

The Energy Management for Solar Powered Vehicle Parking Ventilation System

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ABSTRACT

In summer, when vehicle parks in direct sunlight, the closed cabin temperature would rise sharply, which affects the occupants step-in-car comfort. Solar powered vehicle parking ventilation system adopts the solar energy to drive the original ventilator. Thus, the cabin temperature could be dramatically decreased and the riding comfort could be also improved.

This research analyzed the modified crew cabin thermal transfer model. Then the performance of the solar powered ventilation system is analyzed and optimized combined with the power supply characteristics of the photovoltaic element. The storage and reuse of the solar power is achieved on condition that the cabin temperature could be steadily controlled.

The research shows that, the internal temperature is mainly affected by the solar radiation intensity and the environment temperature. Within the environmental conditions area where the environmental temperature is set from 30°C to 45°C and the solar radiation intensity is set from 200 W/m² to 1000 W/m², the ventilation system without the energy management can keep the temperature inside the car higher than the highest environmental temperature by 5 to 10 degrees under about 80% of the environmental conditions. Under the condition of reaching same effect on controlling internal temperature as above, the energy management system can distribute electrical energy reasonably, making the ventilation system adapt to more than 90% of the environmental conditions. Under normal weather condition in the summer, the system works from 7 am to 5 pm, while the internal temperature is well controlled, it collects electrical energy of around 0.02KW·h. The system can collect electrical energy of about 0.1KW·h after the car with the system has driven for 2 hours under the condition that the sun radiation intensity is about 900W/m². The saving electrical energy can effectively guarantee the system to adapt to changing environmental conditions.

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INTRODUCTION

In summer, due to sun exposure, the interior temperature of parked vehicle will rise sharply. In summer, solar powered vehicle parking ventilation system can effectively solve the problem of high temperature inside the vehicle [1]. Solar powered vehicle parking ventilation system is easily affected by solar radiation intensity, environmental conditions and other factors, for example, the photovoltaic device generates power unsteadily. These factors will affect the system's stability and the cooling effect of systems. This paper studies the crew cabin thermal transfer model, the photovoltaic characteristics of the photovoltaic element and the relationship between the actual air flow and the blower power. The ventilation model will be modified through the experiment, so that it has better predictive ability. The ventilation cooling model can reflect the characteristic of the changing relationship between the size of the ventilation flow and the temperature inside the vehicle. Based on the variation characteristic between the ventilation flow and the temperature inside the vehicle and the photovoltaic characteristics of the photovoltaic element, we have designed an energy management system. Not only can the management system make the solar powered vehicle parking

ventilation system work steadily to achieve the requirement of cooling, but also it can recycle a part of energy, which makes the solar powered vehicle parking ventilation system easier to be promoted.

DESCRIPTION

The paper is partly based on the experiments which takes the Honda Spirior as the object of study (see Fig 1) and we measure the size of the crew cabin to establish the simplified physical model of the cabin. After consulting parameters of heat transfer of all parts of crew cabin and measuring the size of crew cabin, we set up one dimensional static heat transfer model of crew model. Considering one dimensional heat transfer model of crew cabin influenced by the factor that blower ventilates the vehicle and brings heat out of the cabin which reduces the air temperature, we establish the ventilation cooling model. And the ventilation model can indicate the functional relationship among solar radiation intensity, environment temperature, the temperature inside the vehicle and air flow of blower.

The ventilation cooling model need to be modified by experiment which takes the Honda Spirior as test vehicle. We measure the congruent relationship between blower power and the actual ventilation flow rate by using the A/C system of the test vehicle. A physical model of solar panels is established to study how solar radiation intensity and environmental temperature influence the volt-ampere characteristics and the offer of power. To take account of ventilation cooling capacity and photovoltaic components supply capacity, we choose the best ventilation air flow so as to ensure the relationship among the ventilation rate, the environment temperature and solar radiation intensity. By the congruent relationship between the air flow and the blower fan power, the needed power of blower under different environmental conditions can be calculated. By comparing provide surface and demand surface of the electrical energy, we distribute electrical energy reasonably, making the ventilation system can adapt to more than 90% of the environmental conditions.



Figure 1. The test vehicle Honda Spirior.

MODEL

Ventilation Cooling Model

Temperature variation will be influenced by many factors, mainly including environment temperature, solar radiation intensity and parts of the autobody's physical parameters, when the vehicle parks outside. The thermal transfer among air inside, the windows, the auto body and the external environment including heat conduction, heat convection and thermal radiation. The heat in and out through the wall of auto body changes rapidly in this process. At relatively stable environmental conditions, the vehicles keep heat balance and make the cabin temperature stay stable. The car's actual using situation are taken to account, and assuming that the car's exposure time under the sunlight is long enough, so the various parts of the vehicle have reached a steady state. Thus, the body heat transfer characteristics and he factor that blower ventilates the vehicle and brings heat out of the cabin which reduces the air temperature are combined to establish the ventilation cooling model [2].

