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Photovoltaics noise barrier: acoustic and energetic study

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Abstract

In the light of global warming, renewables such as solar photovoltaics (PV) are important to decrease greenhouse gas emissions. An important issue regarding implementation of solar panels on large scale, is the limited available area. Therefore, it can be interesting to combine PV with alternative applications, as a ways of not requiring "additional" space. One example is a photovoltaic noise barrier (PVNB), where a noise barrier located along a highway or railway is used as substructure for PV modules. Even though PVNB is not a novel concept, in this paper it is studied the best shape of the barrier to optimize the acoustic and energy properties.

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Keywords:

1. Introduction

To counter global warming, renewables are important to decrease greenhouse gas emissions. The sun provides the most abundant source of energy available. One way to capture this solar energy, is by the use of photovoltaic (PV) systems that convert the energy of the sun directly into electricity. One issue concerning the implementation of solar panels on a large scale, is limited available area. The issue of land use has often been cited as an important concern for renewable technologies. Therefore, it can be interesting to look for alternative PV applications that do not require "additional" space. Examples include PV on rooftops, building integrated PV [1], agrovoltaic systems [2], and PV sited in areas of low land quality such as brown fields [3]. Another example is a photovoltaic noise barrier (PVNB), where a noise barrier is used as substructure for the PV e modules [4].

A PVNB is most appropriately located along a highway or railway nearby a densely populated area. This is an interesting theoretical concept for several reasons. Firstly, on these locations noise barriers are

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needed, since many local residents are affected by noise nuisance. Secondly, in a crowded area there is not much room available to install ground mounted PV, which makes a sound barrier an interesting alternative to mount PV on. Finally, when the energy supply system - in this case the PVNB - is located nearby the consumer, advantages of decentralized electricity generation are realized. Examples include reduced energy transportation costs, savings in primary energy consumption, and emission reduction of CO2 and other pollutants [5-12]. It should be noted that in a crowded residential area a large surface is accessible to install roof mounted solar panels. Yet, there are many specific issues regarding the integration of PV panels in the roof structure. The roof tilt angle can significantly impact the efficiency of the panels [13-15]. Further, structural roof characteristics are not always ideally suited for the installation of solar panels. There can be a possible need for re-roofing within the lifetime of the PV array or the roof might be too unstable to support the transferred loads of solar panels [16]. Additionally, it is possible that residents are not willing to accept the installation of solar panels on their roofs, due to concerns about economic and financial risks (whether the home insurance would increase, what would happen with the PV panels if the owner moved,.), health and safety concerns (roof damage, vandalism, etc.), and esthetic concerns [17]. In brief, the need for an increased share of renewables in contrast to limited available ground space, constraints regarding rooftop PV, and the presence of a noise barrier nearby a residential area, can lead to a win-win situation where sound barriers - complementary to roofs - can be used as PV support structures. PVNBs as an integrative concept were introduced in Switzerland in 1989 [4]. Studies about technical insights [4, 18-20] and the potential [21] of PVNBs in Europe are already published in the last years.

2. Mathematical model

For the evaluation of acoustic characteristics of the barrier has used the software SoundPLAN®. They were studied and compared models of various barrier different from each other for orientation and tilt of the element relative to the horizontal diffracting main barrier. The study was performed with the same boundary conditions, with the same characteristics of the noise source and other conditions including materials, absorption, reflection and morphology of the land etc.

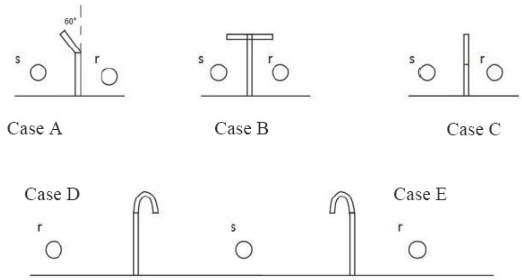

Fig. 1. Several diffractors used to compare the acoustic and energetic characteristics.

