Study on Charging Performance of Solar Panels Auxiliary Batteries for Hainan Electric Bus

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Abstract. Under the background of building free trade pilot area in Hainan Province to promote clean energy vehicles in an all-round way, this paper explores adding solar panel auxiliary batteries to electric buses with subtropical climate characteristics. Based on the solar energy resources of Haikou City, the experimental vehicles and parameters are selected, and the average daily power generation of solar panels is studied. The endurance mileage can be increased under full load air conditioning conditions. The results show that the installation of solar panels for battery auxiliary charging in electric buses has certain energy-saving and environmental benefits, but combined with the current operation of Hainan electric buses, the promotion and use of electric buses has no prospects for development.

1. Introduction

Hainan Province is the first province in the country to ban the sale of fuel vehicles in 2030. At present, most buses in Hainan Province are electric vehicles. Hainan is between subtropical and tropical areas. The annual average temperature is high and the air conditioning is used for more than 9 months in a year, so the air conditioning of Hainan electric buses consume a lot of electricity. Hainan Province has good sunshine penetration and high solar radiation, and has a good regional advantage in the development of solar energy resources [1]. Therefore, installing solar power generation devices on Hainan electric buses can supplement the electricity consumption, lighten other parts of electric buses, and make the weight of solar power generation devices less than that of other parts. Such research can realize environmental protection and energy saving, which has great social and economic significance.

In this paper, the solar thin film device is used at the bottom of the electric bus compartment, and the controller is connected to control the solar cell, so that the on-board power supply can be supplemented. This paper calculates the power consumption of electric bus using air conditioning, and compares the endurance mileage and power generation between the electric bus with solar film device and the original electric bus, so as to provide an effective basis for installing solar cells on Hainan electric bus.
2. Selected experimental vehicles and parameters

The experimental object of this paper is a pure electric bus in Haikou City, Hainan Province. The annual average temperature of Haikou is the lowest in Hainan Province, and the solar radiation is the lowest in Hainan Province. Therefore, Haikou City is taken as an example. Table 1 is give detailed parameters of an electric bus.

| Project              | Parameter Type                              | Numerical Value     |
|----------------------|---------------------------------------------|---------------------|
| Whole vehicle        | Vehicle size (length * width * height)      | 8485mm×2450mm×3030mm|
|                      | Curb weight                                 | 9600kg              |
|                      | Seating                                     | 55/10-30            |
|                      | Air resistance coefficient $C_d$             | 0.71                |
|                      | Windward area                               | 7.42m²              |
|                      | Maximum Speed                               | 69km/h              |
|                      | Rolling resistance coefficient               | 0.03                |
| Power system         | Electric battery                            | LiFePO4             |
|                      | Battery capacity                            | 168kWh/Ah           |
| Endurance Mileage    | Uniform speed                               | 410km               |
|                      | Real Operation Range of Full-load Open Air Conditioner | 200 km          |
| Solar panels         | Area available                              | 14.6 m²             |

3. Selection of solar panels and parameters

In this paper, polycrystalline silicon solar panels with thickness of 2 mm, length of 1700 mm, width of 970 mm, conversion rate of 20%, open circuit voltage of 22, open circuit current of 18.2 are selected. Affected by the area of the roof, eight solar panels of this size are connected in parallel, then the controller and the inverter are connected to recharge the bus batteries.

4. Solar radiation and daily average solar panel power generation in Haikou

The annual total solar radiation in Haikou City is 4858 MJ/m², or 1349 kWh/m². [2] The daily average solar radiation is about 3.70 kWh/m². [2] The average monthly solar radiation in Haikou is shown in Fig. 1.

![Fig.1 The monthly average solar radiation of Haikou city](image)

The power generation efficiency can be estimated by the daily average radiation amount, photoelectric conversion rate and area. The formulas are as follows:

$$P_F = \varphi \times \eta_s$$  (1)
Among them, $P_{\text{avg}}$ is the average daily power of solar panels, $\phi$ is the average daily solar radiation, $\eta_s$ is the photoelectric conversion rate of solar cells.

$$W_T = P_{\text{avg}} \times S$$  \hspace{1cm} (2)

Among them, $W_T$ is the average daily power generation of the solar cell and $S$ is the area of the solar cell.