Q_{body} is the heat transferred between the external environment and the air inside which passed by the auto body. The outer surface absorbed the solar radiation and the long wave radiation of the environment at a certain rate, and at the same time, the outside air also transfers heat with the interior surface of the auto body. Through calculating the equivalent temperature which under the combined action of the external air temperature, the solar radiation as well as the long-wave radiation and the overallcoefficient of heat transfer, the heat transfer process is simplified to the heat transfer between the comprehensive external environment and the interior air. The heat flow Q_{glass} is mainly caused by the solar radiation which through the windows directly at a certain transmission.

The blower's heat flow Q_f takes away the heat from the vehicle through the ventilation. It was found that the air stratification occurs inside the car, then, it is divided into two layers as shown in Fig 2. When the blower working, the new wind blown into the cabin directly affects the change of the upper air temperature, and the lower temperature is mainly affected by the mixed upper air. Considered the modeling convenience, assuming the new wind entered the cabin replaced the same volume of the upper air, and part of the replaced upper air is pushed directly into the trunk of the car, while the other part of replaced upper air replaces the same volume of the lower air. Therefore, the temperature decrease is mainly achieved through blowing new wind into the cabin by the blower.

When the thermal environment inside the vehicle and the initial conditions of the external environment are known, ventilation model can calculate the temperature of the air inside the vehicle function change over time.

$$T_{x1} = -\frac{1}{b_1} e^{\left(-\frac{b_1}{l_1}t\right)} \times (-b_1 T_{01} + c T_{x2} + a_1) + \frac{c T_{x2} + a_1}{b_1}$$

$$T_{x2} = -\frac{1}{b_2} e^{\left(-\frac{b_2}{l_2}t\right)} \times (-b_2 T_{02} + (c + d_2) T_{x1} + a_2) + \frac{(c + d_2) T_{x1} + a_2}{b_2}$$

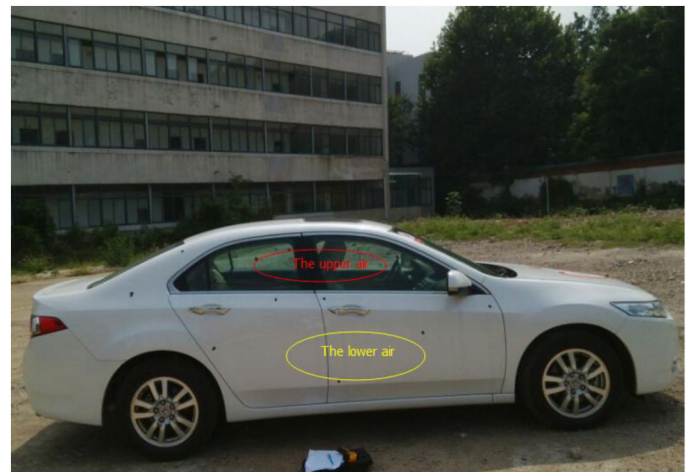


Figure 2. The air in vehicle is divided into two layers.

Blower Model

For the same blower, when its work under two speed n_1 and n_2 , by the characteristics of the fan we can know $\frac{Q_1}{Q_2} = \frac{n_1}{n_2}$, $\frac{Q_1}{Q_2} = \left(\frac{n_1}{n_2}\right)^2$, $\frac{N_1}{N_2} = \left(\frac{n_1}{n_2}\right)^3$. So you can launch the relation between the power and flow rate. Above, x is the unknown coefficients, car inside and outside differential pressure for P_1 and P_2 , flow for Q_1 and Q_2 , power for N_1 and N_2 .

$$N = xQ^3$$

According to the performance characteristics of blower, the blower outlet pressure is different under the same rotate speed, supply air rate is also different too. In-car air duct is quite complex, calculating the relationship between the power of the blower and the blower rate by the model is too complex, and the precision is difficult to guaranteed. So we take the method of experimental measurement to measure the relationship between blower power and the actual blower rate into the car.

Putting motor blower in a gear, we measure the voltage and current at both ends of the blower. The power of blower can be measured by voltammetry. The air flow into the vehicle is hard to be measured in the vehicle, so we can use air flow meter to measure the average velocity of flow at the outer loop of the air inlet. After measuring the area of the air inlet, the air flow can be calculated.

More groups of data can be measured by changing the gear of blower, as is showed in Fig 3. Through the experiment, the relationship between blower power and the actual blower rate can be simulated. Once we figure out the ventilation quantity needed to reach a cooling effect through the crew cabin thermal transfer model, the required power can be also calculated.

