Application of Solar Noise Barrier Power Generation System Envisaged on Urban Elevated Roads

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Abstract. Aiming at the noise problem in the second ring of Kunming is increasingly outstanding. An assumption of constructing solar energy noise barriers is proposed. The construction of solar noise barriers can not only reduce noise transmission, but also use amorphous silicon solar panels to generate electricity for the power load of road street lights. It reduces the economic burden for road management departments. According to the daily average solar radiation data of Kunming, combined with a suitable model of solar panels, the theoretical power generation forecast is performed. The calculation results show that it can meet almost half of the road street light load. It shows that the proposed method will bring good power generation benefits while reducing noise.

1. Preface
With the depletion of petroleum, coal, natural gas and other fossil fuels, the global energy crisis is increasing fairly rapidly in recent years. In order to cope with the lack of resources, it has become a very urgent requirement to seek alternative clean energy continuously and apply it to production and life. With the rapid development of the solar photovoltaic industry, the application fields are gradually expanding. The photovoltaic modules are designed and manufactured as noise barriers and installed on both sides of the highway [1]. Forming a solar noise barrier (PVNB) power generation system, which has the functions of generating electricity and reducing noise, can not only reduce the power generation cost of photovoltaic systems, but also control the noise transmission to a certain extent [2][3]. Germany, Italy, France, Britain, Netherlands, Switzerland, Austria and other countries have installed some solar noise barriers along the highway [4][5], China also installed an 8kW grid-connected photovoltaic noise barrier power generation system test section on Shanghai Rail Transit Line 3.

The solar noise barrier is conducive to the realization of energy saving and emission reduction. According to statistics, the electricity used for lighting on the second ring road in Kunming is as high as 40 million kWh a year. For every 100 kWh of electricity generated by the solar noise barrier, it is equivalent to saving 34.7 kg of standard coal, equivalent to reducing 90.9 kg of CO2 emissions and 0.295 kg of SO2 gases [6].

The application of solar noise barriers on urban elevated roads can not only reduce noise but also generate electricity. At the same time, the generated electricity can be used for street lighting along urban roads. The annual average temperature of Kunming is 15.4 ° C, and the annual solar radiation is about 5 500 MJ / m²[7]. The total length of the elevated road of the Second Ring Road in Kunming is 27.08 km. It is an important hub ring in the rapid transportation system of Kunming's main city. Plays a vital role in the web [8]. According to the 2018 Kunming Transportation Development Annual Report,
the average daily traffic volume of the second ring road viaduct is huge. The problem of noise disturbance is becoming increasingly prominent. Noise barriers system is urgently needed.

This article mainly analyzes the feasibility of the idea of installing a solar noise barrier on the second ring road in Kunming, Yunnan.

2. Introduction of solar noise barrier power generation system

The current solar power generation systems are mainly divided into three categories, off-grid power generation systems, distributed power generation systems and grid-connected power generation systems. The power generated by the off-grid power generation system is used by the load and is not connected to the public power grid. The amount of power generated by the distributed power generation system is mainly supplied to the building's own load, and the excess or insufficient power is adjusted through the grid. The grid-connected power generation system requires that the power generated by solar modules be converted into AC power that meets the requirements of the public power grid and then connected to the public power grid.

The solar noise barrier power generation system installed on the elevated road generates electricity during the day, but the street light load is used at night. The construction battery is placed on the original elevated road and cannot be constructed at the same time, so it is easy to be stolen. Therefore, off-grid power generation systems and distributed Neither the power generation system is suitable. In view of the fact that power generation and use cannot be completed at the same time, it is recommended to use a grid-connected power generation system. As shown in the figure 1, the internal structure is composed of solar noise barrier components, inverters, combiner boxes, box transformers, street light loads and related AC protection switching devices, and measuring instruments.

![Figure 1. Schematic diagram of the access system](image)

3. Comparison of preliminary schemes

3.1. Selection of solar panels

Photovoltaic solar panels are divided into monocrystalline silicon, polycrystalline silicon, and amorphous silicon. Now, most solar panels are mainly monocrystalline and polycrystalline. Because amorphous silicon has the disadvantages of low efficiency and photoinduced decay effects. But it has some technical indicators and production advantages that all other solar cells cannot compare [9]. Making it applicable to building-integrated photovoltaic (BIPV) system. Table 1 is a comparison table of solar panels.
Table 1. Comparison table of solar panels

| Solar Panels       | Monocrystalline Silicon | Polycrystalline Silicon | Amorphous Silicon |
|--------------------|-------------------------|-------------------------|-------------------|
| **Generation Efficiency** | The photoelectric conversion efficiency is high, but it is greatly affected by the inclination of the sun. | It can also generate electricity in low light conditions, with a large daily power generation, but low photoelectric conversion efficiency | Requires the widest range of sunlight incident angles, low light response characteristics, but low efficiency |
| **Noise Reduction Effect** | Single-sided glass package, average sound insulation effect | General sound insulation | Using double-sided glass package, good sound insulation effect |
| **Construction Difficulty** | Difficult construction | Difficult construction | Easy to install, easy to assemble and connect |
| **Economy** | higher cost | higher cost | low cost |
| **Production Process** | 156×156 mm and 125×125 mm | 156×156 mm and 125×125 mm | Flexible size |

