USE OF SOLAR ENERGY IN SMALL CAPACITY ELECTRIC VEHICLES

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Abstract. The paper researched in small capacity shopping vehicles, equipping vehicles with a smaller capacity battery and a solar photoelectric panel. A solar cell with a voltage of 24 V and a 195 W power was used in the research. In a sunny summer day, the developed system allows an electric vehicle to move at a speed of 6-7 km·h^{-1}. The capacity of a standard battery may be decreased from 40 Ah to 12 Ah, which reduces the battery weight and cost, and overall operating costs. In a sunny day, the experimental electric vehicle model can move without additional battery charging. According to the experimental data, moving in nominal regime on average requires electric current of less than 5A; accordingly, the solar cell power may be reduced to 120 W, yet, in this case, no spare power remains for a cloudy period.

Keywords: low-speed electric shopping vehicles, speed, electricity consumed, current, voltage, solar photoelectric panel.

Introduction

Nowadays, low-speed electric vehicles, which cover a limited distance with one full battery charge, are exploited for various needs. If an electric vehicle is equipped with a lead-acid battery, an average exploitation period lasts for 3-4 years. The cost of replacement of such batteries is high. For this reason, it is appropriate to seek ways how to increase the range per charge of low-speed electric vehicles as well as to reduce the cost in case if the batteries are replaced. One of the options is the use of solar cells or photoelectric panels and the use of smaller capacity batteries.

Using batteries with smaller capacity will reduce the range per charge of electric vehicles. The following relationship is valid: by reducing the capacity of the batteries by x times, the range of the electric vehicles will also decrease by x times. It is difficult to use solar cells on the roof of electric vehicles the speed of which exceeds 40 km·h^{-1} as they cause additional air resistance. The air resistance, in its turn, requires a greater capacity of the electric motor as well as reduces the range per charge. Air resistance at speeds less than 40 km·h^{-1} is insignificant and the use of solar cells is appropriate from this perspective. High-speed electric vehicles may be equipped with special "flexible" solar cells built in the roof of an electric vehicle, copying its form. However, the cost of such photoelectric panels is usually much higher compared with solar cells of the traditional type.

Low-speed electric vehicles usually do not require electric motors with much power. For this reason, the following hypothesis is set: to be run at full power, low-speed electric shopping vehicles may be equipped with a solar cell, but its batteries may be replaced by cheaper batteries of smaller capacity, which reduces the operating costs.

Materials and methods

Characteristics of the research. An experimental research was conducted to ascertain the possibilities for the use of solar cells for low-speed electric drive vehicles. The experiment involved an electric shopping vehicle Trendmobil Hawaii. In order that the sun can shine on the photoelectric panel evenly from all sides, the vehicle was driven along a closed square-shaped contour. The average length of a contour was equal to 160 m. The experiment was conducted on an asphalted surface. The road surface was in a good condition, with the average rolling resistance coefficient of 0.020. The data of the vehicle movement were recorded by a data recording device Holux GPSport. The experiment was performed in two series: on sunny days and on partially cloudy days.

Research object and the equipment and methodology used in the experiments. The key technical characteristics of the data recording device Holux GPSport used in the experiments [1]:

- ambient temperature -10 ºC to +60 ºC;
- storage temperature -20 ºC to +70 ºC;
- lithium-ion battery, 1050 mAh, 5 hours charging time, 18 hours operating time;
- diagonal screen size, 1.8 inch;
- IPX-6 water resistance class.

During the experiment, the device was fastened to the electric vehicle, to a well-seen spot, in order to follow the on-screen parameters during the vehicle movement.

A data recording device Pace Scientific XR5-SE is used to record variations in the voltage and current. The technical characteristics of the device Pace Scientific XR5-SE [2]:

- measurement precision within a range of 0-2.5 V: ±0.15%;
- measurement precision within a range of 0-5 V: ±0.35%;
- 20 screwable terminals;
- ambient temperature: -40 ºC to +78 ºC;
- protection class: IP50.

For the experiment, the device Pace Scientific XR5-SE was installed under the electric vehicle seat, connecting measurement and power cables to the electric vehicle.

A Trendmobil Hawaii TM4401DX was chosen as a prototype of the electric vehicle. The key technical characteristics of the vehicle are presented in Table 1 [3].