This analysis was then performed in order to find the various situations the most suitable shape of the barrier noise abatement resulting from road traffic in terms of interest. The equivalent levels of emission source of the road day and night are are calculated by the software according to the standard NMPB - Routes - 96, Guide du Bruit, manually setting the percentages of traffic TGM (Average Daily Traffic veh/24h) according to data ANAS and Autostrade for Italy, for which in the most demanding of the A1 will reach peak TGM > 80,000 veh/24h, with percentages of heavy vehicles by about 26% during the day and slightly less than 10% in night. In the definition of the way you set the cruise speed of cars and heavy vehicles respectively equal to 130 km/h and 80 km/h (day and night) and calculated the multiple reflections through the inclusion of data on the width of the track width and the height of the shielding means bounding it. Finally scissors hourly interest are 6-22 h for the day and 22-6 for the night.

The receivers were arranged at fixed distances from the source, at a height of 1.5 m above the ground and the buildings also placed at fixed distances from the road have been simplified assuming them as cubes with side of 15 m. The shape and arrangement of the diffractive covers considerable importance both from the acoustic point of view and in reference to the energy yield of the photovoltaic system. It shows first of all, the outline of the forms of diffractor concerned.

3. Results

Through noise mapping with SoundPLAN® we were studied the different situations described above and compared the results. The study was performed by placing acoustic shielding on both sides of the road hypothetically oriented east-west, with the same boundary conditions, environmental classes of sound absorption materials, type and arrangement of receivers, equivalent heights of the screens, emission levels of the source etc.... They show the results of the study as a comparison of the various solutions. Figs 2 and 3 shows the comparison between the solution with the diffractor inclined at 60° (Case A) and Case B respectively for the receiver South and North side.

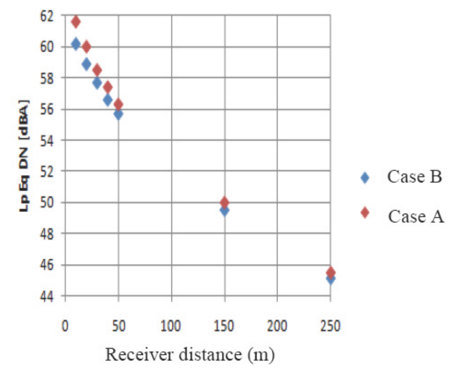

Fig. 2 Noise level as a function of the receiver distance from the source (South side)

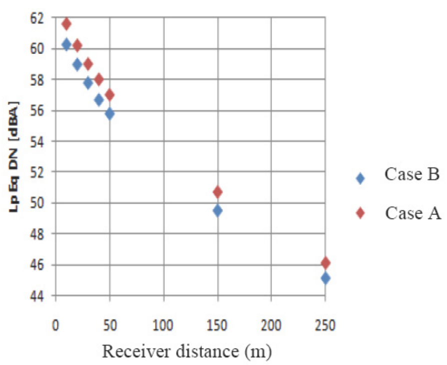

Fig. 3 Noise level as a function of the receiver distance from the source (North side)

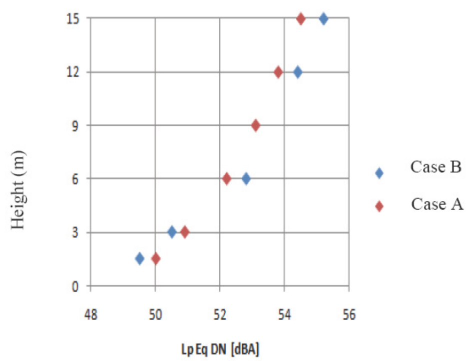

Fig. 4 Noise level as a function of the height building at 150m from the source (South side)

