it may also become possible to develop ways of preventing fixtures from rattling.

It is an undeniable fact that there are complaints about low-frequency noise in the region. People who have been living in the area for a long time subjectively link the start of operations at the wind turbine generator installation "A" with problems they are experiencing. Whether such a link objectively exists is difficult to determine with a short-term survey done over a limited period of time. The current survey should be seen as a first step, but further detailed studies will be required to provide more data for an in-depth evaluation.

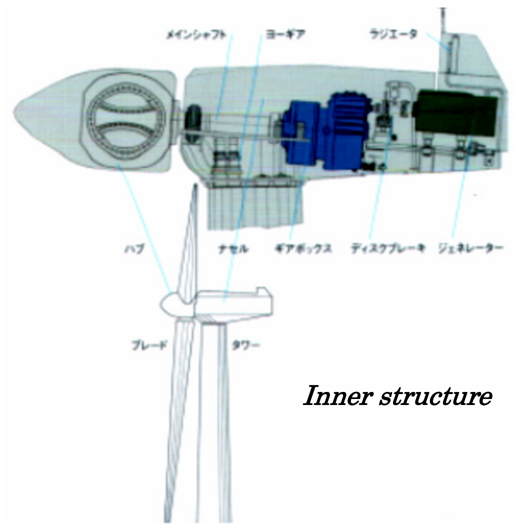

Table.2　Wind Turbine Generator Systems

	Tomamae (Hokkaido)	Nikahokogen (Akita)	Tokyo Rinkai (Tokyo)	Kuzumaki (Iwate)
Output of Power Plant	30,600kW	24,750 k W	1,700kW	21,000kW
Turbine Output	1,650kW x 14 1,500kW x 5	1,650kW x 15	850kW x 2	1,750kW x 12
Annual average wind speed	6.6m / s (60m height)	7.1m / s (60m height)	5.4m / s (44m height)	8.0m / s (60m height)
Annual power generation	59MkWh Equivalent to 17,000 family units	51MkWh Equivalent to 15,000 family units	2.5MkWh Equivalent to 800 family units	54MkWh Equivalent to 16,000 family units
Utility factor for planned facility	22%	23%	16%	29%
Operation starts	December, 2000	December, 2001	March, 2003	December, 2003