The average daily power generation of solar panels in this experiment can be calculated as 9.76 kWh.

5. **Increased range calculation**

According to the relevant formulas.

$$3600 \times E_{\text{out}} \times \eta = \sum F \times L$$  \hspace{1cm} (3)

$$E_{\text{out}} = E \times \xi$$  \hspace{1cm} (4)

$$E = U \times C$$  \hspace{1cm} (5)

$$\sum F = F_f + F_w = mgf + \frac{1}{2}Cd \rho V^2$$  \hspace{1cm} (6)

It can be obtained.

$$L = \frac{7200UC\eta}{2mgf+Cd \rho V^2}$$  \hspace{1cm} (7)

$U$ and $C$ represent the total voltage and capacity of the battery pack, $E$ represent total Energy for Batteries (Wh), $E_{\text{out}}$ represents the output energy of the battery, $m$ represents the mass of the vehicle, $g$ represents the acceleration of gravity, $f$ represents the rolling resistance coefficient when the vehicle is driving on the road, $C_d$ represents the air resistance coefficient when the vehicle is experimenting, $A$ represents the windward area of the vehicle, and $\rho$ represents the air density $\rho = 1.2258 \text{N} \cdot \text{s}^2 \cdot \text{m}^{-4}$. $V$ represents the speed of the vehicle.

Because the vehicle travels at the same speed on the straight road in this experiment condition, the driving force and driving resistance are equal.[3]

It can be calculated that the electric bus equipped with solar panels can increase the endurance mileage by 11.6 km/d and 5.8% in full-load air-conditioning, so it still has certain benefits.

6. **Conclusion**

Although installing solar panels on electric buses can increase the endurance mileage and environmental protection, the power generation efficiency is not very high. If it is necessary to improve the power generation efficiency, installing solar panels on the side of buses to increase the power generation area has to be done. At the same time, it is necessary to reduce the weight of other parts of buses to offset the energy loss.

At present, multi-bus charging mode is adopted in electric buses in Hainan Province, that is, the standby electric buses are parked at the terminal parking lot where they can be fully charged, and wait to replace the electric buses running out of electricity. The electric buses are replaced by full-charged vehicles in the parking lot to continue to run, while the vehicles running out of electricity are parked in the parking lot for rapid charging. The charging can be completed in 1 - 2 hours by using high voltage charging pile. Therefore, it is not suitable or necessary to install solar panels on electric buses to generate electricity at present.

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**References**

[1] Xiao, Z.B., Weng, S.J., Zhang, Y.T. (2009) Solar energy resources comprehensive utilization and development prospect research in Hainan province. Chinese Agricultural Mechanization, 204: 34–37.
[2] Bai, Y.J., Liu, S.h., Zhang, Y.T. et al (2017) Comparative Study on Performance of Solar Electric Sightseeing Vehicle in Hainan's Tropical Environment., Chinese Journal of Construction Machinery., 15: 273-279.

[3] Yu, Z. S. (2009) Theory of automobile. China Machine, Beijing.

[4] Mcconnell, R.,(2002) First international conference on solar electric concentrators.,29th IEEE PVSC,New Orleans.,1737-1741.

[5] Kenisarin,M,M.,(2010)High-temperature phase change materials for thermal energy storage,Renewable and Sustainable Energy Review.,14:955-970.

[6] Xu,J.M.,Kang,L.Y.,Wen,M.Q.,(2016)Design of hybrid power system of electric vehicle.Automation of Electric Power Systems.,36:60-64.

[7] Qu,R.H.,Qin,C.,(2016)Development status and prospects of electric vehicles and their drive motors.,Southen Power System Technology.,10:82-86.