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Shading losses measurements for integrated photovoltaics potential estimation for solar city bus and data driven simulations.

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1. Introductory summary

In order to improve primary energy saving and reduce greenhouse emissions, vehicle integrated photovoltaics have an ongoing interest [1]. Studies on the benefits from vehicle solar roof, which take into account all the losses and the monthly variation in different climate conditions, are required. Therefore, we developed a simulation tool of the mileage covered by VIPV. This tool takes into account various use profiles and different characteristics of the vehicles and of the PV system. Focusing on city bus, simulations show that many parameters can influence the outputs of the model, mainly: the geographic location (first order), the shading losses (second order), the electric architecture (third order) and the battery saturation (fourth order).

As the shading losses have a second order influence, we propose here to use in simulations shading losses measured on city bus during several months to be as close as possible to the real driving conditions.

Auto generated distance, useful PV energy and carbon footprint results will be thus updated taking into account monthly real shading losses values and real bus use profiles.

2. Scientific innovation and relevance

The relevance of our work is in coupling measurement, modeling and so data driven simulations and life cycle assessment methodology to assess the potential of VIPV on city bus in real conditions. The simulations use the experimental shading results on city bus. We used also an extrapolation method to fill the missing data and statistics analysis of city bus trips to identify the use profile. The outputs of the simulation model (used PV energy and annual mileage covered by VIPV) are inputs of the life cycle assessment, which allows calculating the carbon footprint on the whole life of the vehicle.

3. Aim and approach used

The aim is to assess the real potential of VIPV on city bus. For this, we used three complementary approaches: simulation, experiments and life cycle assessment. The simulation approach consists in developing a dedicated modular simulation tool described in our previous work [2]. The experimental methodology consists in evaluating the irradiance received on the roof of a bus while moving in the city with GPS tracking. A correction of the irradiance values is evaluated from the measured temperature values. To perform these experiments, three silicon solar cell sensors were placed on the roof of the bus as shown in Figure 1. These experiments allow to evaluate the shading ratio. The obtained data is used to update the simulation results of PV useful energy, annual and daily mileage covered by VIPV. The life cycle assessment approach allows finally the calculation of the carbon footprint results.

4. Results and conclusions

Our first simulations [2] take into account the shading as a model sensitivity analysis parameter. Figure 2 presents the results with projections of the technology in 2030, at midlife of the city bus, for average Europe use case, for different shading losses, with direct charge in the main battery and without battery saturation. It shows that the VIPV on city bus in this use case covers up to 6269 km and down to 4361 km annual mileage with 0 % and 30 % shading losses, respectively. Life cycle assessment of solar city bus shows neutral to high gains. For average Europe use case in term of solar irradiance and electricity mix, the avoided emissions on 20 years lifespan is up to 10 T and down to 6.5 T CO₂-equivalent, with 0 % and 30 % shading losses, respectively. The work on real irradiance measurements (example in figure 3) and on data driven simulations is ongoing.

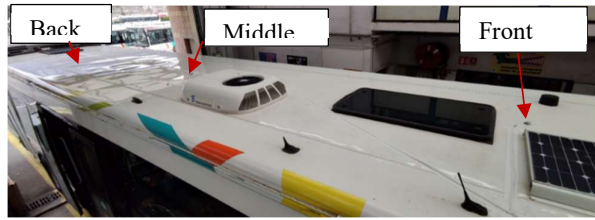


FIGURE 1.Irradiance sensors position on the bus roof

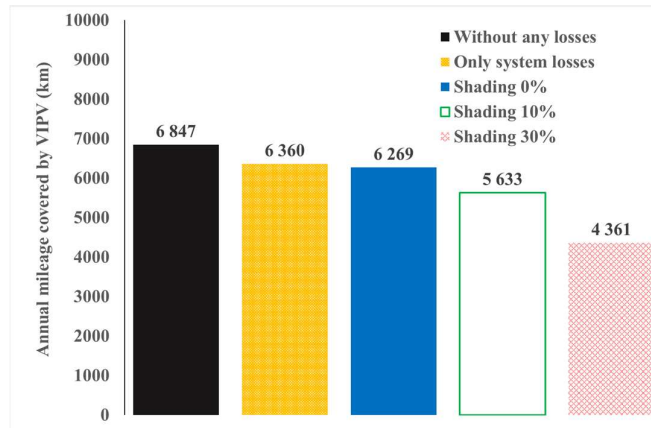


FIGURE 3. Annual mileage covered by VIPV for Paris (~average Europe) for city bus with 5.695 kWp solar roof and 880 Wh/km electrical consumption

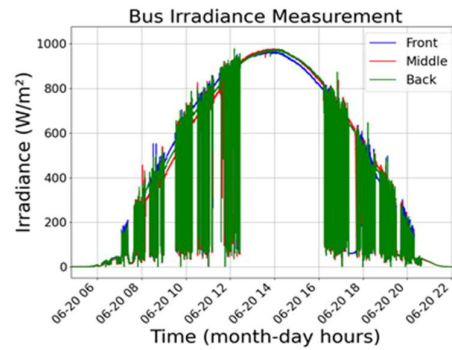


FIGURE 2.Irradiance sensor position on the bus roof

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[2].F. Karoui, F. Claudon, B. Chambion, S. Cattellani, and B. Commault, “Estimation of integrated photovoltaics potential for solar city bus in different climate conditions in Europe” *Journal of physics: conference series*, accepted manuscript (2022).