Table 1

Technical characteristics of the electric shopping vehicle Hawaii TM4401DX

Characteristics	Technical parameter
Length, width, ground clearing, mm	1187.5; 610; 82.6
Weight with batteries, kg	87.54
Weight without batteries, kg	59.74
Load for transportation, kg	29
Maximum speed, $km \cdot h^{-1}$	6
Range per charge with new batteries, km	40
Carrying capacity, kg	159
Motor working voltage and power	24 V, 1 kW
Wheel diameter, mm	254
Batteries	2×12 V 40 Ah deep-cycle Lead-Acid

The roof of the experimental electric vehicle is inclined towards the rear of the vehicle. Cross-mounts are made of flat-shaped iron bars. The cross-mounts ensure that the solar panel console is fixed to the front and rear of the electric vehicle.

A standard electric vehicle version is equipped with two powerful 12 V, 40 Ah batteries. With fully charged batteries, the range may reach 40±3 km. The use of solar cells together with such batteries is not appropriate, as the fully charged electric vehicle may be exploited for 6-8 h at the average speed of 6-7 $km \cdot h^{-1}$, therefore, solar cells are not necessary for such electric vehicles.

To ascertain the possibilities for the use of batteries with smaller capacity, a primary range experiment on the electric vehicle was performed with two 12 V, 12 Ah batteries. The key parameters of original and small-capacity batteries are shown in Table 2.

Table 2

Key parameters of the electric vehicle batteries

Parameter	Original batteries	Small-capacity batteries
Capacity, Ah	40	12
Voltage, V	12	12
Nominal electric current, A	12	4.8
Weight, kg	13.9	3.2
Dimensions (width × length × height), mm	160×200×165	100×150×95
Average price, EUR	130	20

The primary experiments were performed with 12 Ah batteries recording the range, time and average speed. The experiments were repeated three times. The average characteristics obtained in the experiments are as follows: range 9.83 km, driving time in the experiment 86.6 min, average speed

7.01 km·h^{-1}. According to the data of the primary experiment, 12 V, 12 Ah batteries may be used for electric vehicles, thus reducing the weight and cost regarding batteries.

A photoelectric panel KPV PE 195 Q6LTT produced by KIOTO Photovoltaics was used in the experiments. The panel technical data are as follows [4]:

- nominal power – 195 W;
- maximum system voltage – 1000 V;
- short-circuit electric current – 7.89 A;
- voltage at the maximum power – 26.1 V;
- efficiency of the panel – 13 %;
- number and type of cells – foursquare polycrystalline silicon cells;
- dimensions (length, width, height) – 1507 mm × 992 mm × 33 mm;
- weight – 16.5 kg.

A controller Steca PR3030 was used for the electric vehicle system of solar cells. The key parameters of the experimental controller are shown in Table 3 [5].

Table 3

Parameters of the controller Steca PR3030

Parameter	Numerical value
Operating voltage	12 V or 24 V
24 V operating range	17.3 V to 43.0 V
Operating temperature	-10 ºC to +50 ºC
Electric current self-consumption by the device	12 mA
Maximum input voltage	47 V
Maximum electric current	30 A
Weight	350 g
Dimensions	187×96×44 mm
Protection class	IP32

The controller was affixed to the steering wheel column of the electric vehicle. The principal connection scheme of the controller and measuring device is shown in Fig. 1.