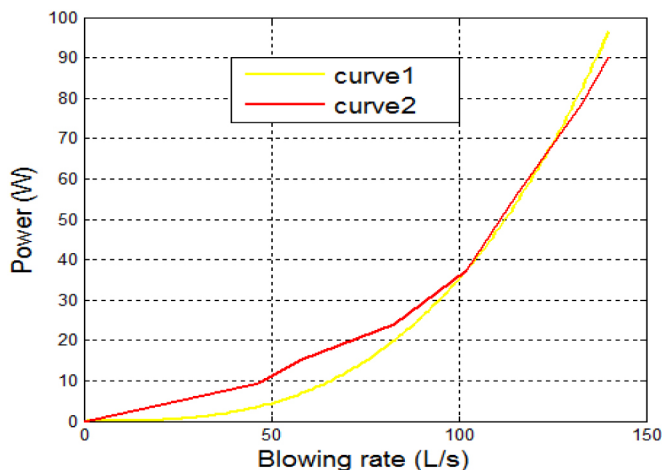


Figure 3. The relationship between blower power and the actual blower rate. The curve 1 is simulation curve fitting on the experimental data, the curve 2 is experimental data points of attachment

The Model of the Solar Panels

The Establishment of a Mathematical Model Based on Physical Concept

The working state of the solar cell can be simulated by an equivalent circuit. Under the condition of constant intensity of solar radiation, the photocurrent of aphotocell in the working state does not change with the working state. In the equivalent circuit, it can be regarded as constant current source. A part of photocurrent flows through the load, and establish the terminal voltage on both ends of the load. In turn, the terminal voltage U is exactly biased on p-n junction, causing a dark current in the opposite direction to photocurrent. After the introduction of the series resistance and the shunt resistance, a simplified equivalent circuit close to the actual relatively will be formed, as is shown in Fig 4. By solar photovoltaic battery equivalent circuit, the output current is

$$I = I_{ph} - I_{sh} - I_d \quad (1)$$

$$I = I_{ph} - I_0 \left(e^{\frac{q(U+IR_s)}{AKT}} - 1 \right) - \frac{(U+R_s)}{R_{sh}} \quad (2)$$

Formula (2) based on the most basic analytic expression of the physical principle has been widely applied to theoretical analysis of solar cells.

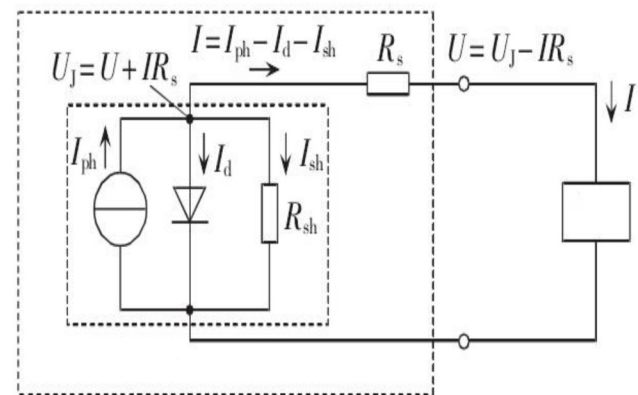


Figure 4. Simplified model of solar cells.

The Establishment of the Application Mathematical Model of Solar Cells

Practical model is known as the engineering model. Usually adopting several important technical parameters provided by the supplier, such as short circuit current, open circuit voltage, short circuit current of maximum power point, open circuit voltage of maximum power point, the practical modal can reappear the characteristics of solar cell under certain precision.

By ignoring $\frac{(U+R_s)}{R_{sh}}$ and setting $I_{ph} = I_{sc}$ on the basis of basic analytical expressions (1), we can get practical application model of solar cells.

$$I = I_{sc} [1 - A(e^{\frac{U}{BU_{oc}}} - 1)] \quad (3)$$

The values of the parameters of A and B can be calculated.

$$A = (1 - \frac{I_m}{I_{sc}}) e^{\frac{-U}{BU_{oc}}} \quad B = (\frac{U_m}{U_{sc}} - 1) [\ln(1 - \frac{I_m}{I_{sc}})]^{-1}$$

Therefore, this model only needs to be input the usual technical parameters of solar cells I_{sc} , U_{oc} , I_m , U_m . Volt-ampere characteristics of battery model can be determined according to expression (3). On the basis of the actual power of the blower, the solar panel of solar-powered vehicle parking ventilation system is the 100 W polycrystalline battery components, its parameters are shown in Table 1. Volt-ampere characteristics of panels can be obtained by practical application model, as shown in Fig 5.