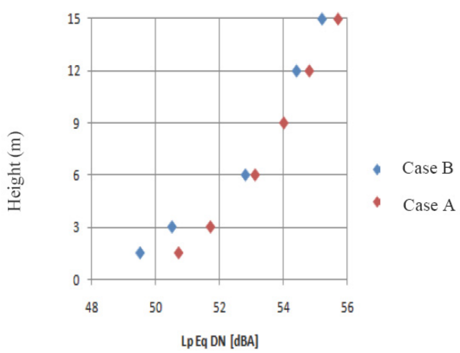

Fig. 5 Noise level as a function of the height building at 150m from the source (North side)

Figs 4 and 5 shows the comparison between the solution with the diffractor inclined at 60° (Case A) and Case B respectively for the building South and North side.

Figs 6 and 7 shows the comparison between the solution with the vertical diffractor (Case C) and Case B respectively for the receiver South and North side.

Figs 8 and 9 shows the comparison between the solution with the vertical diffractor (Case C) and Case B respectively for the building South and North side.

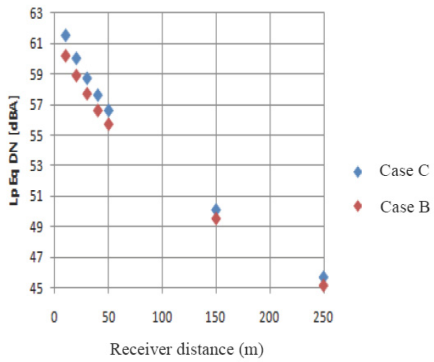

Fig. 6 Noise level as a function of the receiver distance from the source (South side)

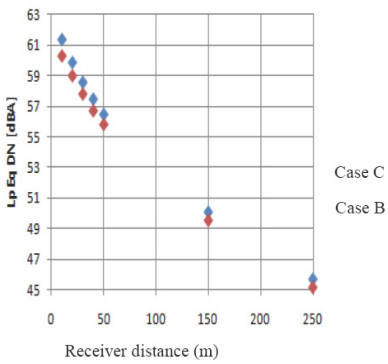

Fig. 7. Noise level as a function of the receiver distance from the source (North side)

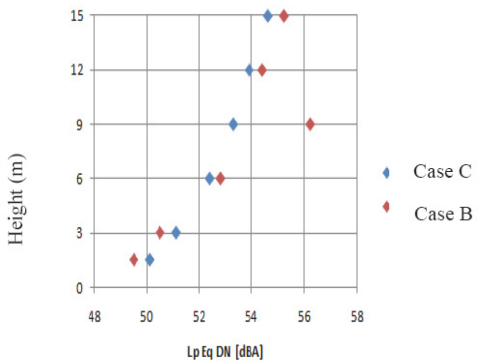

Fig. 8 Noise level as a function of the height building at 150m from the source (South side)

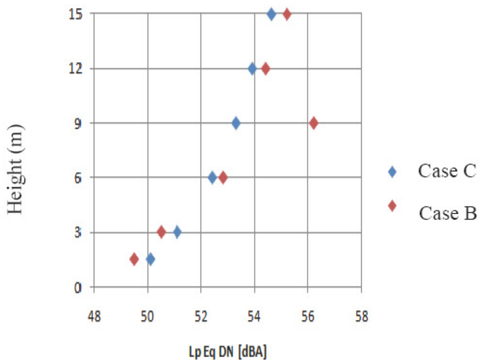

Fig. 9 Noise level as a function of the height building at 150m from the source (North side)

Figs 10 and 11 shows the comparison between the Case D and Case B respectively for the receiver South and North side.

Figs 12 and 13 shows the comparison between the Case D and Case B respectively for the building South and North side.