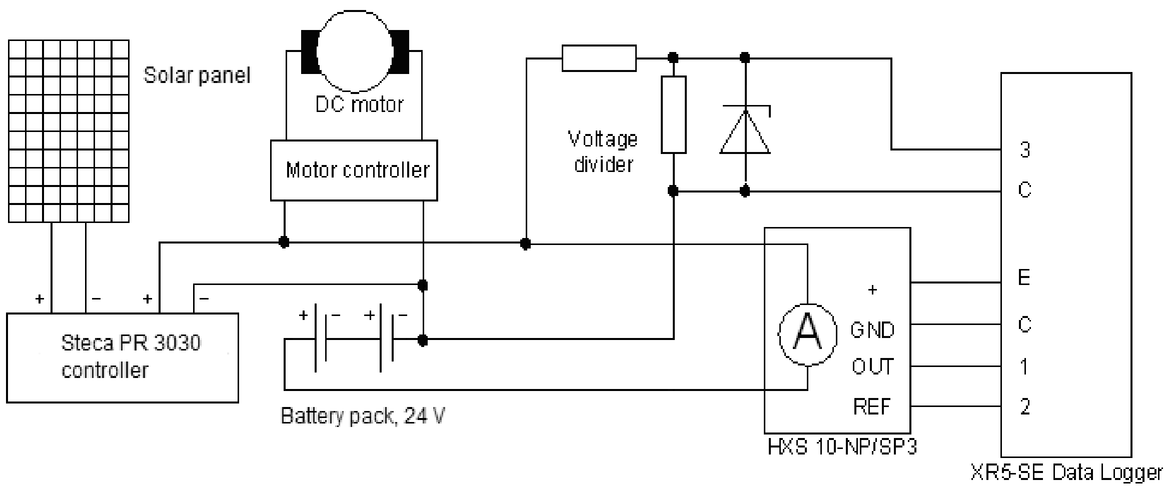

Fig. 1. **Principal Scheme of controller and measuring device connection**

Results and discussion

The first experimental drive was made under variable weather conditions, and the intensity of solar radiation considerably changed during the experiment. The drive began at 12:17 p.m. under sunny conditions, and the voltage of the battery at the beginning of the experiment was 25.5 V (Fig. 2). During the course of the experiment, the voltage gradually rose to 26.5 V. After two hours of the experiment, the voltage started decreasing because of a decline in the intensity of solar radiation (Fig. 6). At the end of the drive, the voltage decreased below 20 V, and the electric vehicle batteries were fully discharged.

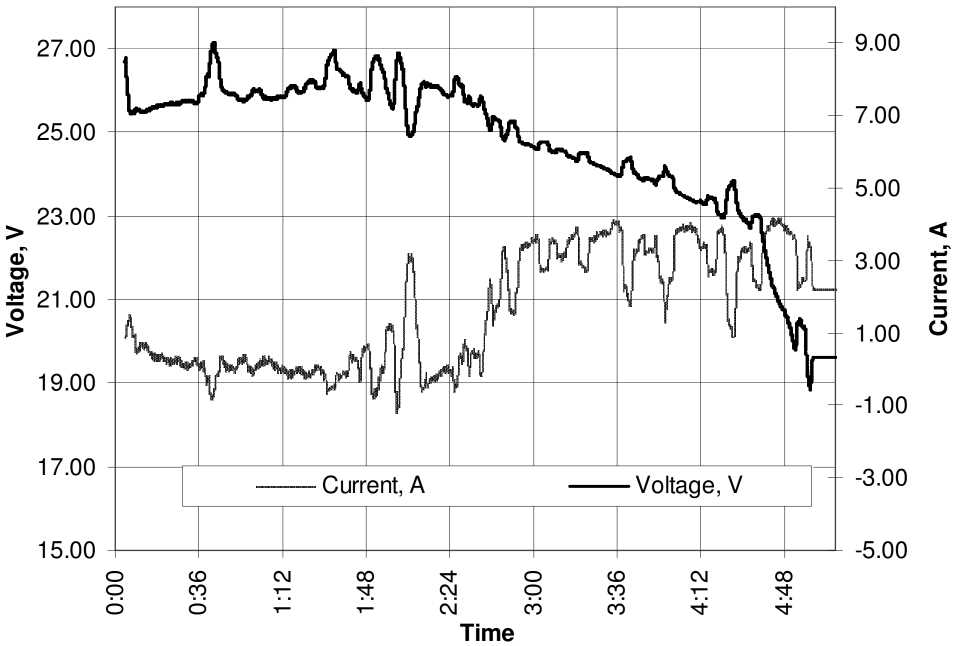

Fig. 2. **Variations in voltage and current in the first experiment**

During the experiment, after 2 hours and 24 minutes, the consumption of electric current started increasing, and the current reached 4 A. The increase in current may be explained by the fact that the voltage of the batteries decreased and they started to discharge.