Table1. The parameters of 100 W polycrystalline battery components

Parameters	I_{sc} (A)	U_{oc} (V)	I_m (A)	U_m (V)
Value	6.65	21.60	5.51	18.17

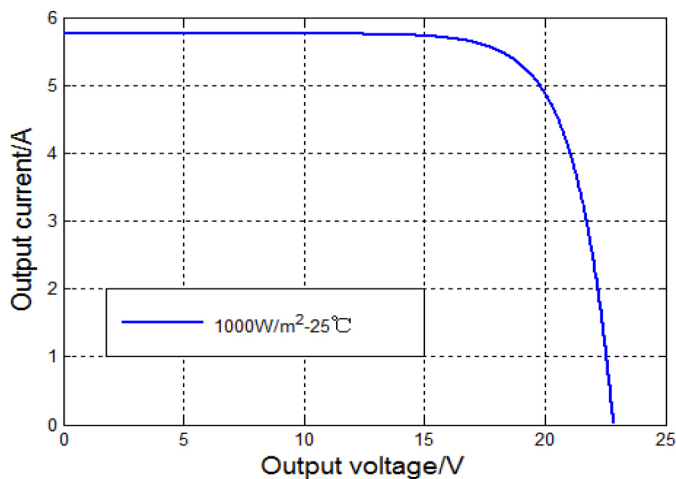


Figure 5. Volt-ampere characteristic curves.

The Influence of Illumination Intensity and Battery Temperature on Battery Technology

According to I_{sc} , U_{oc} , I_m , U_m under the condition of the referential sunshine intensity and the referential battery temperature, I'_{sc} , U'_{oc} , I'_m , U'_m can be calculated under the condition of any solar radiation intensity and any battery. Then the volt-ampere characteristic curve under the condition of any solar radiation intensity and any battery can be obtained.

$$I'_{sc} = I_{sc} \left(\frac{S}{S_{ref}} \right) (1 + a\Delta t)$$

$$U_{oc} = U'_{oc} (1 - c\Delta t) (1 + b\Delta S)$$

$$I'_m = I_m \left(\frac{S}{S_{ref}} \right) (1 + a\Delta t)$$

$$U_m = U'_m (1 - c\Delta t) (1 + b\Delta S)$$

In the process of calculation, standard battery temperature t_{ref} value is 25 °C, the standard solar radiation intensity, S_{ref} value is 1 kW/m². Assuming the basic shape of volt-ampere characteristic curve remains the same, coefficient a, b, c can be desirable typical values: a = 0.0025 /°C, b = 0.5 /°C, c = 0.00288 /°C.

According to the above formula, the volt-ampere characteristic curve can be obtained under the condition of the same temperature and different solar radiation intensity, as is shown in Fig 6, and the volt-ampere characteristic curve can also be obtained under the condition of the same solar radiation intensity and different temperature, as is shown in Fig 7.

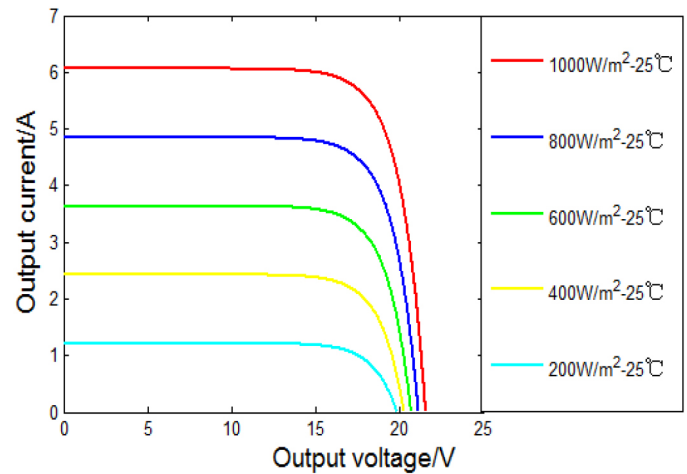


Figure 6. Volt-ampere characteristic curves under the condition of the same temperature and different solar radiation intensity.

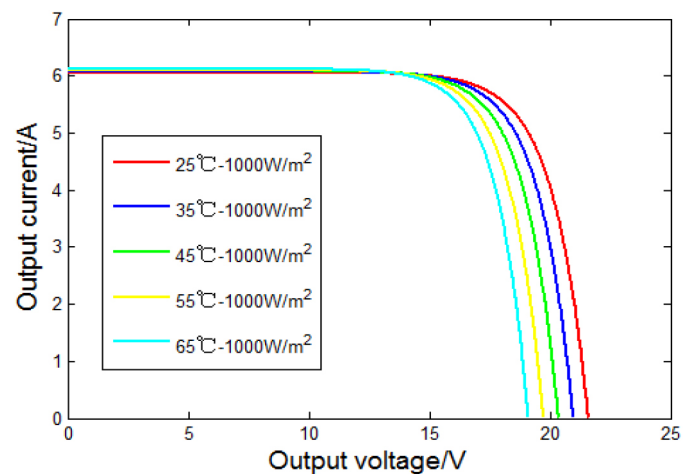


Figure 7. Volt-ampere characteristic curves under the condition of the same solar radiation intensity and different temperature