From the Figures 2-13 is known as the T-shaped turns, from the acoustic point of view, the best solution; In fact, as is evident to all receivers at various distances, placed at 1.5 m above the ground, the sound level is lower than other solutions. The study on the facade on buildings instead signals, at heights from 6 m up, a sound pressure level with T-shaped barrier slightly higher than the levels found with barrier semicircular and straight, with the noise peaks to 9 m height in front. There is definitely a great reduction of the barrier T up to a height of 3-6 m, and then executed by the comparison it is noted that other solutions may be more appropriate. The difference in noise reduction between different conformations of diffracting examined even at heights between 6-15 m is still the smallest scale; It can definitely state that under equal conditions, the shielding acoustic T is significantly better than the other.

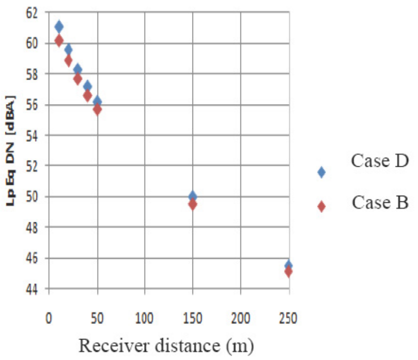

Fig. 10. Noise level as a function of the receiver distance from the source (South side)

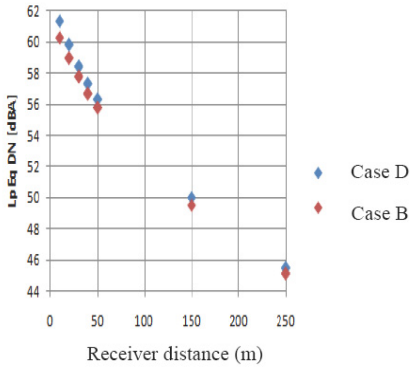

Fig. 11 Noise level as a function of the receiver distance from the source (North side)

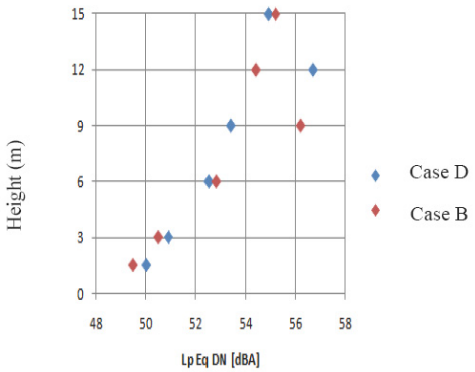

Fig. 12 Noise level as a function of the height building at 150m from the source (South side)

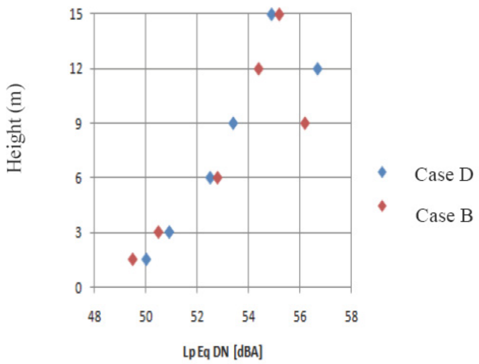

Fig. 13 Noise level as a function of the height building at 150m from the source (North side)

Acoustic analysis performed depending on the type of shielding and the conformation of the element diffracting and then found the best solution (as seen with equal boundary conditions) for the abatement of noise from road traffic, is passed to the energy assessment of different solutions, in order to optimize the conformation of the shield so much respect to the problematic acoustic as to the energy yield of the PV technology integrated to it. We proceed to the study of the shape best for the energy yield of PV modules integrated element diffracting the noise barrier. The study was performed by analyzing the energy yield in terms of kWh / year for a plant of 1 kWp of photovoltaic panels installed on the element diffracting thin film of each of the solutions discussed. The analysis has been performed for the 4 test solutions on each of the four orientations of the road set by dividing the quadrant north-south-west-east in 8 equal wedges. Then the guidelines were defined: a) North-south, b) East-west, c) North-east southwest, d) North west-south east.

Then imposed a type of shielding element and the orientation of the road, were obtained respectively the inclination of the PV module and the azimuth of the same. With the data available to it and climbed back through PVGIS database [29] to the energy output for the latitude and longitude of Rome.