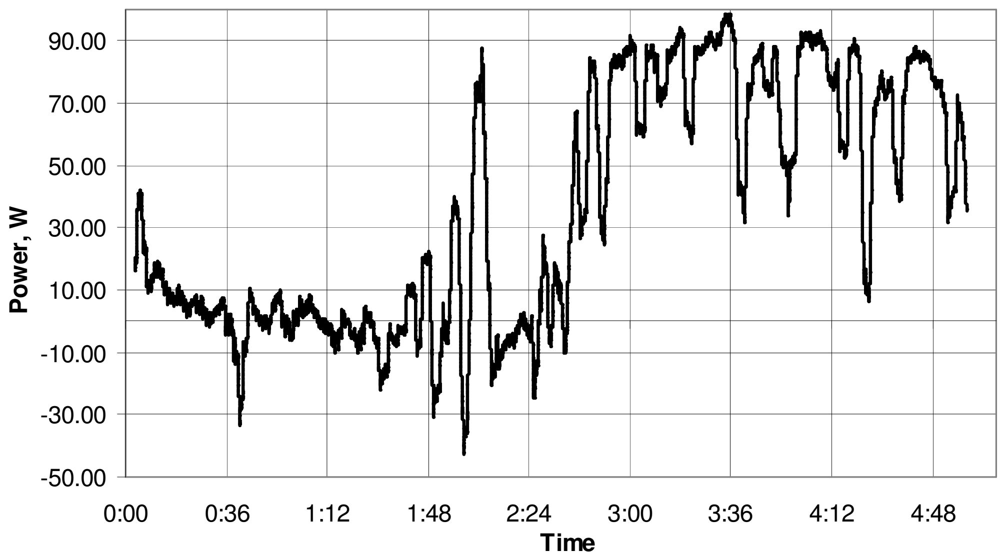

Fig. 3. **Graph for the power released by the batteries in the first experiment**

At the beginning of the experiment, the intensity of solar radiation was approximately 750 $W \cdot m^{-2}$, by 13:30, it increased to 850 $W \cdot m^{-2}$. At 15:00, the intensity of solar radiation decreased below 300 $W \cdot m^{-2}$, and it did not significantly increase until the end of the experiment. Such intensity of solar radiation was insufficient to run the experimental electric vehicle.

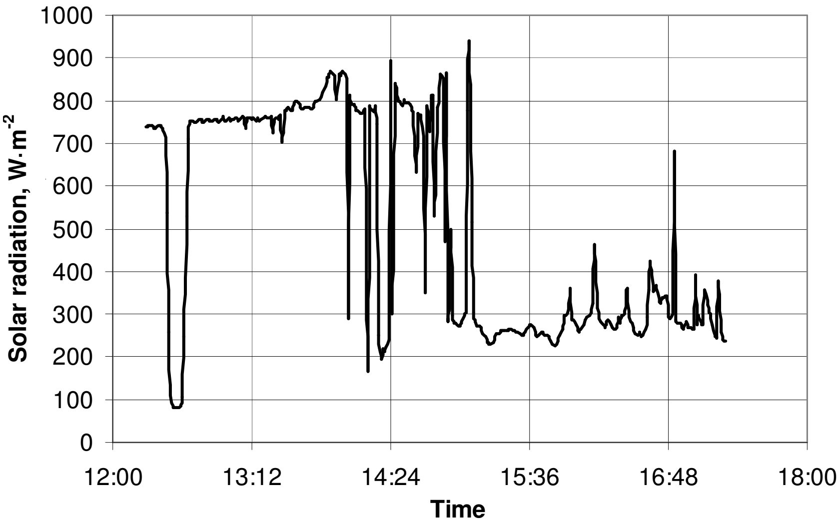

Fig. 4. **Solar radiation during the first drive**

The second drive was conducted in sunny weather when the average solar radiation was not less than 600 W·m^{-2} during the entire drive. The experiment was started early in the morning to find out how the rising solar radiation affects the variations in the voltage and current. After 1 hour and 30 minutes, the voltage varied around 25 V (Fig. 5).