Fig. 4

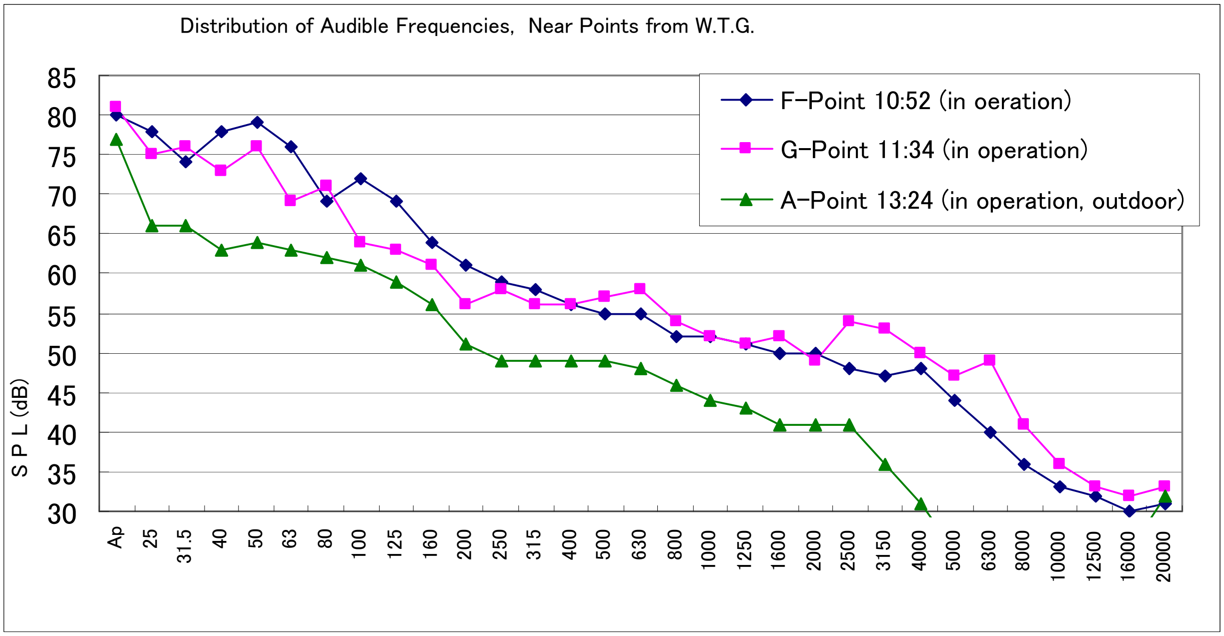

Fig. 5　Distribution of Low Frequencirs,　Near Points from W.T.G.

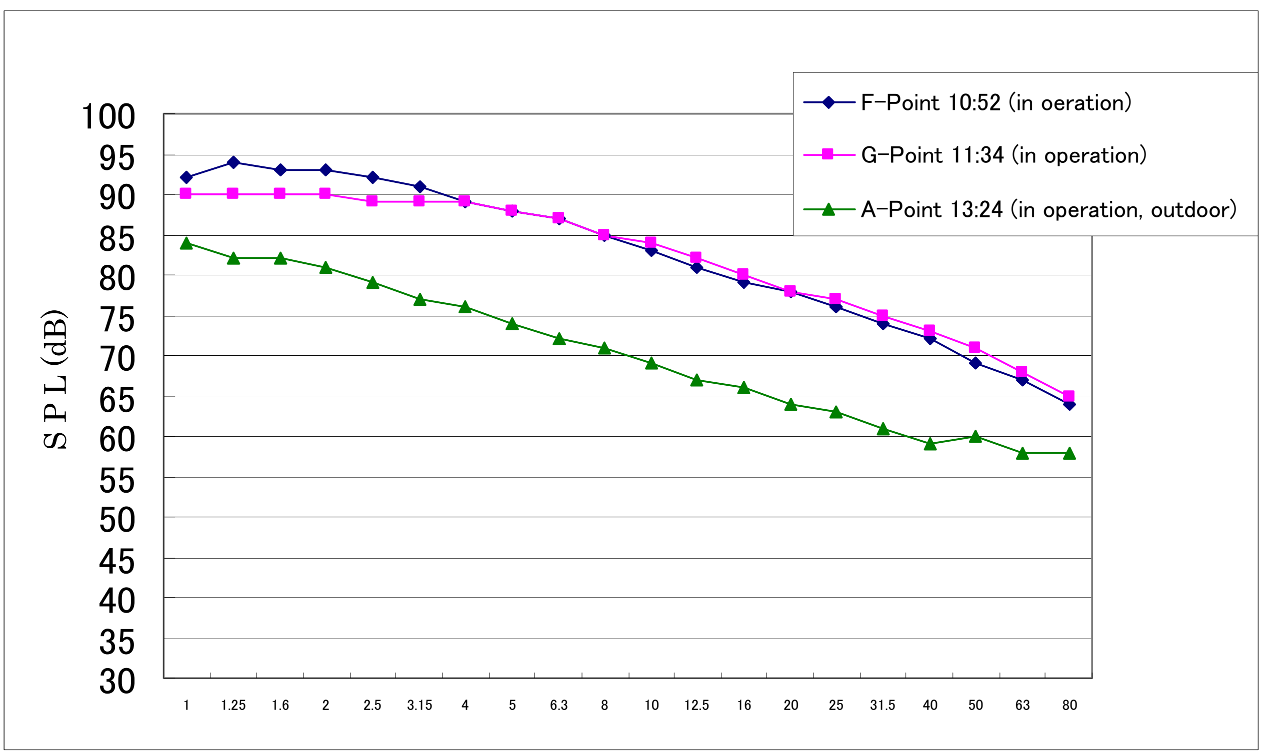

Fig. 6　Long term observation results