Through the analysis of the above table, it can be concluded that the solar sound barrier using an amorphous silicon double-sided glass package requires the widest range of sunlight incident angles. At the same time, it has the advantages of scattered light acceptance, good low-light response characteristics, stable operation, good sound insulation effect, easy installation, and low cost. So, the final decision is to use an amorphous silicon double-sided package solar sound barrier solution.

3.2. Size selection
The width × height design of noise barriers currently installed along elevated expressways is mainly 1500 × 2000 mm. The designed upper solar amorphous silicon battery of the noise barrier consists of two cells with a rated power of 105 W and a size of 600 × 1200 mm in series, each of which has a rated power of 210 W. Figure 2 is a diagram of the envisioned photovoltaic panel installation.

Figure 2. PV panel installation style

3.3. Forecast of power generation
It is assumed that a solar noise barrier system is installed on both sides of the entire 27.08 km section of the second ring of Kunming, with a total length of about 55 km. An amorphous silicon solar noise barrier with a size of 1500 × 2000 mm is used. A total of about 36 100 noise barriers are required. Considering
the differences in the positions of turns and joints, consideration and calculation are based on 36 000 blocks. The total installed capacity is 7.56 MW.

For the long distance of the second ring of Kunming, consider using string (1-5kW) inverter for electrical connection, which not only greatly reduces the cost of the system, but also increases the power generation and system reliability. Photovoltaic layout scheme shown in Figure 3.

Figure 3. Photovoltaic layout

According to Kunming's daily average solar radiation data (see Table 2), the total monthly radiation dose received by a photovoltaic panel at a 90 ° installation angle can be estimated in theory. And the monthly average power generation of the system is shown in Figure 4.

The calculation formula for the theoretical annual power generation of photovoltaic square array is:

$$P = H \times A \times \eta \times K$$

In the formula:
P—-theoretical annual power generation;
H—annual total local radiation;
A—the area of the photovoltaic array;
\(\eta\)—component conversion efficiency
K—correction coefficient.

Among them, the correction coefficient:

$$K = K_1 \times K_2 \times K_3 \times K_4 \times K_5$$

In the formula:

\(K_1\)—consider the attenuation after long-term operation of the module, take 0.8;
\(K_2\)—correction for component power drop and dust obstruction caused by temperature rise, take 0.82;
\(K_3\)—line correction, take 0.95;
\(K_4\)—for inverter efficiency, take 0.85;
\(K_5\)—90 ° tilt correction coefficient for photovoltaic square array, take 0.6.
Table 2. Daily average solar radiation data and predicted power generation in Kunming

| Month     | Days (d) | Horizontal Angle (MJ/m²·d) | Dip Angle, 90° (MJ/m²·d) | Power Generation (kWh) |
|-----------|----------|----------------------------|--------------------------|------------------------|
| January   | 31       | 14.07                      | 15.38                    | 196 390.6              |
| February  | 28       | 16.21                      | 14.73                    | 169 888.3              |
| March     | 31       | 19.93                      | 12.86                    | 164 212.1              |
| April     | 30       | 21.38                      | 10.21                    | 126 168.1              |
| May       | 31       | 16.44                      | 8.33                     | 106 367.6              |
| June      | 30       | 15.20                      | 7.33                     | 90 579.07              |
| July      | 31       | 15.05                      | 7.07                     | 90 278.37              |
| August    | 31       | 14.58                      | 7.90                     | 100 876.8              |
| September | 30       | 13.44                      | 8.45                     | 104 419.3              |
| October   | 31       | 12.43                      | 9.58                     | 122 329.1              |
| November  | 30       | 10.91                      | 12.16                    | 150 264.9              |
| December  | 31       | 11.25                      | 14.41                    | 184 004.4              |

Annual total power generation 1 605 779

4. Conclusion
It is predicted that the installation of solar noise barriers along the second ring road in Kunming will generate more than 16 million kWh of electricity a year, which can supply a part of the electricity consumption of street lights. In addition, it can effectively block the transmission of noise and improve the quality of life of nearby residents. Although compared with traditional energy generation, its power generation cost is still higher. Compared with the traditional noise barrier, it only adds a small amount of cost to the amorphous silicon solar cell panel, but it has obtained good power generation benefits. The potential market for installing solar noise barrier systems on both sides of urban roads, railways and tracks cannot be underestimated.

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