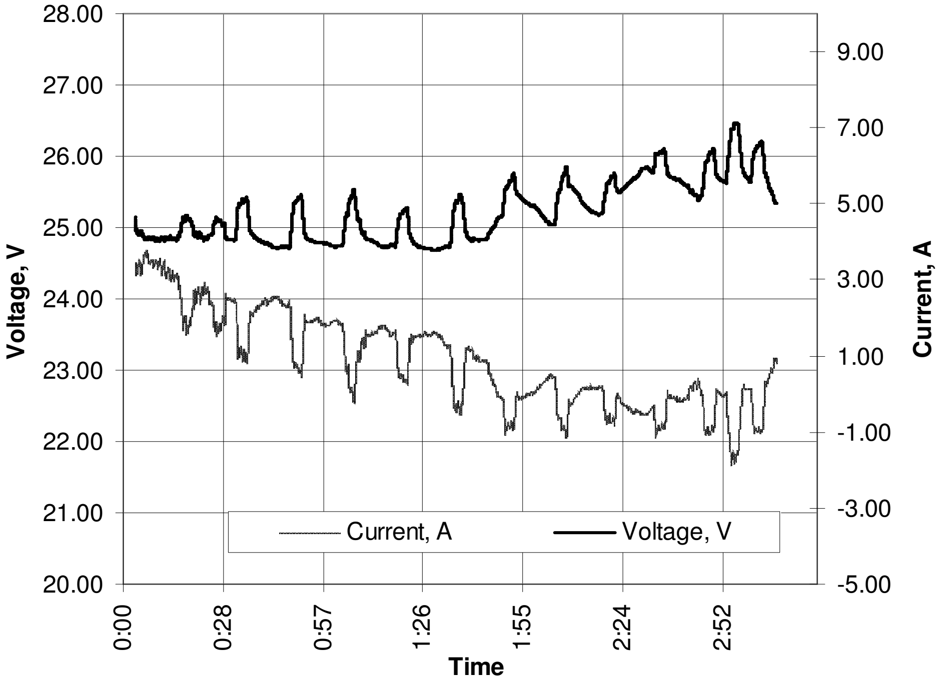

Fig. 5. **Variations in voltage and current in the second experiment**

At the end of the second hour of the experiment, the voltage rose to 25.5 V. The voltage did not decrease during the further course of the experiment. The current gradually decreased during the second drive because the battery voltage rose.

The solar radiation rose from 450 W·m^{-2} at the beginning of the experiment to 700 W·m^{-2} by the end of it (Fig. 6). A short period of decline in solar radiation to 200 W·m^{-2} did not significantly affect the performance of the electric vehicle.

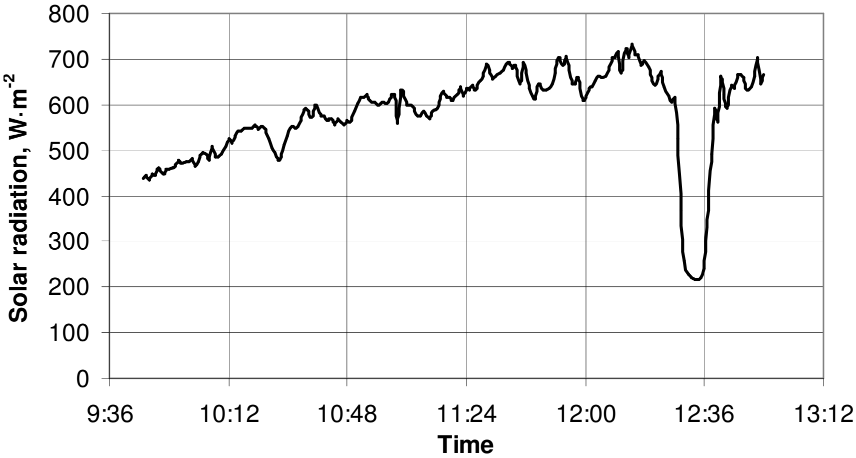

Fig. 6. **Solar radiation during the second drive**

Conclusions

1. Under the climatic conditions of Latvia, the intensity of solar radiation exceeding 500 $W \cdot m^{-2}$ is sufficient in summer months, which allows solar cells to be effectively used for electric vehicles.
2. An experimental electric vehicle with less power was developed for running on solar power and being able to normally operate. The developed construction for the tested electric vehicle additionally serves as a roof that protects its riders from rain or solar radiation.
3. In sunny weather, when the average solar radiation is 600 $W \cdot m^{-2}$, the range of an electric vehicle equipped with a solar cell, from the perspective of consumption of energy, is unlimited.
4. In cloudy weather, when the average solar radiation is 300 $W \cdot m^{-2}$, the solar cell is not able to sufficiently charge the electric vehicle batteries, and unlimited driving is not possible without additionally charging batteries.
5. In the experiments, a rise in voltage, on average from 24.8 V to 25.5 V, might be observed under the conditions of intense solar radiation.

References

1. Holux GPSport 245. (S.a.) [online] [cited 18.04.2013] Available: http://www.holux.com/JCore/en/products/products_download.jsp?pno=349
2. XR5-SE loger. (S.a.) [online] [cited 20.04.2013] Available: http://pace-sci.com/specifications-xr5.htm
3. Trendmobil Hawaii. (S.a.) [online] [cited 02.04.2013] Available: http://trendmobil-gmbh.de/downloads/category/27-hawaii4.html
4. Solar panels. (S.a.) [online] [cited 22.04.2013] Available: http://www.ev-power.eu/Solar-Panels/?cur=1
5. Steca PR3030. (S.a.) [online] [cited 16.04.2013] Available: http://www.steca.com/index.php?Steca_PR_10_30_en