From the figure 14, known as the best solution appears to be the one with diffractor tilted 60 degrees from the vertical, in the case of double noise barrier with diffractor inclined in the same direction, thus one tilted towards the noise source, the other at the receivers. This solution and one with higher energy yield for each orientation of the road section excluding the north - south direction to which the peak power generation and given by the barrier T, the latter appears to have the same yield for each route guidance being photovoltaic modules inclined at 0 ° to the horizontal. The worst solution is seen to be the one with the barrier completely straight, without diffractive element, with photovoltaic modules tilted at 90 degrees to the horizontal. Based on the results described above it is carried out a feasibility study of an investment for the addition of noise barrier PV technology on a stretch of road through simulations with existing software Homer Energy.

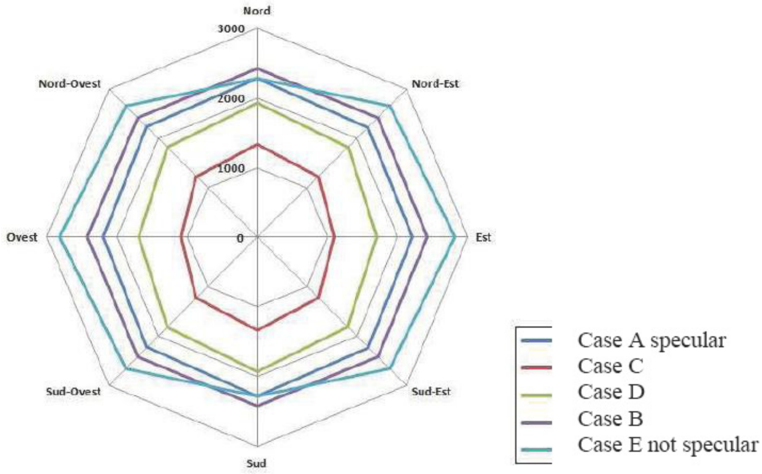

Fig. 14. Evaluation of the annual energy yield according to the orientation and shape of the road barrier

4. Conclusion

Starting from the analysis and mapping of acoustic noise resulting from road traffic for various configurations of noise barrier to equality of class absorption of the shield with respect to the classes required by the legislation, and continuing with the study of acoustic solutions for different installation element diffracting, and you come to the identification of the best solution for the removal of the highway noise. The best configurations and roughly equivalent result to be the T-shaped configuration and with the shielding element in the summit inclined 60° to the vertical. The first detects killing more low average height (1.5 m by law), the second is more powerful for tests at greater heights (by legislation from 4m and up). A noise level so the choice falls on one of the two configurations described above. After studying acoustic analysis and past energy for all 4 solutions discussed above with photovoltaic system installed on the element diffracting. The choice to carry out the study energy even for the solutions less performing acoustic level and due to the fact that it took to get there and ultimately to an optimum solution from the technical point of view - the economic aspects combining acoustic and energy precisely. With the help of the European Photovoltaic Geographical Information System Data Base, and you come to the identification of the best solution of energy yield for each direction rode , as shown in Fig. 14, significant and evident the maximum energy yield for each direction of the road (unless the orientation north - south) of the configuration element with diffractor and then photovoltaic modules inclined at 60 ° on the vertical (Case A).

5. Copyright

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Biography

Andrea Vallati was born in Roma, Italy, on October 16, 1970. He received the M.S. degree in Mechanical Engineering, and the Ph.D. degree in Applied Physics, from University of Ancona (Italy) in 1997 and 2001, respectively. From 2006 he served as Assistant Professor at the Department of "Fisica Tecnica " of the same University. Since 2005 he is Professor of Energy and Applied Physics at the Faculty Engineering of "'Sapienza" University of Rome. He is author or co-author of about 40 scientific works, published in prominent international journals and conferences on heat transfer, thermodynamics and acoustics.