Performance analysis of solar-powered cars for everyday use

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1 Introduction

A solar-powered car can generate its own energy, independently of fuels, using a photovoltaic panel on its roof (or using the electricity grid). It may therefore be an interesting solution to the issue of clean mobility. Currently, only non-commercial prototypes of practical solar-powered cars for everyday use exist and there is little literature on the possible performance of these cars. The question “how far can a solar-powered car drive until it has to be recharged from the grid again?” does not have a trivial answer as it is highly dependent on the vehicle parameters, location, the built environment, daily driving distances, time of day, day of year and more. This work therefore serves as an initial pursuit into the understanding and sensitivity of the solar car performance.

2 Main results

The main results of this work are (1) a method to compute the solar irradiation while taking shading due to buildings into account and (2) a probability model for days between external recharges from the electricity grid for a solar-powered car. The models show that, on average, less than 30% of the solar irradiation is blocked by buildings and at least a 100% increase in vehicle performance can be achieved for very energy efficient cars (energy consumption <120 [Wh/km]) and up to 50% for existing EVs (energy consumption ~150 [Wh/km]) when equipping them with solar panels.

2.1 Modelling shading using the ‘skyline method’

Although there exists a lot of work concerning irradiation and modelling of the position of the sun, not much work has been done on the influence of shading due to buildings on a moving object near ground level.

In order to estimate the effect of the built environment, a 3D model of the city of Eindhoven has been used [1]. This 3D point cloud is converted into a ‘skyline’ for 1463 locations within the city, from which the expected percentage of irradiation that is blocked by buildings can be computed.

2.2 Modelling probability distribution of performance

The performance of the vehicle is clearly highly dependent on the day of the year because the solar irradiation varies strongly over the year. It is therefore of more interest to look at the probability of the next external recharging moment than only the average value.

A method is proposed that computes the probability of the next external recharge by convolution of the probability density functions of (1) the irradiation with shading as discussed in Section 2.1, (2) the battery State-of-Energy and (3) the daily driven distance. The proposed method extends the traditional convolution integral such that the physical upper and lower limits of the battery are taken into account.

Besides the probability densities, a dimensionless ‘solar improvement factor’ (SIF) is introduced, which is defined as the relative performance increase of the solar car with respect to an identical electric vehicle without a solar panel. Figure 1 shows an example contour plot of the SIF for various vehicle configurations.

![Figure 1: Contour plot of SIFs with a solar panel of 4 m² and 20% efficiency and various combinations of energy consumption and battery size.](image-url)

References